PYRO2026

25TH EDITION OF THE INTERNATIONAL SYMPOSIUM ON ANALYTICAL AND APPLIED PYROLYSIS



JUNE 7-11 2026

PISA

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ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA | DEPARTMENT OF CHEMISTRY "GIACOMO CIAMICIAN"

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PYRO2026 25th International Symposium on Analytical and Applied Pyrolysis

Proceedings

and

Book of Abstracts

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Frontier Lab – Gold Sponsor



Frontier Laboratories Ltd., founded 1991, is a global leading company in analytical pyrolysis, based in Japan. Frontier Lab is consistently doing research and development of analytical pyrolysis instruments and methods, and manufacturing pyrolyzers with associated accessories for a wide range of analytical applications that include physical property evaluation of polymer materials used in various advanced scientific fields such as quality control in aircraft and automobile industries, differentiation of rubber, paint, paper in forensic investigations, and identification of environmental pollutants such as microplastics. Frontier Lab's analytical pyrolyzer (EGA/PY-3030D) and accessories can be easily installed on almost all commercially available GC/MS systems.

In the recent years, Frontier Lab set the R&D focus on the development of accessories and software/libraries for Micro- and Nanoplastics analysis by Py-GC/MS:

The new F-Search MPs software allows users to identify and quantify unknown microplastics in the environment, and it consists of a sophisticated search program and mass spectral libraries of pyrolyzates. The software is used with the data obtained by Py-GC/MS and the analytical process is very easy and straightforward. Also, a Microplastic Calibration Standard Kit was developed what includes mixtures of up to 12 polymers in different inorganic diluents for easy weighing and calibration. The Multi-Functional Sampler MFS-2015E makes splitless Pyrolysis without compromises possible, enabling 100x improved sensitivity (with LOQs in ng range). The MFS shortens analysis time by backflushing. The new Cryogenic Mill IQ MILL-2070 is easy to use and simple to operate. It pulverizes samples or micro plastic standards at highest uniformity, homogeneity, and reproducibility.

For further information: https://www.frontier-lab.com/

SRA – Silver Sponsor

SRA Instruments at Pyro2026: Advanced Analytical Solutions for a Sustainable Future.

On the occasion of Pyro2026, SRA Instruments reaffirms its position as a leading reference in advanced analytical chemistry, presenting innovative and customized solutions to address key scientific and industrial challenges. With an established presence in Italy and France, SRA combines technological expertise, research excellence, and international partnerships to provide state-of-the-art instrumentation for the environmental, food, forensic, cultural heritage, human health, and life sciences sectors.

Technologies for any analytical challenge. The key themes of Pyro2026 are fully supported by SRA's broad portfolio of reliable analytical technologies, including Agilent platforms—GC, GC–MS, LC, LC–MS and FT-IR—and specialized systems developed in collaboration with leading international partners.

Food & Beverages: quality control, traceability and food safety solutions based on GC–MS and LC–MS technologies for contaminant identification and nutritional characterization.

Environmental Analysis: high-sensitivity and environmentally friendly technologies for monitoring pollutants and microplastics, as well as for metal speciation.

Cultural Heritage: non-destructive analysis and characterization of historical materials using FT-IR spectroscopy and advanced imaging techniques.

Forensic Chemistry: GC–MS and LC–MS solutions for the identification of illicit and toxic substances and the analysis of forensic traces.

Human Health: development of analytical solutions for monitoring potentially harmful substances—including PFAS, VOCs, emissions and MOSH/MOAH—as well as innovative breath-analysis applications.

Green Analytical Chemistry: sustainable approaches, reduced solvent consumption and automated workflows designed to minimize environmental impact.

Mass Spectrometry & Spectroscopy: high-resolution instrumentation and optimized workflows supporting applications from fundamental research to industrial analysis.

Separation Science: GC, LC and IC systems for complex applications, ranging from purification processes to the analysis of challenging matrices.

Materials Analysis: analytical systems for the identification, quantification and characterization of micro- and nanoplastics.

Tailor-made innovation. Through its in-house laboratory and R&D department, SRA develops customized solutions that integrate state-of-the-art technologies with specific analytical requirements. Partnerships with Agilent and other leading global manufacturers provide access to cutting-edge instrumentation, while SRA's specialized technical service ensures continuous expert support.

For further information: www.srainstruments.com

Gaz Analytique – Silver Sponsor

Gaz Analytique: Excellence in Analytical Sample Preparation.

Gaz Analytique is a premier provider of specialized scientific instrumentation designed to optimize the critical first steps of chemical analysis: sample preparation. Recognizing that the quality of any analytical result—whether from GC-MS, LC-MS, or ICP—is fundamentally limited by the quality of the sample introduced, the company curates a portfolio of high-end equipment that automates and refines these essential laboratory procedures. Based in Brittany, France, Gaz Analytique serves the physico-chemical research and quality control sectors by bridging the gap between raw samples and precise data.

Core Specialization: Bridging the Analytical Gap

The company focuses on three pillars of sample preparation that are vital for modern analytical laboratories:

- Thermal Desorption & Pyrolysis: Providing advanced Curie Point Pyrolyzers for the analysis of solids, polymers, and complex matrices via GC-MS and even LC-MS.
- Concentration & Evaporation: Distributing innovative evaporation solutions like the Smart Evaporator and N-EVAP series, which allow for the rapid and safe removal of high-boiling point solvents like DMSO, DMF, and water without compromising heat-sensitive analytes.
- Sample Mineralization & Pelletizing: Supplying microwave digestion systems and high-precision hydraulic presses for the preparation of samples intended for XRF and IR spectroscopy.

Enhancing Laboratory Environment

Beyond chemical processing, Gaz Analytique addresses the "human element" of the laboratory. They offer a specialized range of acoustic enclosures (caissons anti-bruit) for vacuum pumps and ultrasonic baths. By mitigating the constant decibel load of primary pumps, these solutions create a safer, more focused environment for lab technicians and researchers.

Why Labs Partner with Gaz Analytique

The company differentiates itself through a consultative approach. Rather than acting as a simple catalog vendor, Gaz Analytique selects instruments with unique technical characteristics—such as the ability to analyze solids directly via the CHEMZO system—that solve specific bottlenecks in the analytical workflow. Their focus on automation allows laboratories to increase throughput while improving the "justesse" (accuracy) and robustness of their final results.

For further information: https://www.gaz-analytique.com/

Lab Tech CDS – Silver Sponsor

LabTech CDS Analytical is a global provider of innovative thermal sample preparation and sample introduction solutions for analytical laboratories. For more than 50 years, the company has focused exclusively on the design, manufacturing, and support of advanced analytical instrumentation from its headquarters near Philadelphia, Pennsylvania, USA.

CDS Analytical pioneered analytical pyrolysis technology by commercializing the first analytical pyrolyzer, the Pyroprobe®, in 1970. Today, the company offers a comprehensive portfolio of front-end GC systems, including pyrolysis systems, purge and trap instruments, and thermal desorption systems. CDS's current line of pyrolyzers features our Drop In Sample Chamber (DISC) technology using a proprietary heating mechanism while offering unique and flexible stepwise temperature control. In addition to our DISC technology, our pyrolyzers also provide a range of specialized accessories to support polymer research and advanced materials analysis, including photodegradation, catalysis, hydrolysis, headspace sampling, FTIR integration, and more.

In 2015, CDS Analytical joined the LabTech Group, a global manufacturer of analytical instrumentation and laboratory solutions. This partnership has further strengthened the company's global presence and expanded its technological capabilities.

In addition to its expertise in GC sample introduction technologies, LabTech CDS Analytical has broadened its portfolio to include automated organic sample preparation solutions, such as solid phase extraction (SPE), pressurized solvent extraction, and vacuum and nitrogen concentration systems. Looking ahead, the company continues to invest in research and development for next-generation analytical instrumentation supporting GC-MS, ICP-MS, and AAS applications.

For further information: https://www.cdsanalytical.com/

Jeol Ltd. – Silver Sponsor

JEOL Ltd. (https://www.jeol.com/) (Japan Electron Optics Laboratory) is a premier Japanese multinational corporation and a global leader in the manufacturing of electron microscopes and advanced scientific instrumentation. Founded in Tokyo in 1949, the company is headquartered in Akishima, Tokyo, and is publicly traded on the Tokyo Stock Exchange.

The company operates across the following industrial sectors:

Scientific and Metrological Instruments: High-end electron microscopes (SEM and TEM), Nuclear Magnetic Resonance (NMR) spectrometers, Mass Spectrometers (MS), and X-ray diffractometers.

Industrial Equipment: Electron beam lithography systems for the semiconductor industry and advanced industrial metal 3D printers.

JEOL operates a massive global network spanning the Americas, Europe, Asia, and Australasia. In Italy, the company has been active since 1981 through its official subsidiary, JEOL (Italia) S.p.A. (https://www.jeol.it/), based in Basiglio (Milan), which handles nationwide sales, installation, and technical support.

FKV – Silver Sponsor

FKV began its activity in 1974 as a distributor of scientific instruments for the steel industry.

Over more than 50 years, it has expanded its range of scientific instruments for laboratories for all types of industry.

Today, it is one of Italy's leading distribution companies, serving over 15,000 customers and offering products from more than 20 international manufacturers. Its headquarters are located in Torre Boldone, in the province of Bergamo, where 50 people work in over 3000 m2 of offices and warehouses. FKV is active throughout the Italian market, with its divisions promoting other services beyond the sale of laboratory instruments.

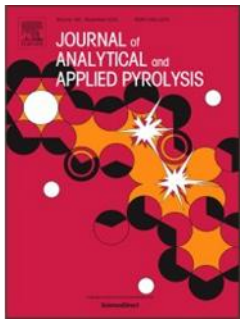
FKV Care: guarantees the proper functioning of your instruments, with technicians trained and certified directly by the manufacturers, through maintenance and installation certifications and periodic requalification.

FKV Lab: product specialists are available in our demonstration laboratories to assist customers in fine-tuning methods and training in the use of equipment (also at the customer's premises).

FKV Learn: basic and advanced training courses on the main analytical techniques are regularly organized at the Torre Boldone headquarters.

For further information: https://fkv.it/

Journal of Analytical and Applied Pyrolysis – Academic supporting journal



The **Journal of Analytical and Applied Pyrolysis (JAAP), Elsevier,** with IF 2025 6.7 and CiteScore 11.0 is devoted to the publication of papers dealing with innovative applications of pyrolysis processes, the characterization of products related to pyrolysis reactions, and investigations of reaction mechanism. The scope of the Journal includes:

Fundamental pyrolysis research on chemical substances and materials comprising:

- experimental studies of pyrolysis reactions such as chemical mechanism and kinetic investigations; this includes preparative pyrolysis methods for the synthesis of novel compounds and mechanisms of high temperature reactions;

- computational and theoretical studies of reaction mechanism, kinetics, and thermodynamics are acceptable, provided they are directly related to experimental data, either new or previously published, but they must be described adequately in the paper;

- computational processing of pyrolysis data, such as advanced pattern recognition and principal component analysis and other multivariate analyses.

Analytical pyrolysis, i.e. the characterization of a material in inert atmosphere by thermally induced degradation reactions;
- exploring chemical composition and structure of materials by revealing thermal and chemical decomposition reactions leading to products fully identified by chemical and spectroscopic methods;
- applications of analytical pyrolysis in environmental, biological, medical, forensic, cultural heritage, food, geochemical, polymer, and materials science;
- new instrumentation and new analytical methods using pyrolysis reactions or to unravel the chemical composition of pyrolysis products.

Applied pyrolysis dealing with the development of pyrolysis processes for producing valuable chemicals and/or energy carriers (gas, liquid, solid or electricity) and/or materials from fossil or renewable feedstock or waste, the recycling of materials, and the disposal of toxic substances. The manuscript must discuss the relationships between pyrolysis conditions and product characteristics. This topic includes:

- various feedstock (fossil fuels, biomass, wastes, polymers, etc.) and the co-processing of different feedstock;

- various thermal processes (slow and fast pyrolysis, torrefaction, carbonization, high pressure pyrolysis, catalytic pyrolysis, deoxygenation, hydropyrolysis, solvent liquefaction).

For further information: https://www.sciencedirect.com/journal/journal-of-analytical-and-applied-pyrolysis

Conference Scientific Programme

Monday, 8th June 2026

ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

09:00 – 09:20 **Opening Ceremony**

09:20 – 09:50 Chairs: Shurong Wang, Anthony Dufour

KN1 Yuyang Li, Shanghai Jiao Tong University, China *"Pyrolysis-driven combustion energy and flame synthesis research: a review of experimental, kinetic modeling, and application advances"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation (S1.1) – Chairs: Shurong Wang, Anthony Dufour

09:50 – 10:10 **O-S1.1-1** *Water leaching of wood barks for biocarbon production: Analysis of extractives,* **Z. Czégény** - HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary

10:10 – 10:30 **O-S1.1-2** *Valorization of brewer's spent grains through cascaded protein recovery and fast pyrolysis of its residues,* **Y. Wei** - Ghent University, Belgium

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S1.1-3** *Thermal conversion regulation of reconstituted tobacco and product application evaluation,* **L. Fu** - Zhengzhou Tobacco Research Institute of CNTC, China

11:20 – 11:40 **O-S1.1-4** *Efficient catalytic pyrolysis of biomass to light aromatic hydrocarbons over Zn/ZSM-5,* **J. Cao** - China University of Mining and Technology, China

11:40 – 12:00 **O-S1.1-5** *Physico-chemical properties of biochars from four different caribbean biomasses,* **M. Drané** - Société Anonyme de la Raffinerie des Antilles, France

12:00 – 12:20 **O-S1.1-6** *Catalytic and inhibitory effects induced by noncovalent interactions between cellulose and lignin during fast pyrolysis,* **H. Wong** - University of Massachusetts Lowell, United States

12:20 – 12:40 **O-S1.1-7** *Activated carbon-based catalyst supports for dry methane reforming and coke formation,* **K. Januszewicz** - Gdańsk University of Technology, Poland

12:40 – 13:00 **O-S1.1-8** *Spatial evolution of mineral phases within pine bark particles during pyrolysis under inert and weakly oxidizing atmospheres,* **E. Arango Durango** - Luleå Tekniska Universitet, Sweden

ROOM A1 – FIRST FLOOR

Parallel Session: Analytical Pyrolysis: Cultural heritage (S1.2) – Chairs: Barbara Scholz-Böttcher, Ilaria Bonaduce

09:50 – 10:10 **O-S1.2-1** *Analytical investigation of cyclohexanone resins for cultural heritage by evolved gas analysis-ms and double-shot Py-GC/MS,* **A. Micheluz** - Deutsches Museum, Germany

10:10 – 10:30 **O-S1.2-2** *Exploring the oxidative polymerization of polyunsaturated methyl esters by EGA-MS: a molecular approach to investigate lipid-based polymer networks in historical paint models,* **G. Caroti** - University of Pisa, Italy

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S1.2-3** *Advances in the investigation of cultural heritage materials through the coupling of pyrolysis with GCxGC-MS,* **M. Sablier** - UMR CBI, Laboratoire des Sciences Analytiques, Bioanalytiques et Miniaturisation, ESPCI, France

11:20 – 11:40 **O-S1.2-4** *Comparison of EGA and py-GCMS data from naturally and artificially aged polyester urethane,* **S. Kunz** - Deutsches Bergbau-Museum Bochum/ Leibniz Research Museum for Geo-resources, Germany

11:40 – 12:00 **O-S1.2-5** *PY-GC-MS as a method for evaluating degradation of paper during material suitability testing,* **M. Samide** - Butler University, United States

12:00 – 12:20 **O-S1.2-6** *Influence of progressive and instantaneous heating on the pyrolysis products of silk,* **C. Campi** - University of Pisa, Italy

12:20 – 12:40 **O-S1.2-7** *Analytical pyrolysis promotes organic residue analysis in China,* **B. Han** - University of Chinese Academy of Sciences, China

12:40 – 13:00 **O-S1.2-8** *Optimizing multifunctional Py-GC/MS workflows for historical gold varnishes: first application to a 17th-century gilt leather panel,* **V. Pintus** - Louvre Abu Dhabi, United Arab Emirates

ROOM C1 – FIRST FLOOR

Parallel Session: Fundamental pyrolysis reactions and kinetics/modelling (S1.3) – Chairs: Ondrej Masek, Martin Olazar

09:50 – 10:10 **O-S1.3-1** *Peeling and subsequent radial degradation pathways during cellulose pyrolysis below 320 °c: insights from isothermal TG-MS analysis,* **H. Kawamoto** – Kyoto University

10:10 – 10:30 **O-S1.3-2** *Modeling approach for the electromagnetic field and heating of biomass in a microwave reactor using OpenFOAM,* **A. Dernbecher** - TU Dortmund University, Germany

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S1.3-3** *Kinetic analysis of biochar formation by Py-GC/MS during fast pyrolysis of lignocellulosic biomass,* **M. Carrier** - CNRS, France

11:20 – 11:40 **O-S1.3-4** *Integrated computational, experimental, and kinetic modeling study of the pyrolysis mechanisms of hemicellulose molecular constituents,* **B. Ballotta** - School of Physics, Trinity College Dublin, Ireland

11:40 – 12:00 **O-S1.3-5** *Framework for reaction mechanism investigation of pyrolysis process for carbon-based fuels with reactive molecular dynamics simulation,* **M. Zheng** - State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences

12:00 – 12:20 **O-S1.3-6** *Multiscale and AI-Enabled Investigation of Biomass/Plastic Fast Pyrolysis in Fluidized Bed Reactors,* **X. Gao** - Guangdong Technion, Israel Institute of Technology, China

12:20 – 12:40 **O-S1.3-7** *Thermal reactivity of the cellulose crystalline core: insights into metal cation effects via deuterium labeling and TG-MS Analysis,* **Y. Maruichi** - Kyoto University Japan

12:40 – 13:00 **O-S1.3-8** *Strategy for revealing thermolysis mechanism of CL-20 cocrystals by ReaxFF MD simulations,* **C. Ren** - State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, China

13:00 – 14:00 **Lunch**

14:00 – 15:00 **POSTER Session 1**

ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

15:00 – 15:30 Chairs: Osvalda Senneca, Frederik Ronsse

KN2 Clemens Schwarzinger, Johannes Kepler University Linz, Austria, *"Derivatisation in Analytical Pyrolysis"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation (S1.4) – Chairs: Osvalda Senneca, Frederik Ronsse

15:30 – 15:50 **O-S1.4-1** *Decomposition kinetics and product distribution of a very fast pyrolysis of algal biomass,* **G. Ji** - Dalian University of Technology, China

15:50 – 16:10 **O-S1.4-2** *Simultaneous pyrolysis-activation-doping of biomass for porous N-doped biochar,* **L. Wang** - Nanjing Agricultural University, China

16:10 – 16:30 **O-S1.4-3** *In-situ Pyrolysis Vapor Recirculation in a Continuous Auger Reactor: Characterization of Bio-oil from Pyrolysis of Pine Bark,* **Y. Tolunay Kilic** - Luleå University of Technology, Sweden

16:30 – 17:00 **Coffee Break**

17:00 – 17:20 **O-S1.4-4** *Pyrolysis of C5 Cyclic Hydrocarbons and Derived High-Energy-Density Fuels: Kinetic Modeling and Aromatics Formation Mechanisms,* **H. Wang** - China University of Mining and Technology, China

17:20 – 17:40 **O-S1.4-5** *Pyrolysis of marine biomasses with different heating technologies: The case of study of Posidonia Oceanica fibrous spheres,* **D. Licursi** - University of Pisa, Italy

17:40 – 18:00 **O-S1.4-6** *Effect of hydrothermal carbonization conditions on carbon partitioning and catalytic pyrolysis of fish-based biomass,* **T. R. Siddhartha** - Ghent University, Belgium

ROOM A1 – FIRST FLOOR

Parallel Session: Analytical Pyrolysis: Cultural heritage, natural materials (S1.5) – Chairs: Valentina Pintus, Jeannette J. Lucejko

15:30 – 15:50 **O-S1.5-1** *Understanding the ageing of polyurethane foams in art and design: a thermoanalytical approach,* **G. Biale** – University of Pisa, Italy

15:50 – 16:10 **O-S1.5-2** *Layer-specific identification of organic binders in 17th–18th century korean dancheong by Pyrolysis-GC/MS,* **J. Yu** – National Institute of Cultural Heritage, South Korea

16:10 – 16:30 **O-S1.5-3** *Py-GC/MS investigation of the formation of various anhydrosugars from carbohydrates for efficient green chemical synthesis,* **K. Meile** - Latvian State Institute of Wood Chemistry, Latvia

16:30 – 17:00 **Coffee Break**

Parallel Session: Analytical Pyrolysis: Natural materials (S1.5) – Chairs: Valentina Pintus, Jeannette J. Lucejko

17:00 – 17:20 **O-S1.5-4** *Detailed characterization of leather solid wastes using analytical Py-GC/MS and TG-IR to evaluate resource recovery potential,* **R. Vinu** - Indian Institute of Technology Madras

17:20 –17:40 **O-S1.5-5** *Characterization of modified lignin for applications in sustainable biobased formulations,* **M. Traoré** - Centro Tecnológico de Investigación Multisectorial, Spain

17:40 –18:00 **O-S1.5-6** *High-performance software for deconvolution and annotation of PY-GC/MS data for lignocellulosic biopolymer characterization,* **O. Ilchenko** - Swedish University of Agricultural Sciences, Sweden

ROOM C1 – FIRST FLOOR

Parallel Session: S1.6 Fundamental pyrolysis reactions, kinetics/modelling (S1.6) – Chairs: Matteo Pelucchi, Valerie Burkle-Vitzthum

15:30 – 15:50 **O-S1.6-1** *From gas-phase chemistry to carbon formation and deposition: validation of a kinetic framework for light hydrocarbons pyrolysis,* **L. Giardini** - Politecnico di Milano, Italy

15:50 – 16:10 **O-S1.6-2** *Effect of coal macromolecular network fragments on char during coal pyrolysis,* **H. Yang** - Dalian University of Technology, China

16:10 – 16:30 **O-S1.6-3** *A comprehensively experimental and kinetic modelling investigation of C6 ketone isomers pyrolysis and oxidation: Insight into effects of isomerism,* **X. Sun** - China University of Mining and Technology, China

16:30 – 17:00 **Coffee Break**

17:00 – 17:20 **O-S1.6-4** *Resolving formic acid pyrolysis: integrating automated generation with high-fidelity theory,* **A. Grinberg Dana** - Technion, Israel Institute of Technology, Israel

17:20 – 17:40 **O-S1.6-5** *A robust NLSM-based kinetic approach for pyrolysis valorization: application to polymers, biopolymers, and biomass,* **N. Kouraa** - Mohammadia School of Engineers, Mohammed V University in Rabat, Rabat, Morocco

17:40 – 18:00 **O-S1.6-6** *Cellulose carbonization pathways studied using reactive force field methods,* **O. Pakarinen,** A. Paajanen, E. Virtanen, L. Fliri, C. Guizani, M. Hummel, J. Vaari - VTT Technical Research Centre of Finland Ltd., Finland

Tuesday, 9th June 2026

ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

09:00 – 09:30 Chairs**:** Haruo Kawamoto, Aneta Magdziarz

KN3 Marja Lamoree, Vrije Universiteit Amsterdam, Netherlands, *"Progress and challenges in quantification of micro- and nanoplastics in human blood"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation; Fundamental pyrolysis reactions and kinetics/modelling (S2.1) – Chairs**:** Haruo Kawamoto, Aneta Magdziarz

09:30 – 09:50 **O-S2.1-1** *Heating rate and solid residence time effects on carbon transformation pathways in slow and fast pyrolysis of woody and herbaceous residues,* **P. Giudicianni -** CNR-STEMS, Italy

09:50 – 10:10 **O-S2.1-2** *Can the pyrolysis kinetics of cellulose, hemicellulose and lignin serve as building blocks to describe the behavior of physical mixtures and real biomass?,* **E. Benedetto** - Politecnico di Milano, Italy

09:10 – 10:30 **O-S2.1-3** Withdrawn

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S2.1-4** *Effect of extraction pretreatments on composition and porosity of biochar from Quercus robur bark,* **R. Herrera Diaz** - University of the Basque Country, Spain

11:20 – 11:40 **O-S2.1-5** *Important role of thermal ejection in condensable volatiles formation during cellulose pyrolysis,* **H. Wu** - Curtin University of Technology, Australia

11:40 – 12:00 **O-S2.1-6** *Gas-phase thermal stability of levoglucosenone derived from biomass pyrolysis,* **S. Kudo** - Kyushu University, Japan

12:00 – 12:20 **O-S2.1-7** *Production of hydrogen-rich syngas from catalytic reforming of biomass gasification tar coupled with in-situ CO2 capture,* **C. Quan** - Xi'an Jiaotong University, China

12:20 – 12:40 **O-S2.1-8** *Evolution characteristics and mechanism of products from large-particle biomass pyrolysis in molten salt media,* **L. Zhang** - Ningxia University, China

ROOM A1 – FIRST FLOOR

Parallel Session: Analytical Pyrolysis: Environment (S2.2) – Chairs: Clemens Schwarzinger, Jacopo La Nasa

09:30 – 09:50 **O-S2.2-1** *Expanding the pyrolysis toolkit: Automated comparative analysis complex materials using Py–GC×GC–TOF MS and advanced chemometrics,* **A. Buchanan** - SepSolve Analytical, United Kingdom

09:50 – 10:10 **O-S2.2-2** *Assessment of Conventional and Biodegradable Microplastics in Agricultural Soils applying Py-GC/MS,* **E. López Rodríguez** - University of Almeria, Spain

10:10 – 10:30 **O-S2.2-3** *Evolved Gas Analysis (EGA-MS) for polyethylene quantification in compostable bioplastics shopping bags,* **M. Filomena** - University of Pisa, Italy

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S2.2-4** *What are we breathing at home? - Household Micro- and Nanoplastics: Composition, Differences, potential Sources & Determinants,* **B. Scholz-Böttcher** - Carl von Ossietzky Universität Oldenburg, Germany

11:20 – 11:40 **O-S2.2-5** *Unravelling the chemical complexity of artificially aged tire wear particles by Py-GCxGC-ToFMS,* **S. Lievens** - ACESSS, OBiAChem, ULiège, Belgium

11:40 – 12:00 **O-S2.2-6** *Quantification of polyvinyl chloride in atmospheric particulate matter using Pyrolysis GC/MS: Matrix effects and marker behavior,* **H. Mizuguchi** - Tokushima University, Japan

12:00 – 12:20 **O-S2.2-7** *Splitless analytical pyrolysis of museum foraminifera tests: historical insights on oceanic plastic pollution,* **M. Mattonai** - University of Pisa, Italy

12:20 – 12:40 **O-S2.2-8** *Molecular characterisation of the environmentally labile fraction of biochars by hydropyrolysis,* **W. Meredith** - University of Nottingham, UK

12:40 – 13:00 **O-S2.2-9** *Py-GC-MS method development and validation for micro- and nanoplastics in human biological fluids,* **F. Nardella** - Vrije Universiteit Amsterdam, Netherlands

ROOM C1 – FIRST FLOOR

Parallel Session: Catalytic pyrolysis: Biomass valorisation (S2.3) – Chairs: Subhasis Das, Victoria Navarro

09:30 – 09:50 **O-S2.3-1** *PyroFriction - New low-temperature biomass pyrolysis technology,* **M. Klaptocz** - Ekotrend Sp. z o.o., Poland

09:50 – 10:10 **O-S2.3-2** *Exploring the role of acid-modified and metal (Ni, Co, Ni/Co) impregnated chilean natural zeolite during catalytic co-hydropyrolysis of biomass/plastics,* **S. Alejandro-Martín** - Universidad del Bío-Bío, Chile

10:10 – 10:30 **O-S2.3-3** *Ex-situ catalytic pyrolysis of paper sludge to bio-BTX on a staged free-fall reactor using three commercial catalysts,* **Y. Chen** - Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S2.3-4** *Upgrading of slow pyrolysis oil via mild and deep hydrodeoxygenation for green marine fuels,* **E. Ekici** - Karlsruhe Institute of Technology, Germany

11:20 – 11:40 **O-S2.3-5** *Catalytic hydrotreatment efficiency on HTL bio-crudes from two microalgae strains, Chlorella sorokiniana and Chlorella vulgaris, evidenced by FT-ICR MS,* **J. Hertzog** - Université de Lorraine, France

11:40 – 12:00 **O-S2.3-6** *Investigation of bones waste catalytic pyrolysis for bio-based compounds production*, **C. Marculescu** - National University of Science and Technology Politehnica Bucharest, Romania

12:00 – 12:20 **O-S2.3-7** *Pressure effect on catalytic pyrolysis of eucalyptus over hierarchical BETA zeolite*, **A. M. Montero-Csanady** - Rey Juan Carlos University, Spain

12:20 – 12:40 **O-S2.3-8** *Role of active phases based on Fe, Zn and $MgCl_2$ for in-situ upgrading of bio-crude during hydrothermal liquefaction of tannery sludge,* **G. Marotta** - University of Naples Federico II, Italy

ROOM B – GROUND FLOOR

Parallel Session: Applied pyrolysis: polymers and recycling (S2.4) – Chairs**:** Shogo Kumagai, Alba Dieguez Alonso

09:30 – 09:50 **O-S2.4-1** *Machine learning based optimization of pyrolysis oil yield from waste plastics under sensitivity and uncertainty analysis frameworks,* **S. R. Naqvi** - Karlstad University, Sweden

09:50 – 10:10 **O-S2.4-2** *Influence of additives, fillers and pigments via thermo-catalytic pyrolysis of polypropylene and polyethylene over HZSM-5 zeolites,* **K. Klemencová** - Technical University of Ostrava, Czechia

10:10 – 10:30 **O-S2.4-3** *Impact of intra-particle heat conduction on waste plastic pyrolysis,* **S. Tavakkol**- Karlsruhe Institute of Technology, Germany

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S2.4-4** *Bifunctional magnetic Co3O4-B/C catalysts for the thermochemical conversion of non-recyclable plastic waste* - **M. J. Muñoz-Batista -** University of Granada, Spain

11:20 – 11:40 **O-S2.4-5** *Trade-offs between pyrolysis oil quality and valuable chemicals: the case of the co-pyrolysis of HDPE and PET,* **D. C. Ruiz Flores** - Maastricht University, Netherlands

11:40 – 12:00 **O-S2.4-6** *Stepwise thermochemical conversion strategies for waste plastics: coupling auger and fluidized bed reactors for PE and PVC valorization,* **J.-W. Kim** - University of Seoul, South Korea

12:00 – 12:20 **O-S2.4-7** *Heating rate of the rotary-kiln reactor on the pyrolysis of waste plastics,* **W. Piao** - Dalian Institute of Chemical Physics, China

12:20 – 12:40 **O-S2.4-8** *Hydrogen and syngas production from plastic waste pyrolysis and in line sorption enhanced steam reforming,* **G. Lopez** - University of the Basque Country, Ikerbasque, Spain

12:40 – 13:00 **O-S2.4-9** *Validating solar relevant PHC: biomass ratios in fluidized bed fast pyrolysis,* **F. Viteri** - Instituto de Carboquímica (ICB-CSIC), Spain

13:00 – 14:00 **Lunch**

14:00 – 15:00 **POSTER Session 2**

ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

15:00 – 15:30 Chairs: Hongwei Wu, Chamseddine Guizani

KN4 Osvalda Senneca, CNR - STEMS, Italy, *"Why lignocellulosic components make thermochemical conversion of biomass so interesting?"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation (S2.5) – Chairs: Hongwei Wu, Chamseddine Guizani

15:30 – 15:50 **O-S2.5-1** *Slow pyrolysis under recirculated exhaust gas atmospheres: effect of steam on biochar and co-products,* **C. M. Grottola** – CNR STEMS, Italy

15:50 – 16:10 **O-S2.5-2** *Oxidative torrefaction of biomass in a fluidized bed to produce biochar with high grindability,* **X. Wu** - Shenyang University of Chemical Technology, China

16:10 – 16:30 **O-S2.5-3** *Influence of Wood Anisotropy on Pyrolysis Behavior: Experimental and Numerical Study,* **F. Ryll** - TU Dortmund University, Germany

16:30 – 17:00 **Coffee Break**

ROOM A1 – FIRST FLOOR

Parallel Session: Analytical Pyrolysis: synthetic polymers; Py instrumentation and methodology (S2.6) - Chairs: Alessandro Rombolà, Ilaria Degano

15:30 – 15:50 **O-S2.6-1** *Extending the Analytical Power of Applied Pyrolysis for Polymers through Online FT-ICR MS Analysis of Heavy Thermo-desorption and Pyrolysis Products,* **F. Aubriet** - Université de Lorraine, France

15:50 – 16:10 **O-S2.6-2** *Fundamental Study on Abnormal Peak Appearance in the Mid-Boiling Point Range in Pyrolysis-GC/MS,* **A. Watanabe** - Frontier Laboratories Ltd., Japan

16:10 – 16:30 **O-S2.6-3** *Evaluation of recycling potential of wind turbine blade using catalytic pyrolysis and its life cycle assessment,* **M. Giridara Srinivaas** - Indian Institute of Technology Madras, India

16:30 – 17:00 **Coffee Break**

ROOM C1 – FIRST FLOOR

Parallel Session: Catalytic pyrolysis: Biomass valorisation (S2.7) – Chairs: Liang Wang, Luis Arteaga-Pérez

15:30 – 15:50 **O-S2.7-1** *Low pressure catalytic hydropyrolysis of chlorella vulgaris,* **I. Moreno** - IMDEA Energy Institute, Spain

15:50 – 16:10 **O-S2.7-2** *Ex-situ catalytic co-pyrolysis of Bamboo and Polystyrene with Nickel, Molybdenum and cobalt impregnated Red Mud for bio-oil synthesis,* **A. Mugundan Chandran** - Indian Institute of Technology Madras, India

16:30 – 17:00 **Coffee Break**

ROOM B – GROUND FLOOR

Parallel Session: applied pyrolysis: Polymers and recycling (S2.8) – Chairs: Lijun Jin, Haoquan Hu

15:30 – 15:50 **O-S2.8-1** *Impact of Minerals on the Pyrolysis Behavior and Product Distribution of Polystyrene,* **T. Kurtz** - Karlsruhe Institute of Technology, Germany

15:50 – 16:10 **O-S2.8-2** *Simulation of plastic pyrolysis in a fluidized bed reactor under batch-wise and continuous feeding mode,* **M. Li** - Karlsruhe Institute of Technology, Germany

16:10 – 16:30 **O-S2.8-3** *The role of branching in polyethylene pyrolysis,* **M. Denton** - Ghent University, Belgium

16:30 – 17:00 **Coffee Break**

Wednesday, 10th June 2026

ROOM A GROUND FLOOR (streaming in Room B, GROUND FLOOR)

09:00 – 09:30 Chairs: Ravikrishnan Vinu, Zsuzsanna Czégény

KN5 Alba Dieguez-Alonso, TU Dortmund University, Germany, *"Progressive development of the understanding of transport–reaction interactions in pyrolysis over the years and current challenges associated with plastic waste conversion"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation (S3.1) – Chairs: Ravikrishnan Vinu, Zsuzsanna Czégény

09:30 – 09:50 **O-S3.1-1** *Hydrogen-Rich Syngas Production from Biomass via Low-Temperature Pyrolysis coupled Gasification of Biochar-oil briquette fuels,* **H. Su** - Zhejiang University, China

09:50 – 10:10 **O-S3.1-2** *Pressure carbonisation of iron doped cellulose Pickering Emulsions towards catalytical applications,* **L. Nowack** - TU Bergakademie Freiberg, Germany

10:10 – 10:30 **O-S3.1-3** *Biomass valorization to furfural: minimizing humin byproduct to enhance furfural yield,* **M. Yang** - Shenyang University of Chemical Technology, China

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S3.1-4** *Fermentability of water-soluble products from HTC-Py-AD processes: comparison of fast and intermediate pyrolysis,* **A. Facchin** - University of Bologna, Italy

11:20 – 11:40 **O-S3.1-5** *Exploiting fast pyrolysis conditions for one-step synthesis of carbon dots from biomass,* **C. Russo** - National Research Council of Italy

11:40 – 12:00 **O-S3.1-6** *Experimental and Modelling Studies on Biomass Pyrolysis in Molten Salts,* **A. Hommes** - University of Groningen, Netherlands

12:00 – 12:20 **O-S3.1-7** *Integrating hydrothermal treatment and microalgal cultivation for brewery spent grains valorization,* **M. Gobbo** - University of Florence, Italy

12:20 – 12:40 **O-S3.1-8** *Assessment of heterogeneous secondary reactions and the role of char loading in fluidized bed pyrolysis of biomass,* **M. Troiano** - University of Naples Federico II, Italy

12:40 – 13:00 **O-S3.1-9** *Long-duration low-temperature pyrolysis of wood: from polymer degradation to char formation,* **C. Preimesberger** - Kompetenzzentrum Holz GmbH, Austria

ROOM A1 – FIRST FLOOR

Parallel Session: Applied pyrolysis: Fossil fuels (S3.2) – Chairs: Xiangwen Zhang, Marcin Sajdak

09:30 – 09:50 **O-S3.2-1** *Performance and synergistic mechanism on co-pyrolysis of PVC/ PVC-containing mixed plastics and coal,* **H. Hu** - Dalian University of Technology, China

09:50 – 10:10 **O-S3.2-2** *Investigation on sulfur distribution and chemical forms in products from co-pyrolysis of coal and waste tire,* **L. Jin** - Dalian University of Technology, China

10:10 – 10:30 **O-S3.2-3** *Catalytic selective hydrogenolysis of coal-based aromatic ethers,* **X. Chen** - Dalian University of Technology, China

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S3.2-4** *Hydropyrolysis: towards fluorescence-free Raman analysis of internal diesel injector deposits,* **W. Meredith** - University of Nottingham, England

11:20 – 11:40 **O-S3.2-5** *Carbon-catalyzed methane pyrolysis in fluidized-bed reactors: analytical investigation of polyaromatic hydrocarbon formation and two-phase reactor modelling,* **S. De Langhe** - Ghent University, Belgium

11:40 – 12:00 **O-S3.2-6** *Catalytic methane pyrolysis in molten media: from bubble dynamics to tailored solid carbon synthesis and process scale-up,* **Z. Shi** - Shanghai Institute of Microsystem and Information Technology, China

12:00 – 12:20 **O-S3.2-7** *Multi-scale investigation of methane pyrolysis for the simultaneous production of COx-free hydrogen and valuable carbonaceous materials for the steelmaking sector,* **M. Orsenigo**, A. Beretta - Politecnico di Milano, Italy

12:20 – 12:40 **O-S3.2-8** *Leaching and enrichment behaviors of hazardous heavy metal elements in the process of coal gasification,* **X. Wang** - East China University of Science and Technology

12:40 – 13:00 **O-S3.2-9** *Carbon formation on surfaces during methane pyrolysis: effects of temperature, methane flow rate, and operation time,* **B. de Caprariis** - Sapienza Università di Roma, Italy

ROOM C1 – FIRST FLOOR

Parallel Session: Catalytic pyrolysis: Polymers and recycling (S3.3) – Chairs: Salar Tavakkol, Cristian Torri

09:30 – 09:50 **O-S3.3-1** *Catalytic pyrolysis of polyethylene: Effects of shaping zeolite particles and of reactor configuration (in-situ and ex-situ),* **S. Denghezli** - University of Lille, Lorraine & CNRS, France

09:50 – 10:10 **O-S3.3-2** *Sustainable valorization of plastic waste via zeolite-catalyzed pyrolysis and in-line CO2 reforming over Ni-Co-based catalysts,* **S. Das** - Institute of Environmental Technology, CEET VSB - TUO, Czech Republic, Czechia

10:10 – 10:30 **O-S3.3-3** *Mechanisms of different carbon sources in the catalytic preparation of carbon nanotubes via plastic pyrolysis,* **H. Yang** - Shandong University, China

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S3.3-4** *Reliability of milligram-scale high-throughput screening for evaluating polyolefin chemical recycling in the melt with heterogeneous catalysis,* **B. Smeyers** - KU Leuven, Belgium

11:20 – 11:40 **O-S3.3-5** *High-throughput on-line mass spectrometry screening of catalytic fast pyrolysis of cellulose over ZSM-5 zeolites,* **N. Traullé** - Université de Lorraine, France

11:40 – 12:00 **O-S3.3-6** *Catalytic pyrolysis of E-waste plastics using red mud,* **M. Madhukar Borker** - Indian Institute of Technology, India

12:00 – 12:20 **O-S3.3-7** *Thermogravimetric insights into polyethylene degradation: effect of clay-based catalyst acidity and textural properties,* **M. Ifeoma Uzochukwu**, D. Grekov, S. Awad - IMT Atlantique, France

12:20 – 12:40 **O-S3.3-8** *Optimization of catalytic hydrocarbon aromatization to BTX in a lab-scale fluidized bed reactor,* **J. Ordonez Loza** - University of Groningen, Netherlands

12:40 – 13:00 **O-S3.3-9** *Pyrolytic modification of wood enhances its cascaded use,* **D. A. Agar** - Swedish University of Agricultural Sciences, Sweden

ROOM B – GROUND FLOOR

Parallel Session: Applied pyrolysis: Polymers and recycling (S3.4) – Chairs: Gartzen Lopez, Umeki Kentaro

09:30 – 09:50 **O-S3.4-1** *Mechanistic insights and bifunctional effects in Pd/TiO_2–ZrO_2-catalyzed conversion of pyrolytic limonene to cymene,* **L. Arteaga-Pérez** - Universidad de Concepción, Chile

09:50 – 10:10 **O-S3.4-2** *Molten KOH-activated conversion of pyrolysis char derived from mixed plastic into hierarchical porous carbon for supercapacitor electrodes,* **J. Yoon** - Korea Institute of Industrial Technology, South Korea

10:10 – 10:30 **O-S3.4-3** *Comprehensive upgrading of plastic-derived pyrolysis oil to improve the quality of steam cracking feedstock,* **M. Auersvald** - UCT Prague and LCT, Czech Republic

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S3.4-4** *Pyrolysis of end-of-life paddle balls: assessing the kinetics and the recovery of value-added product,* **J. D. Martinez Angel** - Instituto de Carboquímica (ICB-CSIC), Spain

11:20 – 11:40 **O-S3.4-5** *Exploring the thermochemical recycling of polystyrene waste using thermo-oxidative degradation,* **M. V. Navarro** - Instituto de Carboquímica (ICB-CSIC), Spain

11:40 – 12:00 **O-S3.4-6** *Comprehensive characterization of pyrolysis oil using GCxGC-TOFMS, FD-TOFMS, and blank tube FI-TOFMS,* **R. Green** - JEOL Europe

12:00 – 12:20 **O-S3.4-7** *Triple synergy in waste plastic upcycling: enhanced BTEX production via plasma-assisted catalysis over ga-modified ϐ-zeolites,* **J. Gu** - University of Leeds, UK

12:20 – 12:40 **O-S3.4-8** *Effect of water content in activated carbon on the low-temperature microwave-assisted pyrolysis of HDPE,* **M. Vastyl** - Institute of Environmental Technology, Czech Republic

12:40 – 13:00 **O-S3.4-9** *Evaluation of operating conditions on the pyrolysis and in-line catalytic cracking of HDPE over a ZSM5 zeolite catalyst,* **M. Amutio** - University of Basque Country, Spain

13:00 – 14:00 **Lunch**

14:00 – 15:00 **POSTER Session 3**

ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

15:00 – 15:30 Chairs: Axel Funke, Haiping Yang

KN6 Stef Ghysels, Ghent University, Belgium, *"Thermochemistry for selective production of platform chemicals"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation (S3.5)– Chairs: Axel Funke, Haiping Yang

15:30 – 15:50 **O-S3.5-1** *Effect of acid and basic pretreatment on the performance of hydrothermal liquefaction of sewage sludge and olive oil pomace as real waste biofeedstocks,* **C. Prestigiacomo** - University of Palermo, Italy

15:50 – 16:10 **O-S3.5-2** *Thermochemical synthesis of tin-containing hard carbons from waste hemp hurd for sodium-ion battery anodes,* **J. J. Manyà** - Universidad de Zaragoza, Spain

16:10 – 16:30 **O-S3.5-3** *Characterization of volatile carbonyl compounds in biorefinery streams using SPME-GC: implications for occupational health and safety,* **P. Bulsink** - Natural Resources Canada

16:30 – 17:00 **Coffee Break**

17:00 –17:20 **O-S3.5-4** *Production and characterization of biocrude oil from hydrothermal liquefaction of sludge digestate: findings from an intensive experimental campaign,* **G. Manente** - University of Salento, Italy

17:20 – 17:40 **O-S3.5-5** *Untreated bamboo-derived carbons as sustainable anode material for sodium-ion batteries,* **V. Sperati** - IIT-Genova, Italy

ROOM A1 – FIRST FLOOR

Parallel Session: Applied pyrolysis: Fossil fuels (S3.6)– Chairs: Will Meredith, Young-Min Kim

15:30 – 15:50 **O-S3.6-1** *Role of solvent-separated group components and their sub-fractions on coal caking properties,* **J. Yan** - Anhui University of Technology, China

15:50 – 16:10 **O-S3.6-2** *Pressure-dependent pyrolysis of cyclopropanated fuel exo-TCN: experiments and kinetic modeling,* **H. Fu** - Tianjin University, China

16:10 – 16:30 **O-S3.6-3** *Molecular-level investigation of hydrocarbon cracking and early coke formation enabled by an enhanced sampling framework,* **J. Guo** - Tianjin University, China

16:30 – 17:00 **Coffee Break**

ROOM C1 – FIRST FLOOR

Parallel Session: Biochar (S3.7)– Chairs: Sophie Schönfeld, Maurizio Troiano

15:30 – 15:50 **O-S3.7-1** *Tailored biochar based composited for electromagnetic enhanced composite preparation,* **M. Bartoli** - Fondazione Istituto Italiano di Tecnologia, Italy

15:50 – 16:10 **O-S3.7-2** *Insight into the pyrolytic characteristic and heavy metal immobilization during the co-pyrolysis of phytoremediation biomass with duckweed,* **W. Cheng** - Huazhong University of Science and Technology, China

16:10 – 16:30 **O-S3.7-3** *Synthesis, characterization and catalytic activity in dry reforming reaction of Ni/C catalysts prepared from different biomasses,* **M. Guilmont** - IS2M, CNRS, France

16:30 – 17:00 **Coffee Break**

17:00 –17:20 **O-S3.7-4** *Sustainable bamboo-derived biochar as a functional enzyme support: effect of pyrolysis conditions on biocatalytic polymerization,* **L. M. Moreno Pascual** - University of Genova, Italy

17:20 – 17:40 **O-S3.7-5** *Aqueous-phase and acid-modified biochar for sustainable and resilient soils,* **A. El-Aradi**, D. Nowakowski, A. Nowak, T. Kasim, D. Webb - Aston University (EBRI), UK

ROOM B – GROUND FLOOR

Parallel Session: Applied pyrolysis: Polymers and recycling (S3.8) – Chairs: Erik Heeres, Fausto Viteri

15:30 – 15:50 **O-S3.8-1** *Chemical recycling of nylon-6 via catalytic pyrolysis for the selective recovery of ε-caprolactam,* **M. Moschos** - CPERI/CERTH, Greece

15:50 – 16:10 **O-S3.8-2** *Impact of stabilizers on the pyrolysis mechanism in chemical recycling of polyvinyl chloride waste,* **G. Straczewski** - KIT, Germany

16:10 – 16:30 **O-S3.8-3** *Chemical recycling of mixed plastic waste via a two-step process combining hydrothermal liquefaction pretreatment and pyrolysis for fuel oil production,* **B. de Caprariis**, - Sapienza University of Rome, Italy

16:30 – 17:00 **Coffee Break**

17:00 –17:20 **O-S3.8-4** *Chemical recycling of polypropylene via heterogeneously catalyzed dehydrogenation and metathesis,* **N. Meyer** - North-West University, South Africa

17:20 – 17:40 **O-S3.8-5** *Interaction mechanism of organic components during decommissioned pv laminates oxidative pyrolysis for sustainable recycling,* **Y. Lei** - Huazhong University of Science & Technology, China

Thursday, 11th June 2026

ROOM A GROUND FLOOR (streaming in Room B, GROUND FLOOR)

09:00 – 09:30 Chairs: Paola Giudicianni, Mario J. Muñoz-Batista

KN7 Hongwei Wu, Curtin University, Australia, *"Pyrolysis-derived bioproducts from biomass for future sustainable development"*

ROOM A – GROUND FLOOR

Parallel Session: Applied pyrolysis: other; biomass valorisation (S4.1) – Chairs: Paola Giudicianni, Mario J. Muñoz-Batista

09:30 – 09:50 **O-S4.1-1** *The power of silylation: toward a molecular description of liquids from thermochemical processes,* **C. Torri** - Università di Bologna, Italy

09:50 – 10:10 **O-S4.1-2** *Experimental investigation of non-catalytic dry reforming of representative bio-oil compounds,* **D. Amato** - CNR - STEMS, Italy

10:10 – 10:30 **O-S4.1-3** *Representation of lignin derived oligomers in pyrolysis bio-oil: Advances towards improved prediction of vapor liquid equilibria for controlling bio-oil quality,* **A. Funke** - KIT, Germany

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S4.1-4** *Analytical NMR framework with synthetic lignin oligomers for surrogate modelling of fast pyrolysis bio-oils and pyrolignin fractions,* **M. Rojas** - Institute of Catalysis Research and Technology (IKFT); Karlsruhe Institute of Technology (KIT), Germany

11:20 – 11:40 **O-S4.1-5** *Pyrolysis-driven combustion of polylactic acid in hybrid aerospace propulsion,* **F. Cerciello** - Consiglio Nazionale delle Ricerche, Italy

11:40 – 12:00 **O-S4.1-6** *High-Performance biochar: Transforming filler technology in plastics,* **S. Schönfeld** - Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany

12:00 – 12:20 **O-S4.1-7** *Model for cellulose pyrolysis combining kinetic Monte Carlo simulation and vapor-liquid equilibrium,* **S. Vattaparambil Sudharsan** - Luleå. University of Technology, Luleå, Sweden

ROOM A1 – FIRST FLOOR

Parallel Session: Applied pyrolysis: Biomass valorisation; Fossil fuels (S4.2) – Chairs: Joan Manyà, Marion Carrier

09:30 – 09:50 **O-S4.2-1** *Effect of steam and solid residence time on wood pyrolysis-gasification products,* **M. Hechmi Aissaoui** - LRGP/CNRS, France

09:50 – 10:10 **O-S4.2-2** *In-situ release detection and mechanism of alkali metals during coal and biomass co-pyrolysis/gasification,* **X. Song,** L. Zhang, G. Yu - Ningxia University, China

10:10 – 10:30 **O-S4.2-3** *Eucalyptus biomass valorization: evaluation of the influence of slow pyrolysis bio-oil inclusion in refining processes,* **N. Pontes** - Federal University of Rio de Janeiro, Brazil

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S4.2-4** *Thermochemical conversion of digestate waste for hydrogen-rich syngas production using TGA,* **V. Belandria** - ICARE CNRS UPR3021, Orléans, France

11:20 – 11:40 **O-S4.2-5** *Advanced molecular elucidation of biogenic contributions from pyrolysis bio-oil co-processed in conventional refining: a viable and sustainable pathway for the energy transition,*

R. Vieira Santana da Silva - Federal University of Rio de Janeiro, Brazil

11:40 – 12:00 **O-S4.2-6** *Nanoscale mixing of cellulose and lignin alters their pyrolysis interactions and derived carbon reactivity,* **C. Guizani** - VTT, Finland

12:00 – 12:20 **O-S4.2-7** *Study on biocarbon produced from untreated and water leached bark,* **L. Wang** - SINTEF Energy Research, Norway

12:20 – 12:40 **O-S4.2-8** *Conversion of cellulose into azaheterocycles through pyrolysis under a reactive NH3 atmosphere,* **E. Kooy** - Universiteit Gent, Belgium

ROOM C1 – FIRST FLOOR

Parallel Session: Catalytic pyrolysis (S4.3) – Chairs: Benedetta De Caprariis, Stelios Stefanidis

09:30 – 09:50 **O-S4.3-1** *A Tandem Micro Reactor–GC/MS Approach to Probing Catalytic Pyrolysis and High-Pressure Hydropyrolysis of Biomass,* **Y. Kim** - Daegu University, South Korea

09:50 – 10:10 **O-S4.3-2** *Understanding nitrogen-induced catalyst deactivation in plastic waste pyrolysis from lab to pilot scale,* **J. Vogt** - Karlsruhe Institute of Technology (KIT), Germany

10:10 – 10:30 **O-S4.3-3** Withdrawn

10:30 – 11:00 **Coffee Break**

Parallel Session: Catalytic pyrolysis; Applied pyrolysis: other (S4.3) - Chairs: Benedetta De Caprariis, Stelios Stefanidis

11:00 – 11:20 **O-S4.3-4** *Highly efficient selective co-hydrodeoxygenation of bio-oil and plastic wastes to naphthenes over Co/HZSM-5,* **X. Yin** - Zhejiang University, China

11:20 – 11:40 **O-S4.3-5** *Operation and results of a pilot-plant carbon-moving-bed methane cracking reactor for the production of sustainable hydrogen and solid carbon,* **A. Riorda** - Politecnico di Torino, Italy

11:40 – 12:00 **O-S4.3-6** *Impact of oxygen content on the storage stability of catalytic fast pyrolysis oils: insights from pilot scale production,* **T. Khazraie** - Valmet Technologies, Finland

12:00 – 12:20 **O-S4.3-7** *Influence of fluid bed operating conditions on waste pyrolysis products,* **B. B. Hansen** - DTU, Chemical Engineering, Denmark

ROOM B – GROUND FLOOR

Parallel Session: Applied pyrolysis: Polymers and recycling (S4.4) – Chairs: Osvalda Senneca, Katarzyna Januszewicz

09:30 – 09:50 **O-S4.4-1** *Inline High-Sensitivity Analysis of Brominated Pyrolysates from TBBPA-Containing Polystyrene Using Py-GC/NICI-MS,* **S. Kumagai** - Tohoku University, Japan

09:50 – 10:10 **O-S4.4-2** *Unraveling the pyrolytic degradation mechanisms and recycling potential of non-isocyanate polyurethanes,* **A. Bukowczan** - Kracow University of Technology, Poland

10:10 – 10:30 **O-S4.4-3** *A novel strategy for recycling waste wind turbine blades under steam and air conditions: chemical recovery and char removal,* **C. Ma** - Chongqing University, China

10:30 – 11:00 **Coffee Break**

11:00 – 11:20 **O-S4.4-4** *Multi-phase kinetic modeling of LDPE pyrolysis: From condensed-phase degradation to secondary gas-phase reactions,* **K. Wu** - Department of Chemistry, Materials, and Chemical Engineering “G. Natta”, Politecnico di Milano, Italy

11:20 – 11:40 **O-S4.4-5** *Chemical recycling of biaxially oriented PP (BOPP) films,* **M. T. Nogueira** - CERENA/IST, Portugal

11:40 – 12:00 **O-S4.4-6** *High temperature vortex pyrolysis of polyethylene for ultra high light olefin yields*

H. Khakpour - Laboratory for Chemical Technology (LCT), Belgium

12:00 – 12:20 **O-S4.4-7** *Heteroatom transfer and product composition of plastic waste pyrolysis,* **F. Calik Ulu** - Ghent University, Belgium

12:20 – 12:40 **O-S4.4-8** *Co-pyrolysis of polypropylene and asphalt waste: insights into synergistic effects and oil yield optimization,* **Y. Ech'Chalh** - Lorraine University, France

ROOM A – GROUND FLOOR

12:40 – 13:00 **Closing Ceremony**

LIST OF POSTER CONTRIBUTIONS

Poster Session 1, Monday June 8th, Floor 0 (P-S1F0) Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation		
P-S1F0-01	Thermal decomposition and kinetics of a nitrochitosan-based energetic composite	M. Dourari
P-S1F0-02	Effects of phase separation and storage temperature in slow pyrolysis bio-oils: insights from a 145-days monitoring study	D. Amato
P-S1F0-03	Structure–Activity Relationships in the Reductive Amination of Furfural over Pd/ZrO_2–TiO_2 Bifunctional Catalysts	L. Arteaga-Pérez
P-S1F0-04	Pressurised pyrolysis of sugarcane bagasse for hydrogen-rich syngas production	Q. Sun
P-S1F0-05	Development of new forms of carbonaceous adsorbents suitable for water purification: activated biochar for Congo red adsorption	R. Marsalek
P-S1F0-06	Study of liquid and solid product formation after hydrothermal processing of carbohydrate and aromatic biomass derivatives	A. Zhurinsh
P-S1F0-07	Design and characterization of a promising chitin-based energetic polysaccharide	S. Ouahioune
P-S1F0-08	Energetics of torrefied droppings of ZOO animals	B. Taraba
P-S1F0-09	Process integrated valorization of fast pyrolysis co-products: enhancing the textural and environmental quality of biochar via post-pyrolysis treatment.	I. Aziz
P-S1F0-10	Torrefaction of the ZOO animals droppings	M. Mucha
P-S1F0-11	Co-pyrolysis of greenhouse tomato plant waste contaminated with plastics: influence of process parameters and biochar potential for thermal plasma treatment	A. Castagna
P-S1F0-12	Green hydrothermal synthesis of catechol from 2 acetylfuran	S. Ghysels
P-S1F0-13	Plasma and ball milling pretreatment for enhanced production of levoglucosenone from catalytic conversion of cellulose over a sulfonated carbon catalyst	X. Huang
P-S1F0-14	Acid washing and carbonization of biomass bottom ash for recycling into bio-coke	U. Chung
P-S1F0-15	Structure–Performance relationships in Ni/C catalysts for Power-to-Gas applications	A. Cleemput
P-S1F0-16	Effect of pre- and post-treatments on the pyrolysis condensate of pine bark	Z. Sebestyén
P-S1F0-17	Characterization and antifungal activity of wood vinegar produced from slow pyrolysis of canola stalk	T. Aktas
P-S1F0-18	Turning agro-industrial pruning residues into biochar: insights from slow pyrolysis and value chain analysis	P. Giudicianni
P-S1F0-19	Effects of pyrolysis temperature on biochar yield, CO_2 adsorption capacity and kinetic from coconut husk biomass	R. Chamnanmor
P-S1F0-20	Optimized lignin-derived pyrolytic oils enhance oxidative aging resistance of asphalt binders	J. R. Colina
P-S1F0-21	Biomass pyrolysis in a fixed-bed reactor: effect of pressure and sweep gas velocity	A. Dufour
P-S1F0-22	Energy recovery from slaughterhouse waste: gasification performance and digestate valorization	V. Belandria

P-S1F0-23	Pyrolysis-driven iron redox systems: a multifunctional approach to hydrogen, biofuels, and carbon capture	O. Senneca
P-S1F0-24	Thermo-catalytic co-pyrolysis of waste rain tree pods and natural rubber: influence of temperature, feed ratio, and catalysts on bio-oil yield and its properties	R. Mishra
P-S1F0-25	Unraveling the characteristics and pyrolysis mechanism of energetic cellulose carbamate nitrate supplemented with organic stabilizers.	L. Boumaza
P-S1F0-26	Enabling a global view of reaction class in hydrocarbon pyrolysis with ReaxFF MD and machine learning	X. Li
P-S1F0-27	Accounting for structural variability of lignin in CRECK-S-B kinetic models for pyrolysis across different extraction methods	M. Suleiman
P-S1F0-28	Evaluating the ReaxFF reactive force field for simulations of cellulose carbonization	E. Virtanen

Poster Session 1, Monday June 8th, Floor 1 (P-S1F1) Analytical Pyrolysis		
P-S1F1-01	Analytical pyrolysis of bamboo residues: a case in point of climate variation in North China Plain during 4th century BC	B. Han
P-S1F1-02	Cosmetic Residues in Greek Lekythoi from the Necropolis of Spina Investigated by Analytical Pyrolysis	A. Rombolà
P-S1F1-03	Thermoanalytical techniques for the knowledge of plastic heritage: from chemistry to conservation	A. Ferretti
P-S1F1-04	Py-GC-MS in archaeometry: identifying materials, degradation, restorations, and authenticity markers in cultural heritage	J.J. Lucejko
P-S1F1-05	Air quality monitoring in museum environment using magic chemisorbers	A. Micheluz
P-S1F1-06	Scientific analysis of lacquerware bearing stamp patterns excavated from different archaeological sites	R. Tanaka
P-S1F1-07	Artificial and natural UV aging of beeswax: new insights into its chemical composition from Py-GC/MS and SPME-GC/MS	I. Bertelli
P-S1F1-08	From waste to resources: product valorization and elemental evolution during hydrothermal liquefaction of food waste	R. Bao
P-S1F1-09	Field applicability evaluation of size-segregated microplastics in air in representative metropolitan areas using analytical pyrolysis–GC/MS	S. Kim
P-S1F1-10	Characterization of microplastics in ambient air and their relationship with PM2.5 organic components using pyrolysis–GC/MS	S. Kim
P-S1F1-11	Microwave-assisted treatment to convert commercial polyethylene microbeads into a liquid suspension used as reference material for Py-GC-MS	R. Domingues
P-S1F1-12	Soot formation and polycyclic aromatic hydrocarbons in soot during p-cymene pyrolysis	K. Alexandrino
P-S1F1-13	Multi-analytical and multi-matrix approach for microplastics characterization: the synergy of Py-GC/MS and µ-FTIR	E. Gregoris
P-S1F1-14	Characterization and quantification of tire and road wear particles (TRWP) in environmental samples: Integration of Py-GC/MS and Rock-Eval® techniques	P. Cologon
P-S1F1-15	Quantitative analysis of trace PTFE in polymer materials by double-shot pyrolysis-GC/MS	M. Soll
P-S1F1-16	Chronological characterization of airborne microplastics in Kanagawa, Japan by Pyrolysis-Gas Chromatography/Mass Spectrometry	H. Shirata
P-S1F1-17	Unravelling the impact of microwave-assisted pre-treatment on tire wear particles by Py-GC-MS	G. Dumont

P-S1F1-18	Optimization of pre-treatment protocols for micro- and nanoplastics detection in human keratinous and blood tissue samples using analytical Py-GC/MS	S. Charushree
P-S1F1-19	Characterization and quantification of microplastics in water in mid-Atlantic watersheds in the United States by pyrolysis GC-MS	K. Sam
P-S1F1-20	Exploring the potential of one-pot microwave-assisted pretreatments coupled with PY-GC-MS for the quantification of mps and associated contaminants	J. La Nasa
P-S1F1-21	Analytical pyrolysis for the characterization of hypercrosslinked polymers	N. Treml
P-S1F1-22	Preliminary application of pyrolysis and TD-GC-MS/MS to study additive leaching from plastics induced by sediment abrasion and fragmentation	F. De Falco
P-S1F1-23	Assessing airborne microplastics concentrations in indoor working environments using Py-GC-MS	L. Barlucchi
P-S1F1-24	Quantification of nano/microplastic in urban atmospheric deposition using pyrolysis-GC-MS	I. Coralli
P-S1F1-25	Chemical markers for tyre wear particles using pyrolysis-GC-MS	G. D. Abbott
P-S1F1-26	Biodegradable bioplastics in soil: multi-analytical evidence of fragmentation and soil organic matter changes	A. Rombolà
P-S1F1-27	Decoding subsurface biomarkers in a Mars-analogue lava tube through analytical pyrolysis and isotope fingerprints	A. Miller
P-S1F1-28	Enhanced processing ability with a newly designed underwater microparticle collection device for Pyrolysis-GC/MS of microplastics	A. Watanabe
P-S1F1-29	Addressing matrix effects in micro- and nanoplastic quantification using Pyrolysis-GC-cIMS-HRMS	F. Nardella
P-S1F1-30	Overcoming matrix and oligomer interferences in pyrolysis GC-MS analysis of microplastics in animal tissue	S. Böhmdorfer
P-S1F1-31	Metagenomic analysis of key methanogenic pathways in solid-state co-anaerobic fermentation of weathered coal and cattle manure	B. Song
P-S1F1-32	Improving the determination of atomic mass balances of biochars produced from biomass pyrolysis	A. Dufour
P-S1F1-33	Which pyrolysers should you choose based on your samples, your analytical methods and your instrumentation (GC, GC-MS)? How can you reduce the maintenance costs of a pyrolyser?	Y. Simon

Poster Session 2, Tuesday June 9th, Floor 0 (P-S2F0) Catalytic pyrolysis		
P-S2F0-01	Catalytic co-hydropyrolysis of biomass/plastic over Chilean natural zeolite modified with acid and impregnated with mono- and bimetallic nickel - cobalt	B. Puentes-Navarro
P-S2F0-02	The mechanism of biomass pyrolysis quality improvement catalyzed by calcium oxide-based catalysts	G. Yu
P-S2F0-03	Comprehensive utilization of corn cob (Zea Mays) for the production of biofuels and platform molecules through a hybrid bio-thermocatalytic conversion route	D. Bustos-Martinez
P-S2F0-04	Valorization of non-edible vegetable oil through zeolite-catalyzed pyrolysis: a model study on oleic acid for aromatics and SAF precursors production	W. Piao
P-S2F0-05	Performance of Ni/Al_2O_3, Ni/SiO_2, and Ni/ZrO_2 in the biomass pyrolysis and in-line oxidative steam reforming process for hydrogen production	M. Amutio
P-S2F0-06	Preparation of carbon nanosheet from molten salts assisted pyrolysis of biomass towards to carbon-negative technology	S. Xia

P-S2F0-07	Enhanced hydrocarbons generation of cyclic catalytic pyrolysis of acid-washed sweet sorghum stalk through Mo/HZSM-5	D. Chen
P-S2F0-08	Thermal and catalytic pyrolysis of olive stone to produce phenol-rich bio-oils	R. Migliaccio
P-S2F0-09	Thermo-metallic engineering of MOF-derived catalysts: Influence on selectivity during biomass-plastic co-hydropyrolysis	S. Alejandro-Martín
P-S2F0-10	Advances in catalytic pyrolysis of lignocellulosic biomass for bio-oil upgrading	E. Ramirez
P-S2F0-11	Catalytic upgrading of pyrolysis vapors from residual *Acacia longifolia* biomass: comparative performance of commercial Fe-, Ni-, and Mo-based catalysts	C. Marques
P-S2F0-12	Polymer to fuel-range hydrocarbons: an investigation of thermal and β-zeolite-catalyzed pyrolysis of polypropylene (PP) using Py-GC-MS and Py-FT-IR techniques	Ł. Korzeniowski
P-S2F0-13	Tailoring hierarchical nanocrystalline zeolite NaY: a template-free hydrothermal strategy for advanced catalytic pyrolysis applications	C. Ayoub
P-S2F0-14	Thermal decomposition and energetic behavior of ammonium nitrate modified with nitrocellulose-coated AlMg–NGO@nFe_2O_3 Nanothermite	F. Gahfif
P-S2F0-15	Spray pyrolysis synthesis of Cu-CeO2-ZrO2 catalysts with enhanced oxygen storage capacity for reverse water-gas shift reaction	I. Jeon
P-S2F0-16	Structurally stable methanation-resistant catalysts for the reverse water-gas shift reaction	C. Yoon
P-S2F0-17	Catalytic fast pyrolysis of biomass over hierarchical zeolites: comparison of mordenite, beta and ZSM-5	A. Dufour
P-S2F0-18	Catalytic pyrolysis of organic waste over nanosponge zeolite for enhanced aromatic hydrocarbon production	Y. Park
P-S2F0-19	Catalytic co-pyrolysis of woody biomass and waste plastics: mechanistic insights into selective BTX production	Y. Park
P-S2F0-20	Catalytic co-conversion of biodegradable polymer and plastics over hierarchical zeolite catalyst	Y. Park
P-S2F0-21	N-doped reduced graphene oxide supported Fe_2O_3: a high-performance catalyst for AN-based propellants	N. Manel
P-S2F0-22	Effect of nano structuring on the decomposition kinetics of cellulose nitrate	C. Tennache
P-S2F0-23	Zn-Fe Co-modified HZSM-5/MCM-41 catalytic co-pyrolysis of miscanthus and polystyrene to produce aromatic-rich oil	Y. Wang
P-S2F0-24	Structural tailoring of pyrolysis-derived carbon from thermo-catalytic methane decomposition	S. Bazri
P-S2F0-25	Microwave-assisted catalytic pyrolysis of mixed medical plastic waste: sustainable hydrocarbon, fuel gas, and carbon material recovery	K. Kumar
P-S2F0-26	Thermal conversion of heterogeneous marine polymer waste via catalytic pyrolysis using waste-derived catalysts: assessment of conversion efficiency and product quality for future applications	M. Sajdak
P-S2F0-27	Zeolite catalysed upgrading of CFRP pyrolysis vapours for enhanced hydrogen production	H. Llona
P-S2F0-28	Enhancing Syngas production from plastic waste via catalytic steam gasification	A. Fivga

Poster Session 2, Tuesday June 9th, Floor 1 (P-S2F1), Pyrolysis instrumentation and methodology, Applied pyrolysis - other		
P-S2F1-01	Optimizing activated carbon properties: the role of precursor source, carbonization and activation parameters	A. Volperts
P-S2F1-02	Bromination mechanism of typical metallic radionuclides on defective graphite surface by HBr ： insight from first principles	M. Chen
P-S2F1-03	Hydrothermal carbonization of sewage sludge for thermal plasma treatment: influence of process parameters on energy and mineral recovery in hydrochars	A. Castagna
P-S2F1-04	Oxidative slow pyrolysis in an auger reactor: autothermal operation and process intensification	G. Lombardi
P-S2F1-05	Evaluation on the migration and occurrence mechanism of impurities in decommissioned nuclear graphite by multi-halogen synergistic roasting	Z. Ma
P-S2F1-06	Biochar from intermediate pyrolysis for enhanced cementitious grouts	D. Nowakowski
P-S2F1-07	Upgrading fast-pyrolysis chars through thermal stabilization: analytical insights and implications for their use	A. Rizzo
P-S2F1-08	Rapid biochar quality screening using hyperspectral imaging and machine learning	A. El-Aradi
P-S2F1-09	Study on CO2 activation on properties of biochar	L. Wang
P-S2F1-10	Modeling of residence time for screw conveyors and auger reactors	E. Aschenbrener
P-S2F1-11	Evolution mechanism of mechanical properties of recycled glass fibers during pyrolysis–oxidation treatment of waste wind turbine blades	Y. Hu
P-S2F1-12	Comprehensive characterization of pyrolytic aqueous phases for valorization via aqueous phase reforming	L. Nossova
P-S2F1-13	Hydrogen evolution through ammonia borane hydrolysis over iron tailored pig manure biochar catalyst	M. Bartoli
P-S2F1-14	Corn stalk pyrolysis: process characterization and properties of products	J. Kluska
P-S2F1-15	Sustainable valorisation of almond residues to hard carbon cathodes for aqueous zinc hybrid supercapacitors	J. Manyà
P-S2F1-16	Gas composition dynamics in biomass gasification processes	R. Panizio
P-S2F1-17	Conceptual pathways for the valorisation of gasification-derived biochars	R. Panizio
P-S2F1-18	Effect of CaO Loading on in-situ CO_2 capture during pruning biomass gasification	B. Rijo
P-S2F1-19	Valorisation of intermediate pyrolysis oils from woody biomass towards marine residual fuels	D. Nowakowski
P-S2F1-20	Evolution of magnetic and paramagnetic behavior in pyrolyzed bamboo: influence of thermal treatment and iron incorporation	O. Pandoli
P-S2F1-21	Integrating hydrothermal carbonization and pyrolysis for the revalorization of sewage sludge digestate: a hybrid thermochemical-biological perspective	Y. Küçükağa
P-S2F1-22	Pyrolytic conversion of rubber fig leaves into porous carbon material for environmental application	B. Tripathy
P-S2F1-23	High-temperature pyrolysis of pine sawdust using metallurgical slag as oxygen carrier and gasification of solid residues	H. Hu
P-S2F1-24	Conversion of hazelnut shell waste into hard carbon materials for the sustainable production of hybrid capacitors	D. Licursi

P-S2F1-25	Pyrolysis of carbonaceous xerogels synthesized via polycondensation of m-substituted phenols with furfural: thermogravimetric and thermomechanical investigation	P. Bulavová
P-S2F1-26	A novel application of the spontaneous liquid-gas imbibition method for pore structure characterization in pyrolytic porous materials	Y. Wu
P-S2F1-27	Thermal-analysis-based characterization of the heating-combustion boundary in biomass systems	L. Fu
P-S2F1-28	Fluidised-bed pyrolysis of contaminated biomass – process parameters and product analysis	P. Wąsik
P-S2F1-29	Residual energy recovery from digestate via Py-AD approach: water-soluble fraction of bio-oil as feedstock and its molecular characterization by silylation-GC-MS	F. Zimbardi
P-S2F1-30	The influence of physical parameters and puffing conditions on the thermal characteristics of cigar combustion cones	Q. Zhang

Poster Session 3, Wednesday June 10th, Floor 0 (P-S3F0), Applied pyrolysis: Polymers and recycling		
P-S3F0-01	Improving liquid and BTEX production via co-pyrolysis of polystyrene and road asphalt waste	Y. Ech'Chalh
P-S3F0-02	Co-pyrolysis characteristics of polyethylene and biomass in a bubbling fluidized bed	A. Taehwi
P-S3F0-03	Development and Validation of a Py-GC/MS method for the simultaneous determination of microplastics and biomicroplastics in seawater	E. Rodríguez
P-S3F0-04	Synthesis and characterization of a promising energetic nitrochitosan	M. Hamouche
P-S3F0-05	Unveiling interactions of enzymatic hydrolysis lignin and waste tires during co-pyrolysis	S. Cui
P-S3F0-06	Design of experiments for PS pyrolysis in a conical spouted bed reactor	S. Sivanandan
P-S3F0-07	Deep insights into fluorine transformation mechanisms during pyrolysis of retired photovoltaic backsheets: experimental validation and ReaxFF molecular dynamics simulations	S. Deng
P-S3F0-08	Experimental and modelling investigation of primary and secondary reactions in LDPE Pyrolysis	L. Marchetti
P-S3F0-09	Modulating neat and catalytic polyolefin pyrolysis using Damköhler numbers	H. Wong
P-S3F0-10	Characteristics of pyrolysis products from waste polyolefin plastics using 15 kg/hr continuous auger system	K. Su
P-S3F0-11	Circular economy pathways for artificial turf waste: pyrolysis as a recycling strategy	M. Jampolski
P-S3F0-12	One-pot synthesis of hierarchical ZSM-5 for lifetime improvement in catalytic conversion of plastic waste	C. Ke
P-S3F0-13	A study on rapid analysis of pyrolysis oil using the high-resolution GC-MS and blank tube field ionization method	T. Satoh
P-S3F0-14	Chemical upcycling of waste plastics over metal–acid bifunctional catalysts	C. Liang
P-S3F0-15	Pretreatment improving in-situ catalytic pyrolysis of plastic waste feedstocks	H. Leuven
P-S3F0-16	Catalytic pyrolysis of polystyrene over zeolite materials toward BTEC fraction production	K. Vikanova

P-S3F0-17	Utilization of plastic waste-derived heavy hydrocarbons as steam cracking feedstock	B. Csutorás
P-S3F0-18	Pyrolysis as the gateway thermochemical route for plastic-to-hydrogen-rich gas valorization	M. Muñoz-Batista
P-S3F0-19	Pyrolysis of multilayer plastic packaging to yield steam cracking feedstock	M. Auersvald
P-S3F0-20	On the purification of tire pyrolysis oil using a lab-scale TRL-4 packed distillation column for limonene and BTEX recovery	J. Angel
P-S3F0-21	Pyrolysis of multilayer plastics: optimising the process	J. Lahtinen
P-S3F0-22	Steam cracking of HDPE over different FCC catalysts in a fountain-enhanced conical spouted bed reactor	J. Alvarez
P-S3F0-23	Synergistic effects of co-hydrothermal carbonization of PVC and spent coffee grounds for enhanced dechlorination and fuel quality	J. Y. Lee

Poster Session 3, Wednesday June 10th, Floor 1 (P-S3F1), Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other		
P-S3F1-01	Catalytic pyrolysis of biomass using BECCS-derived ash: enhanced biochar yield, carbon retention, and process performance	J. Sun
P-S3F1-02	Tuning pyrolysis temperature to engineer bamboo biochar for laccase immobilisation and water treatment	O. Pandoli
P-S3F1-03	Spent coffee biochar contained poly(dimethylsiloxane) composites as membranes for gas separation	R. Salvo
P-S3F1-04	Biowaste valorization using a pilot scale continuous pyrolysis unit within the ENREGAT large research infrastructure	B. Grycová
P-S3F1-05	Novel activated bonechar prepared by microwave pyrolysis of waste animal bones for xylene adsorption from air	Z. Jankovská
P-S3F1-06	Iron tailored biochar for waterborne bacterial treatment	M. Bartoli
P-S3F1-07	Valorisation of reindeer bone via pyrolysis: Product distribution and characterisation for environmental applications	P. Premchand
P-S3F1-08	Selective condensation behavior of biomass pyrolysis vapors at wide condensation temperatures: component evolution,prediction, and validation	W. Ge
P-S3F1-09	Effect of pyrolysis temperature on the Crystal Violet adsorption performance of ball-milled functionalized biochar	C. Grottola
P-S3F1-10	Effect of blends of hydrochar and straw during co-pyrolysis for biochar production	C. Grottola
P-S3F1-11	Wood cell wall ultrastructure investigated via hydrolyzable sugars in char and TG-MS analysis	H. Kawamoto
P-S3F1-12	Study on the recovery method for lacquer films in epoxy resin-embedded samples for stratified analysis by py-GC/MS	K. Tsubouchi
P-S3F1-13	Untreated pyrolysed 3D Bamboo as a solar steam generation device	O. Pandoli
P-S3F1-14	Volatile composition and thermal behavior of hydrochars produced from carbohydrates and wood biomass	B. Babinszki
P-S3F1-15	Impact of process conditions on hydrochars derived from the hydrothermal carbonization of goat manure	Z. Sebestyén

P-S3F1-16	Comparative thermal degradation analysis of pomegranate, walnut, and pistachio biomasses: influence of drying method on thermochemical stability and volatile content	S. Shaghaghi
P-S3F1-17	Hydrothermal liquefaction of the invasive macroalga chaetomorpha linum: parametric optimization and product characterization	R. Giannelli
P-S3F1-18	Thermochemistry as synthesis tool for new chemical building blocks from isosorbides and isomannides	S. Ghysels
P-S3F1-19	Comparative study on the hydrothermal carbonization of glucose and levoglucosan: understanding carbon sphere formation pathways	A. Plavniece
P-S3F1-20	Pyrolysis characteristics and thermo-kinetic parameters for hydrochars produced from agricultural industries	V. Belandria
P-S3F1-21	Valorizing blended spent coffee grounds and date seeds for hydrogen production: pyrolysis, kinetics, and machine learning applications	S. Kordoghli
P-S3F1-22	Thermogravimetric and kinetic study of pomegranate peel, prickly pear peel, and their mixture for bioenergy applications	S. Haddad
P-S3F1-23	In-situ study of particle evolution at different stages during coal gasification process	Y. Gong
P-S3F1-24	Effect of lignite thermal dissolution solubles addition on coke reactivity and its dissolution loss kinetics under a hydrogen-rich atmosphere	H. Shui
P-S3F1-25	Unlocking lignite’s value through structure-guided alkaline depolymerization and electro-oxidative upgrading	Z. Wang
P-S3F1-26	Study on the modification of coal gasification fine slag for corn-stalk pyrolysis catalysts	Q. Guo
P-S3F1-27	Catalytic reforming of lignite pyrolysis volatiles over metal oxide and zeolite tandem catalysts for light aromatics production	J. Cao
P-S3F1-28	Thermal and catalytic co-pyrolysis of olive stone and LDPE in a spouted bed reactor for sustainable drop-in hydrocarbon	R. Migliaccio
P-S3F1-29	Hydrogen transfer and reaction mechanism during gradient temperature pyrolysis of coal under steam atmosphere	H. Hu
P-S3F1-30	From pyrolysis to application: long-term evaluation of sewage sludge biochar (greenchar) in green roof substrates	V. Frišták
P-S3F1-31	In-situ detection of catalytic cracking of Naomaohu pyrolysis volatiles over Fe and Al components in red mud	H. Hu

Keynote Speakers



KN1 Yuyang Li, School of Mechanical Engineering, Shanghai Jiao Tong University, China. Prof. Yuyang Li is a tenured professor and Vice Dean at the School of Mechanical Engineering, Shanghai Jiao Tong University. His research focuses on carbon-neutral energy and power, particularly through pyrolysis approaches. He has published more than 200 peer-reviewed journal papers and has been elected a Fellow of the Combustion Institute. He serves/has served as the Editor-in-Chief of Progress in Reaction Kinetics and Mechanism, an Associate Editor of Carbon Neutrality, the Chair of the 3rd Symposium on Ammonia Energy, and the Chair of the 21st China Symposium on Analytical and Applied Pyrolysis.



KN2 Clemens Schwarzinger, Johannes Kepler University Linz, Austria. Clemens Schwarzinger has studied technical chemistry at the Johannes Kepler University in Linz where he also finished his Master and PhD (2002), both theses in the field of analytical pyrolysis of lignocellulosic materials, especially carbohydrates. After two industrial PostDocs and a visit as Guest Professor at the Petroleum Institute in Abu Dhabi, he became associate Professor in Linz in 2008. His current research interests are the analysis and characterization of polymeric materials (natural and synthetic) as well as the scientific analysis of gems and minerals.



KN3 Marja Lamoree, Vrije Universiteit Amsterdam, Netherlands. Marja Lamoree, PhD, is Professor of Analytical Chemistry for Environment and Health at the Amsterdam Institute for Life and Environment of the Vrije Universiteit, Amsterdam. In A-LIFE, she is the head of the section “Chemistry for Environment and Health”. She works on the development and application of advanced analytical methodologies to assess human and environmental exposure, focusing on chemicals and/or particles for which no routine methods are available. She contributes to the advancement of the field of quantitative analysis of micro- and nanoplastics in human blood and other tissues with a strong focus on quality assurance and quality control aspects.



KN4 Osvalda Senneca, STEMS-CNR, Italy. PhD in Chemical Engineering at University of Naples Federico II, Naples, 1998. Head of Research at Italian National Council of Research, Institute of Science and Technology for Sustainable Energy and Mobility, Naples, Italy (STEMS-CNR). “Gastprofessor” at RUB University (DE), chair in Thermochemical carbon conversion. Mercator fellow of the German Research Foundation (DFG). In 2022 member of PNRR-PNIEC Commission (Recovery Fund for Energy) of the Italian Ministry of Ecologic Transition. Top 2% scientist according to Stanford Career Rankings 2018-2023. Editor of the Journal of Analytical and Applied Pyrolysis.



KN5 Alba Dieguez-Alonso, TU Dortmund University, Germany. Alba Dieguez Alonso studied Industrial Engineering at the University of Vigo (Spain) and earned her PhD from Technische Universität Berlin (Germany) in 2015. She then continued at TU Berlin as a postdoctoral researcher and group leader (2015 – 2020). During this time, she did two scientific stays at Lawrence Livermore National Laboratory (California, USA) in 2016 and 2017. In September 2020, she was appointed Junior Professor at Otto von Guericke University Magdeburg (Germany), where she led the Heat and Mass Transfer group. Since November 2023, she is Professor at TU Dortmund University, heading the Laboratory of Transport Processes at the Department of Biochemical and Chemical Engineering.

KN6 Stef Ghysels, Ghent University, Belgium. Stef Ghysels graduated in 2017 as a bioscience engineer (chemistry and bioprocess technology), and currently holds a position as post-doctoral researcher/lecturer at Ghent University (Belgium). His research focuses on “biomass-to-chemical building blocks”. In his research, Dr. Ghysels applies pyrolysis to convert complex biomass into pyrolysis liquids, as a starting point for biorefineries. Here, the intention is to embrace, rather than erase, the intrinsic chemical functionalities. Another research interest concerns thermochemical reaction engineering: (i) harnessing the power of heat to perform intramolecular chemical rearrangements and (ii) using ammonia as reactive gas upon pyrolysis to obtain N-heterocycles. During his research stay at the University of Groningen, he worked on catalytic subcritical conversions.





KN7 Hongwei Wu, Curtin University, Australia. Prof Hongwei Wu received his PhD in Chemical Engineering from the University of Newcastle, Australia. He is currently full Professor of Chemical Engineering at Curtin University, where he manages the High Temperature Processing Laboratory. The research interests of Prof. Wu include mainly thermochemical processing of solid fuels, biofuels and biochemicals, biocarbon, and green metals. His research has developed new technologies that led to spin-off. Prof Wu is a fellow of the Combustion Institute (2019). Since Jan 2020, he has also been serving as the Editor-in-Chief of *Energy & Fuels* – a journal published by the American Chemical Society

Abstracts: Keynotes

KN1 - Pyrolysis-Driven Combustion Energy and Flame Synthesis Research: A Review of Experimental, Kinetic Modeling, and Application Advances

Yuyang Li (Shanghai Jiao Tong University, China)

09:20-09:50 Session KN1: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

Pyrolysis plays a central role in a wide range of fields related to energy conversion and material synthesis, encompassing key areas such as engine combustion and flame synthesis of nanomaterials. This lecture provides a systematic review of recent advances in the study of pyrolysis processes, covering fundamental experimental investigations, kinetic model development, and the extension toward engineering applications. Particular emphasis is placed on frontier topics including fuel active cooling, reaction control of ammonia combustion in gas turbines, and flame synthesis of silicon-based nanoparticles. First, recent advances in experimental methodologies for studying pyrolysis are introduced. Through the development and application of experimental platforms such as constant-volume combustion vessels, shock tubes, and flow reactors, precise control of pyrolysis reaction pathways and reaction progress has been achieved over wide ranges of temperature and pressure. When combined with advanced diagnostic techniques such as synchrotron vacuum ultraviolet photoionization mass spectrometry, quantitative measurements of stable species, radicals, and key intermediates become possible. These experimental approaches provide unprecedented insights into radical pool evolution and reaction pathway competition during fuel pyrolysis. Second, the lecture presents recent progress in the development and validation of pyrolysis kinetic models. Based on high-level quantum chemical calculations and kinetic calculations, accurate rate constants for key pyrolysis pathways have been obtained. Comprehensive kinetic models capable of describing fuel decomposition, radical formation, and molecular growth have been constructed. By integrating newly acquired experimental data with literature data, the models have been cross-validated against multiple types of experimental data. The results demonstrate excellent predictive capability over a wide range of operating conditions, laying a solid foundation for practical applications of these models under realistic conditions. Finally, recent advances in the application of pyrolysis processes across multiple scenarios are highlighted. In propulsion and energy systems employing active cooling, fuel pyrolysis serves not only as an efficient heat sink but also as a critical source of reactive intermediates, making accurate prediction of pyrolysis initial temperatures and conversion rates essential. In the context of reaction control for ammonia combustion as a novel zero-carbon gas turbine fuel, strategies based on ammonia pre-cracking and oxygen enrichment driven by self-promoted fuel pyrolysis offer new perspectives toward addressing the long-standing “holy grail” challenge of simultaneously enhancing reactivity and controlling pollutant formation. In addition, the application of pyrolysis in flame synthesis is explored, with particular attention to the decisive role of reaction pathways and intermediate evolution in the transformation of precursors into silicon-based nanoparticles.

KN2 Derivatisation in Analytical Pyrolysis

Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

15:00-15:30 Session KN2: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Analytical pyrolysis has become one of the standard characterization techniques for many complex materials, such as natural and synthetic polymers, lignocellulosics, composites, etc. While it works best with non polar materials such as polyolefins or vinyl polymers, polar materials with heteroatoms sometimes undergo more complex degradation reactions and yield products that do not allow straight forward identification of the material. John Challinor was the first to introduce pyrolysis experiments in the presence of tetramethyl ammonium hydroxide (TMAH), a strong organic base that favours hydrolysis reactions over pyrolytic cleavage [1]. Thus, polar materials are broken down mostly to their monomers and are simultaneously transferred into their less polar and more volatile methyl derivatives by TMAH. Since its first use the techniques has been applied to samples such as polyesters, polyethers, resins, varnishes, bio- and geopolymers, carbohydrates, triglycerids, and many more. Alternatives to TMAH have been tested, which allow e.g. the separation of free fatty acids besides esterified fatty acids, milder hydrolysis conditions to suppress unwanted side reactions or use of silicon-based reagents to achieve silylation. This talk will give an overview on what has been done in the field of thermally assisted hydrolysis and methylation (THM) as well as closely related techniques since their introduction in 1989, walk through the mechanisms involved and show the scopes but also limitations of such techniques.

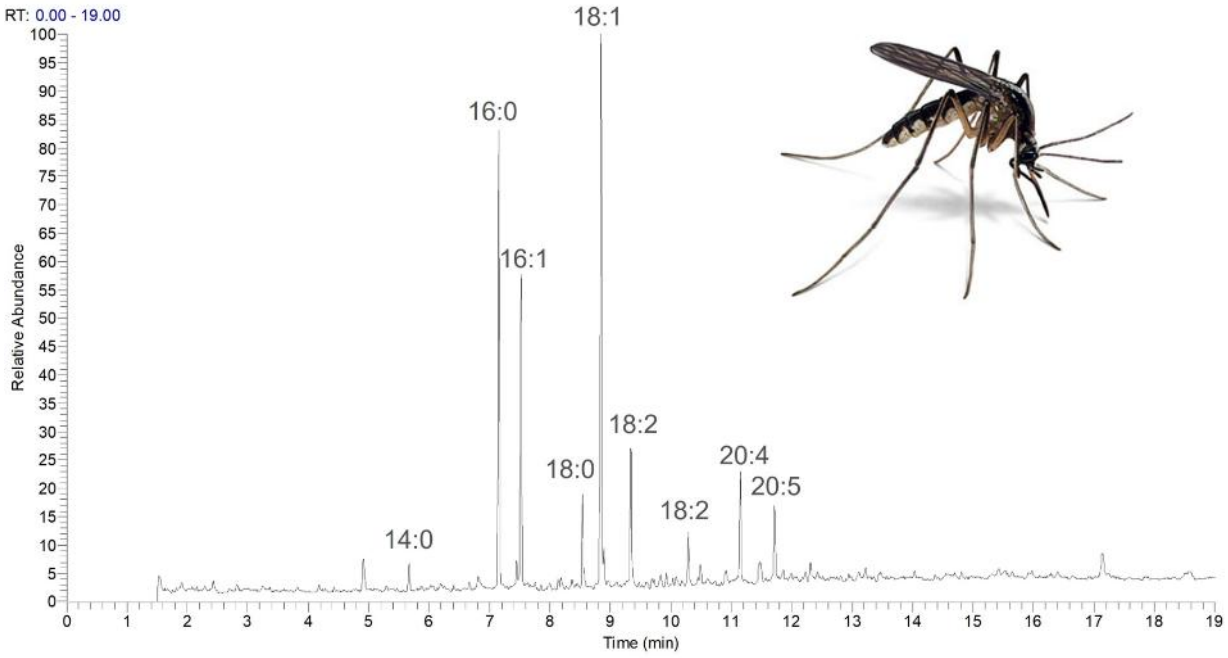


Fig. 1. Fatty acid profiling in anopheles arabiensis using thermally assisted hydrolysis and methylation (THM) [2].

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[2] R. Hood-Nowotny, B. Schwarzinger, C. Schwarzinger, S. Soliban, O. Madakacherry, M. Aigner, M. Watzka, J. Gilles, An Analysis of Diet Quality, How It Controls Fatty Acid Profiles, Isotope Signatures and Stoichiometry in the Malaria Mosquito Anopheles arabiensis, PLOS one, 7/10 (2012), e45222

KN3 Progress and challenges in quantification of micro- and nanoplastics in human blood

Marja Lamoree (Vrije Universiteit Amsterdam, Netherlands)

09:00-09:30 Session KN3: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

The study of the occurrence, fate and effects of micro- and nanoplastics (MNPs) has its origins in the field of environmental analysis, with the first observations of MNPs reported for the aquatic (marine) environment. Gradually, the idea has taken hold that we as humans are also exposed to these tiny particles. While it was already difficult to reliably quantify MNPs in environmental matrices, accurately measuring the multitude of polymer materials in different sizes and shapes in human samples proved to be a major challenge, although this field is developing very rapidly. Currently, pyrolysis gas chromatography mass spectrometry (Py-GC-MS) is the most promising technique, partially due to its throughput, but also due to its suitability to study particle sizes in the nanometer range, depending on the sample preparation. The power and potential of Py-GC-MS has already been amply demonstrated in other areas of research, such as forensics, material sciences, biomass conversion and also for the analysis of organic materials in artworks and archaeological artifacts. Building on best practices from these fields, we explored the application of Py-GC-MS to address the complexity of measuring MNPs in human blood. Recently, we have been working on the development of our methodology by enhancing the quality and reliability of our data. Initially, method development was hindered by the limited availability of suitable analytical standards and the absence of certified reference materials which still are lacking. This has led us to study the quantification reliability in relationship to the choice of pyrolysis settings and pyrolysis markers, as well as the choice of analytical standards of different particle sizes and characteristics like endcapping, tacticity, chain braining. Furthermore, we prepared our own internal reference materials for quality assurance and quality control. We used multivariate and machine-learning techniques to identify the most robust set of variables for polymer identification and quantification, while minimizing the impact of co-pyrolysis and matrix effects. Finetuning the enzymatic and chemical digestion protocols and the sequential cleanup steps supported the overall method performance. Apart from instrumental and sample preparation aspects, background contamination control is one of the most important factors to obtain reliable quantitative exposure data. In addition, sample quality is key: typically, archived samples in human biobanks are stored in plastic containers. To assess whether these valuable samples can be used for retrospect analysis and epidemiological studies, contamination of the sample with the container material have been studied. In the meantime, based on our lessons learned, we are expanding our working area to other fields of exposure assessment, with sample preparation methods tuned for cow and human breast milk and human organs in order to study the distribution of MNPs in the human body. With our efforts, we aim to contribute to the advancement of human internal exposure assessment, and to help unravel the eventual causality between MNP exposure and adverse health outcomes.

KN4 Why lignocellulosic components make thermochemical conversion of biomass so interesting?

Osvalda Senneca (Institute of Sciences and Technologies for Sustainable Energy and Mobility, National Research Council, Italy, Italy)

15:00-15:30 Session KN4: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Chamseddine Guizani (VTT, Finland) Hongwei Wu (Curtin University of Technology, Australia)

ABSTRACT

Pyrolysis is a central process in thermal conversion technologies and plays a governing role in solid-fuel aerospace propulsion systems. In both solid and hybrid rocket motors, pyrolysis constitutes the primary mechanism by which condensed-phase materials are transformed into gaseous species that sustain gas-phase combustion. The characteristics of pyrolysis—namely decomposition pathways, kinetics, and product distribution—directly affect fuel regression rates, flame structure, and combustion efficiency. For this reason, a detailed thermo-chemical characterization of solid fuels, with specific focus on pyrolysis phenomena, is essential for the development of advanced propulsion concepts. In hybrid rocket propulsion, the coupling between heat feedback from the flame and pyrolysis at the solid fuel surface controls the generation rate and composition of gaseous fuel species. Unlike conventional solid propellants, where oxidizer and fuel are premixed, hybrid systems rely entirely on pyrolysis-driven mass transfer from the solid phase to the reacting flow. Consequently, the efficiency and stability of hybrid combustion are intrinsically linked to the thermal degradation behavior of the solid fuel. Insufficient pyrolysis rates, unfavorable melting/decomposition windows or volatiles composition may result in reduced regression rates and incomplete combustion. Recent research has increasingly focused on the pyrolysis of non-traditional polymeric materials, including thermoplastics and bio-based polymers, as alternative solid fuels. These materials offer advantages in terms of processability, reduced toxicity, and compatibility with additive manufacturing, while also enabling more sustainable material sourcing. Polylactic acid (PLA) is a biodegradable thermoplastic polymer extensively used in additive manufacturing that has recently emerged as a candidate solid fuel for hybrid aerospace propulsion. Its molecular structure suggests a well-defined thermal response, making it a suitable model material for investigating the interplay between thermal transitions, pyrolysis onset, and volatile release. In this work, PLA is characterized through a combination of differential scanning calorimetry (DSC), thermogravimetric analysis (TG/DTG), and analytical pyrolysis coupled with gas chromatography–mass spectrometry (Py-GC/MS). DSC measurements were performed to identify thermal transitions such as melting behavior, and possible pre-decomposition phenomena, providing insight into the thermal stability and heat flow associated with structural changes in the polymer. TG/DTG analysis was used to determine mass loss profiles, decomposition onset temperatures, and apparent reaction rates under controlled heating conditions. Py-GC/MS enabled the identification and quantification of volatile and condensable species released during thermal degradation, offering detailed information on pyrolysis pathways and product distribution. The results indicate that PLA undergoes a reproducible pyrolytic decomposition over a relatively narrow temperature range, preceded by well-defined thermal transitions. The pyrolysis process yields a significant fraction of low-molecular-weight combustible species, including acetaldehyde, which are expected to play a key role in sustaining homogeneous combustion when adequately mixed with common hybrid rocket oxidizers. While these laboratory-scale experiments do not directly reproduce the complex thermo-fluid-dynamic conditions of an operating hybrid rocket motor, they represent essential input for pyrolysis-driven combustion modeling. Overall, this study emphasizes pyrolysis as the key link between material properties and combustion behavior, supporting the assessment of PLA as a solid fuel for hybrid propulsion systems governed by pyrolysis-controlled mass transfer.

KN5 Modelling Biomass Pyrolysis Across Scales: Bridging Reaction, Transport, and Morphology

Alba Dieguez Alonso (Technical University Dortmund, Germany, Germany)

09:00-09:30 Session KN5: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Pyrolysis is a key step in thermochemical conversion processes, governing the formation of gases, vapours, and solid char in systems ranging from combustion and gasification to emerging bio-based and waste-valorisation technologies. Understanding and accurately describing the underlying physical and chemical phenomena is therefore essential not only for improving the predictive capability of pyrolysis models and optimizing pyrolysis processes, but also for predicting reaction times and gas compositions in combustion and gasification systems, which ultimately determine their performance. However, the level of detail required for these applications may differ significantly. Over the past decades, pyrolysis modelling has evolved from global kinetic descriptions toward increasingly sophisticated approaches aimed at capturing the inherently hierarchical and multiscale nature of biomass [1]. Global models rely on lumped reaction schemes calibrated against thermogravimetric analysis (TGA) or bench-scale pyrolysis experiments. While useful for process design, these approaches strongly simplify the complex composition and heterogeneity of biomass feedstocks, as well as the interplay between chemical reactions and transport. Further developments introduced semi-detailed kinetic schemes in which reaction networks describe the formation and transformation of major chemical families [2]. These models provide a more realistic representation of product distributions while remaining computationally tractable even for reactor-scale applications and allowing a more explicit description of biomass macromolecular constituents. Parallelly, molecular-level simulation tools have gained renewed attention in biomass pyrolysis research in recent years, providing mechanistic insights into elementary reaction pathways and supporting the development of more physically grounded microkinetic models [3]. They also offer opportunities to progressively incorporate a more detailed representation of the hierarchical feedstock structure. Beyond the kinetic level, advances in experimental diagnostics and computational capabilities have enabled the development of particle-scale models that explicitly account for the coupling between chemical reactions, intra-particle transport phenomena, and dynamic morphology. In pyrolysis, as in many multiphase conversion processes, reactor behaviour is often governed at the particle scale, where transport and reaction occur on comparable time scales within a continuously evolving structure [4]. Capturing these interactions remains a major challenge, particularly when bridging particle-scale descriptions with reactor-scale simulations. The intrinsic heterogeneity of biomass, the complexity of reaction networks, and the evolving physical structure of the solid continue to limit predictive modelling.

[1] P. N. Ciesielski, M. B. Pecha, A. M. Latttanzi, C. S. Bharadwaj, M. F. Crowley, L. Bu, J. V. Vermaas, K. X. Steirer, M. F. Crowley, Advances in Multiscale Modeling of Lignocellulosic Biomass, ACS Sustainable Chem. Eng. 8 (2020) 3512-3531. doi: 10.1021/acssuschemeng.9b07415.

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[3] L. Li, R. Van de Vijver, Y. Zhu, K. M. Van Geem, Y. Liao, Fast pyrolysis of biomass: recent advances in molecular-level reaction mechanisms and detailed kinetic modeling, Renewable and Sustainable Energy Reviews 226 (2026) 116319. doi: 10.1016/j.rser.2025.116319.

[4] P. N. Ciesielski, M. B. Pecha, N. E. Thornburg, M. F. Crowley, X. Gao, O. Oyedeji, H. Sitaraman, N. Brunhart-Lupo, Bridging Scales in Bioenergy and Catalysis: A Review of Mesoscale Modeling Applications, Methods, and Future Directions, Energy & Fuels 35 (18) (2021) 14382–14400. doi:10.1021/acs.energyfuels.1c02163.

KN6 Thermochemistry for selective production of platform chemicals

Stef Ghysels (Department of Green Chemistry and Technology, University of Gent, , Belgium)

15:00-15:30 Session KN6: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

Pyrolysis and hydrothermal conversions are often associated with the depolymerisation of complex biomass streams into equally complex bio-oils that are notoriously difficult to integrate into existing chemical value chains. In this keynote, I present 2 case studies, which argue for an integration of thermochemical unit operations into modern biorefineries, not merely as crude depolymerisation tools, but as synthesis tools capable of delivering aromatics and heterocycles with high selectivity. The first case concerns the conversion of 2-acetylfuran in subcritical water, to catechol — a major drop-in platform chemical. By coupling precise thermal control with Lewis-acid catalysis ($ZnCl_2$), a maximal yield 50% and maximal selectivity of 73% was achieved. This case reveals how hydrothermal conditions can be engineered to balance conversion and selectivity, and channel reactivity toward a single aromatic product. The second case demonstrates an analogous principle in the pyrolytic domain. By starting not from whole biomass but from isosorbide-based esters and carbonates, I show that flash pyrolysis and controlled hot-vapour residence times can unlock concerted Ei β-elimination pathways, enabling the first pyrolytic access to dihydrofuro[3,2-b]furan (DHFF) — a new-to-industry molecule of high potential.

KN7 Pyrolysis-derived Bioproducts from Biomass for Future Sustainable Development

Hongwei Wu (Discipline of Chemical Engineering, Western Australia School of Mines, Curtin University, Australia, Australia)

09:00-09:30 Session KN7: Keynote session

Location: ROOM A – GROUND FLOOR (streaming in Room B, GROUND FLOOR)

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

Carbonaceous wastes including biomass is envisaged to plan an important role in future sustainable energy transition for achieving circular economy. This talk starts with the key biomass features that must be considered in biomass utilisation. Biomass is widely dispersed, available locally, bulky, of high moisture content and low-energy-density, leading to its high logistic cost in practical applications. Biomass is also of a fibrous nature and has a poor grindability. Therefore, a bioenergy plant, which directly takes biomass as feedstock, needs to be distributed, of small scale, and flexible to handle large particles. During thermochemical processing, biomass conversion is dominated by gaseous phase reactions as results of its high moisture and volatile contents, leading to mismatch in fuel properties when co-processed in existing stationary plants. This talk further recognises pyrolysis as a flexible thermochemical technology for local processing. Pyrolysis can be used to convert biomass into solid (biochar), liquid (bio-oil) and pyrolytic gas that can be used to supply the energy for drying and pyrolyser operation. Biochar and bio-oil, a mixture of these two, or other bioproducts derived, are high-energy-density fuels/products that are favourable for transport. The yields and properties of these bioproducts are highly dependent on feedstock properties, processing conditions and the underlying reaction mechanisms. This enables a favourable concept based on a combination of many distributed small-scale pyrolysers to produce these high-energy-density products locally in areas where biomass is available, and centralized applications of such products that are produced and transported from many of these distributed pyrolysers. This talk further discusses the potential opportunities for establishing a favourable supply chain based on some of these key bioproducts, the roles of fundamental reaction mechanisms, the optimisation required for targeted applications, the associated challenges, and potential R&D needed.

Abstracts:

Orals Day 1

Monday, 8th June 2026

Water leaching of wood barks for biocarbon production: Analysis of extractives

Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Budapest,, Hungary) István Sándor Czirok (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Budapest,, Hungary) Gergő Szabó (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Budapest,, Hungary) Bence Babinszki (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Budapest,, Hungary) Zoltán Sebestyén (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Budapest,, Hungary) Liang Wang (SINTEF Energy Research, Trondheim, , Norway) Øyvind Skreiberg (SINTEF Energy Research, Trondheim, Norway)

09:50-10:30 Session S1.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

The use of renewable energy sources, including biomass, represents a viable pathway for reducing the global net greenhouse gas emissions through partial or full substitution of fossil fuels. Biocarbon, the solid product of biomass pyrolysis, has various applications, which require specific physicochemical properties of the carbon source. Key characteristics include volatile matter amount and composition, biocarbon yield and fixed carbon content, while ash content and its composition is critical for determining the suitability for industrial uses, i.e., specific metallurgical processes. Metallurgical applications require substantial quantities of biocarbon to partially or fully replace fossil carbon with a renewable alternative. Although stem wood yields high-quality biocarbon with low ash content, its limited availability and high alternative economic value constrain its use for biocarbon production. Consequently, a less intensively used and cheaper feedstock is needed for the biocarbon production. Bark, an abundant and low-cost by-product of the wood processing industry, is a potential alternative feedstock. However, its inorganic content, which is higher than that of stem wood, must be reduced to make it a suitable feedstock for carbonization and subsequent application in certain metallurgical processes.

This study investigates water leaching as a pretreatment for birch, spruce and pine bark to reduce their water-soluble inorganic contents in both the feedstock and the resulting biocarbon. Leaching experiments were conducted on ground bark (d < 1 mm) using deionized water at 25 and 60 °C under static and stirred leaching conditions. The influence of water leaching on the bark physicochemical properties was evaluated using ICP-OES and TG/MS methods. Results indicated that water leaching removed significant amounts of organic material alongside the targeted inorganics. Consequently, the chemical profile of the leachates was characterised by Py-GC/MS, performed both with and without thermally assisted hydrolysis and methylation (THM). Using the THM-GC/MS method improved the volatility of the leachate components, enabling the GC/MS analysis of a larger fraction of the samples. Significant differences in leachate profiles were observed, reflecting a species-specific composition. Birch extract was dominated by rhododendrol and platyphylloside derivatives, while spruce leachate was primarily characterised by stilbene derivatives. Significant amounts of carbohydrate decomposition products in the spruce leachate indicated the effective water leaching of stilbene glycosides. The compositional characterisation of the solubilized organics can reveal the potential of the leachates for direct valorisation, tuning a waste remediation step into a source of valuable chemicals.

Valorization of brewer's spent grains through cascaded protein recovery and fast pyrolysis of its residues

Yingyuan Wei (Ghent University, Coupure Links 653, 9000 Ghent, , Belgium) Stef Ghysels (Ghent University, Coupure Links 653, 9000 Ghent, , Belgium) Frederik Ronsse (Ghent University, Coupure Links 653, 9000 Ghent, , Belgium)

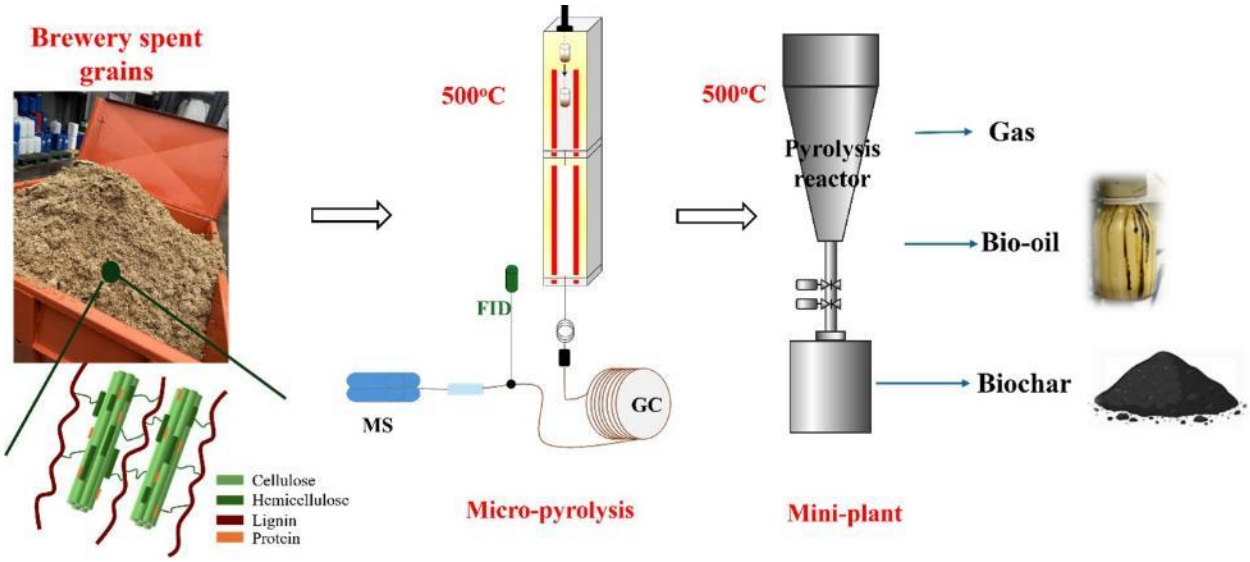
09:50-10:30 Session S1.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

This study investigated fast pyrolysis and the products thereof form brewer's spent grains (BSG), in comparison with BSG that underwent water leaching and protein extraction (PWBSG) prior to pyrolysis. This allowed us to investigate value creation from this voluminous industrial residue through cascaded protein removal and pyrolysis. Proteins were removed and comparatively quantified through different laboratory techniques (Kjeldahl-N based, bicinchoninic acid assay and trichloroacetic acid precipitation). After protein extraction of BSG (N content of 4.42 wt.%), a crude protein fraction was obtained in a yield which had a nitrogen content of 9.17 wt.%. This corresponds to a nitrogen recovery in the extracted proteins of 28.72%. Thermogravimetric analyses showed that the protein removal step (using NaOH) altered the physicochemical properties of the BSG from which the proteins were removed (PWBSG). Indeed, this residue (PWBSG) resulted in a smaller relative peak area for levoglucosan upon micropyrolysis, compared to BSG, while also having a reduced peak area for protein-derived N-containing compounds. Performing fast pyrolysis in a 250g·h-1 continuous fast pyrolysis (mini-plant) set up resulted in bio-oil yields of 47.27 ± 0.55 wt.% and 53.45 ± 1.97 wt.% for BSG and PWBSG, respectively. Upon fractionation of the bio-oil in an aqueous and organic phase (EtOAc), a desired decomplexation of the bio-oil was observed, retaining valuable biorefinery chemicals (phenol, 2-furanmethanol, etc.). This renders these bio-oil fractions good streams for further downstream processing.



Analytical Investigation of Cyclohexanone Resins for Cultural Heritage by Evolved Gas analysis-MS and Double-shot Py-GC/MS

Anna Micheluz (Deutsches Museum, Germany) Ursula Baumer (Doerner Institut, Bayerische Staatsgemäldesammlungen, Germany) Charlotte Hoffman (CICS – Cologne Institute of Conservation Sciences, Technische Hochschule Köln, Germany) Ester S.B. Ferreira (CICS – Cologne Institute of Conservation Sciences, Technische Hochschule Köln, Germany) Wibke Neugebauer (Staatliche Akademie der Bildenden Künste Stuttgart, Germany) Patrick Dietemann (Doerner Institut, Bayerische Staatsgemäldesammlungen, Germany) Marisa Pamplona (Deutsches Museum, Germany)

09:50-10:30 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

Cyclohexanone (ketone) resins were first used as a substitute for natural resins by conservators and artists in the early 1940s at the latest. These synthetic resins were low–molecular weight oligomeric compounds, produced by condensation reactions involving cyclohexanone, and, sometimes, methylcyclohexanone and formaldehyde with an alkaline catalyst. These reactions led to amorphous products with unknown exact chemical structures. First formulations were patented in 1918 by BASF and produced as “AW2” between 1930–1967. This was later substituted by “Keton Resin N” (1967–1980) and then “Laropal K80” (1980–2014). The first hydrated – and thus more stable – ketone resins were introduced in the late 1950s (“MS2A” by Howards). This study presents evolved gas analysis-mass spectrometry (EGA-MS) and double-shot pyrolysis -gas chromatography mass spectrometry (DS-Py-GC/MS) results of several type of ketone resins, namely “AW2”, “MS2A” and “Keton Resin N”, with the aim to identify the principal markers characteristic for each type of resin. Sixteen different cyclohexanone resins dating from the 1950s to the 1980s (as well as undated samples) were investigated. The EGA-MS provided thermal decomposition profiles of the resins enabling a first categorization of the resin types in particular in the first part of the thermogram (until 300 °C), corresponding to the desorption of the oligomers. Further characterization of these fractions was carried out by DS-Py-GC/MS. In the thermal desorption step peaks corresponding to monomers, dimers and trimers, were detected. Among the “AW2” samples, two main resin groups were recognized, which presented similar monomer markers (such as as cyclohexanol, 2-methylcyclohexanol and 3-methylcyclohexanol), but distinct dimers. The first group (AW2-g1) has dimer markers with characteristic ions m/z 98, 194, 212 and m/z 98, 111, 192, 210, while the second group (AW2-g2) has markers with m/z 95, 111, 206 and m/z 95, 125, 220, 238. Within these major AW2 groups, heterogeneities could be detected which require further investigation. The “MS2A” samples presented a characteristic monomer fraction composed by 4-methylcyclohexanol and 4-methylcyclohexanone and a dimer fraction characterized by the markers 4-methyl-2-(5-methylcyclohex-1-enyl)cyclohexanol, 2,2´-methylenebis(4-methylcyclohexanol) and 2-((2-hydroxy-5-methylcyclohexyl)methyl)-4-methylcyclohexanone. The “Keton Resin N”, which is composed only of cyclohexanone, was characterized by cyclohexanol in the monomer fraction. The dimer fraction had peaks with m/z 98, 194, 212 ions as the main marker, followed by those with m/z 133, 162, 180, m/z 111, 192 and m/z 98, 111, 192, 210 ions. In the second step of the DS-Py-GC/MS, a division into monomer, dimer and trimer pyrolysis products was also observed for each resin, with the markers 3-methylenecyclohexene and the compound with m/z 93, 108 ions for the resins “AW2” and “MS2A”, respectively. However, in general the resulting pyrograms were complex and did not provide additional information compared to thermal desorption. This study enabled the distinction of different groups of cyclohexanone resins, primarily through the characterization of their volatile fractions, which can support the identification and categorization of previously uncharacterized samples. “AW2” resins were shown to consist of several distinguishable groups, which eventually might become attributable to different procedures of productions, companies or decades.

Exploring the oxidative polymerization of polyunsaturated methyl esters by EGA-MS: a molecular approach to investigate lipid-based polymer networks in historical paint models

Giulia Caroti (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Silvia Pizzimenti (Department of Chemical Science, University of Naples "Federico II", Italy) Celia Duce (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Ilaria Bonaduce (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy)

09:50-10:30 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

The curing and ageing of an oil paint is the process through which the organic molecular composition of an oil evolves from polyunsaturated triglycerides into a more complex system, whose composition changes over time and includes low molecular weight compounds; oxygenated derivatives, such as epoxides, ketones, free fatty acids and free dicarboxylic acids; mono-, di- and triglycerides; and cross-linked fractions.[1] The curing process can be described as a competition between two phenomena: cross-linking and oxidative degradation.[2, 3] It is not yet entirely clear which conditions favour cross-linking and which promote oxidative degradation; however, it has been shown that the balance between these two competing phenomena may play a crucial role in the emergence of degradation issues in oil paintings.

Achieving a detailed molecular characterization of the oil polymeric network, and thus determining the degree of cross-linking and oxidation of an oil paint layer, still remains a significant analytical challenge. Analytical pyrolysis coupled to mass spectrometry (MS) is the only MS–based technique that allows the analysis of the entire organic fraction of the sample, including the crosslinked fraction, although the data obtained are often difficult to interpret.[4] To address this issue, in the present work a new set of experiments was designed using methyl linoleate and methyl linolenate as model binders, representing a semi-drying oil and a drying oil, respectively. Owing to their simpler molecular architecture, polyunsaturated methyl esters lead to the formation of curing products whose mass spectra are more informative, since polymerized triglyceride-based films are largely dominated by aliphatic chain fragmentation, whereas methyl esters preserve more diagnostic ions.[5]

Model paint layers were prepared by admixing methyl linoleate or methyl linolenate with three pigments: lead white, ultramarine blue and cadmium red. These systems were systematically analysed over a period of seven months by evolved gas analysis coupled with mass spectrometry (EGA-MS). This technique was employed to investigate the molecular structure of components with different thermal stability, from the volatile fraction up to the polymeric network, to assess how they differ across binder–pigment combinations and how they evolve during curing. The data presented in this work demonstrate that the use of methyl esters as model oil binders greatly simplifies the mass spectral features of the lipid paint fraction. EGA-MS enables the detection of oxidation and cross-linking products and the kinetics of evolution with an unprecedented level of molecular detail, thereby improving our understanding of the chemistry of oil paints.

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Peeling and Subsequent Radial Degradation Pathways during Cellulose Pyrolysis below 320 °C: Insights from Isothermal TG-MS Analysis

Yuta Masuda (Kyoto university, Japan) Eiji Minami (Kyoto university, Japan) Haruo Kawamoto (Kyoto university, Japan)

09:50-10:30 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

Although the pyrolysis mechanism of cellulose remains not fully understood, one of the main challenges lies in its complex structure: cellulose consists of microcrystalline aggregates with a degree of polymerization around 200 and includes amorphous (or paracrystalline) regions. For instance, under isothermal pyrolysis conditions, a characteristic inductive time is observed between the point at which the target temperature is reached and the onset of significant weight loss due to pyrolysis. To describe this behavior, the Broido–Shafizadeh kinetic model introduced the concept of "active cellulose," though the detailed nature of this state remains unclear. Our research focuses on elucidating this activation behavior. In this study, we investigated the isothermal pyrolysis of cellulose below 320 °C using thermogravimetry–mass spectrometry (TG–MS). We report that a zero-order reaction first occurs, followed by a degradation behavior that can be described by a radial degradation pathway, assuming the cellulose microcrystals degrade inward from their cross-sections without shortening along their longitudinal axis. Isothermal TG–MS analysis of cellulose at various temperatures revealed a clear difference in pyrolytic behavior around the temperature range of 310–320 °C. Below 310 °C, cellulose exhibited a linear decrease in weight over time, indicating a zero-order reaction. In this temperature range, levoglucosan—a typical depolymerization product—was not detected. Instead, water and low-molecular-weight fragments were selectively generated. In contrast, above 320 °C, the weight loss rate increased rapidly after an inductive time, and a significant production of levoglucosan was observed under these conditions. Upon prolonged heating below 310 °C, it was found that, regardless of the set temperature, the rate of weight loss and the generation rates of water and fragments remained constant until approximately 30% of the mass had been lost—consistent with zero-order kinetics. Beyond this point, the rate of degradation began to decrease linearly with time. This behavior can be rationally explained by a radial degradation pathway, where degradation proceeds inward from the outer cross-section of cylindrical cellulose microcrystals. Activation energies determined via Arrhenius plots were 173 kJ/mol for the zero-order reaction and 186 kJ/mol for the radial degradation process. The former is attributed to a peeling reaction initiated at the reducing ends of cellulose chains via a dehydration mechanism. GPC analysis of pyrolysis residues also supported the occurrence of the peeling reaction.

Modeling approach for the electromagnetic field and heating of biomass in a microwave reactor using OpenFOAM

Andrea Dernbecher (TU Dortmund University, Germany) Luis Ohm (TU Dortmund University, Germany) Alba Dieguez-Alonso (TU Dortmund University, Germany)

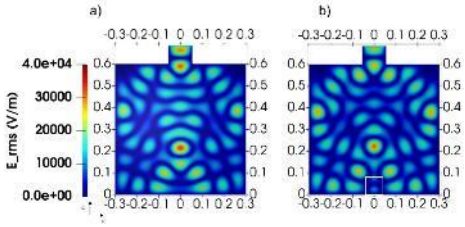
09:50-10:30 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

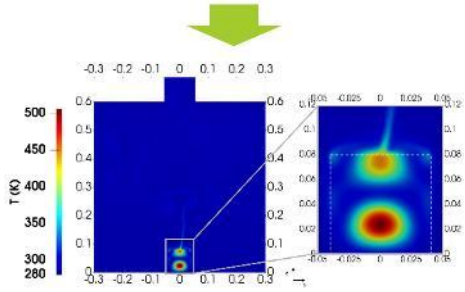
Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

The pyrolysis of biomass is a promising technology for the sustainable production of renewa-ble platform chemicals and energy. However, this endothermic process, which is carried out in the absence of oxygen, requires the addition of energy. In order to improve the energy effi-ciency of the process, microwave-assisted pyrolysis (MAP) has recently gained in importance [1,2]. In MAP, the biomass is heated volumetrically by dielectric losses [3,4]. This enables a more direct heating with accelerated heating rates in large wood pieces as compare to conven-tional heating. However, microwave heating results in complex interactions between the elec-tromagnetic field, the reactor geometry, and the material to be heated, which undergoes significant changes during the conversion process [5]. These interactions must be taken into ac-count in the design of new innovative microwave reactors. It is therefore necessary to develop robust and versatile simulation tools that reliably predict the influence of the electromagnetic field, flow conditions in the reactor, and thermal transport processes on biomass heating. For this purpose, a modeling approach for the electromagnetic field within a microwave reactor was implemented in this work and coupled with a multi-region solver in the open-source soft-ware OpenFOAM. The accuracy of the solver was demonstrated by simulating the heating of a wooden block and verified using data from the literature [5]. The influence of the sample on the shape of the electromagnetic field is clearly visible in simulation results, emphasizing the importance of correct implementation. Dielectric losses in the wood block create two hot spots that are in-troduced as energy sources in the multi-region solver. The wood sample heats up particularly in these two hot spots and transfers heat to the surrounding nitrogen through conjugate heat transfer due to the coupling of the solid and gas phases.



Electromagnetic field in the reactor without (a) and with (b) wooden sample.



Heating of the wooden sample caused by dielectric losses.

The simulation results showed good agreement with literature data for the heating of biomass and are therefore well suited for simulating the heating of solids. An extension of the solver to take into account pyrolysis reactions and the associated material changes is currently under development.

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[3] Vorhauer-Huget N, Seidenbecher J, Bhaskaran S, Schenkel F, Briest L, Gopalkrishna S et al. Dielectric and physico-chemical behavior of single thermally thick wood blocks under microwave assisted pyrolysis. Particuology 2024; 86:291–303.

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A Strategy for Tuning Pyrolysis and Release Profiles of Reconstituted Tobacco

Chunping Wang (a Zhengzhou Tobacco Research Institute of CNTC, b Tianjin University of Science & Technology, China) Yuhan Li (a Zhengzhou Tobacco Research Institute of CNTC, b Tianjin University of Science & Technology, China) Qi Zhang (Zhengzhou Tobacco Research Institute of CNTC, China) Yangbing Wen (Tianjin University of Science & Technology, China) Le Wang (Zhengzhou Tobacco Research Institute of CNTC, China) Bin Li (Zhengzhou Tobacco Research Institute of CNTC, China) Lili Fu (Zhengzhou Tobacco Research Institute of CNTC, China)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

The thermal conversion behavior of reconstituted tobacco (RT) directly determines the aerosol release efficiency of heated tobacco products. This study focuses on regulating the pyrolysis and release characteristics of RT through structural design strategies, without relying on specific functional fillers. Two main approaches were developed and evaluated: (1) constructing integrated thermal networks within the fiber matrix through nanofiber-stabilized dispersion combined with wet papermaking processes; (2) fabricating multilayer functional sheets via coating and self-assembly techniques. The in-situ constructed three-dimensional thermal network significantly improved the thermal conductivity of RT, leading to more uniform temperature distribution during heating. Pyrolysis analysis demonstrated that the optimized thermal pathway altered the decomposition kinetics, increasing the release rate of key aerosol constituents compared to conventional RT. Release performance evaluation under programmed heating revealed enhanced release controllability and reduced temperature lag effect. Through the structural integration of components with distinct release properties, a multilayer functional sheet was designed. This approach achieved an improvement in total release efficiency by establishing synergistic thermal-mass transfer pathways. The structural designs effectively addressed challenges in filler dispersion and retention while creating controllable thermal conduction pathways. These methods provide valuable strategies for thermal management of RT and demonstrate significant potential for developing next-generation heated tobacco products with optimized aerosol release profiles.

Efficient catalytic pyrolysis of biomass to light aromatic hydrocarbons over Zn/ZSM-5

Jing-Pei Cao (China University of Mining and Technology, China) Nai-Yu Yao (China University of Mining and Technology, China) Hong-Yan Wang (China University of Mining and Technology, China)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

The depletion of fossil fuel resources and escalating environmental issues (such as CO2 emissions and pollution) require a transition to renewable alternative energy sources. Biomass energy, as the only carbon-rich and abundant renewable resource, provides a sustainable pathway for the production of fuels and chemicals. The catalytic conversion of volatile from biomass pyrolysis into high-value platform chemicals such as light aromatic hydrocarbons (LAHs), represents an effective strategy to enhance energy security and facilitate carbon neutrality. Among them, ZSM-5 stands out from other zeolites due to its high thermal stability, unique pore structure, and adjustable acid sites, making it the most suitable for LAHs production. However, traditional commercial ZSM-5 zeolites still need improvement in terms of catalytic activity and stability. Therefore, this study employed a series of modifications using metallic zinc on ZSM-5, analyzed the structure-activity relationship between catalyst performance and products during its application in the catalytic pyrolysis of cellulose, and evaluated its stability in the catalytic pyrolysis reaction of corncobs. Initially, ZSM-5 was modified using a simple impregnation method. Results indicated that optimal performance was achieved at a metal Zn loading of 0.2 wt.%, with a significant increase in LAHs yield compared to commercial ZSM-5. However, issues such as poor catalyst stability still exist. Subsequently, the LAHs yield was further enhanced by directly doping metallic Zn during a one-step hydrothermal synthesis process. Research revealed that the catalyst's pore size, specific surface area, and particle size significantly influence its performance. Therefore, a seed-induced and Dry Gel Conversion-Steam Assisted Crystallization method was employed to synthesize a multi-porous, nano-doped Zn-ZSM-5 catalyst, which further enhanced the LAHs production capacity, achieving a maximum yield of 174.68 mg/g. The results indicate that the formation of mesopores and nanocrystals during synthesis promotes the generation of ZnOH+ active sites, thereby enhancing the dehydrogenation and aromatization reaction capacity and improving the mass transfer capability of the catalyst. To further enhance catalyst stability, a catalyst was synthesized by coating nano-ZSM-5 with Zn/SiO2. By adjusting the core-shell ratio, the catalyst's stability was significantly improved. Compared to commercial ZSM-5, which exhibited complete deactivation after 160 min of reaction, the LAHs yield decreased by only 14.6% after 320 min of reaction.

Physico-chemical properties of biochars from four different caribbean biomasses

Méghane Drané (Société Anonyme de la Raffinerie des Antilles - SARA, Le Lamentin, France) Mohamed Zbair (Institut de Science des Matériaux de Mulhouse (IS2M), Université de Haute-Alsace, CNRS, IS2M UMR 7361, F-68100 Mulhouse, France) Dominique Boeuf (SERD Caraïbes, Laboratoire de Biotechnologie, Le Lamentin, Martinique) Frédéric Ferrer (Société Anonyme de la Raffinerie des Antilles - SARA, Le Lamentin, Martinique) Roger Gadiou (Institut de Science des Matériaux de Mulhouse (IS2M), Université de Haute-Alsace, CNRS, IS2M UMR 7361, F-68100 Mulhouse, France) Yann Rogaume (Université de Lorraine, INRAE, LERMAB, F-88000 Epinal, France)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

Biochar production via pyrolysis is a strategic thermochemical pathway for the sustainable valorization of diverse biomass feedstocks [1]. To elucidate the critical interplay between feedstock origin and process parameters, this study presents a systematic investigation of biochars produced from four distinct biomass classes: a marine macroalga (Sargassum sp.), two lignocellulosic woods (Black Locust and Niaouli), and an agricultural residue (sugarcane bagasse). The selection of these biomasses is motivated by their representativeness of Caribbean resources, as well as by the environmental issues associated with the proliferation of certain species. The primary objective is to identify and quantify how the feedstock's biochemical composition and the pyrolysis temperature influence the yield, key physicochemical properties, and functional performance of the resulting biochars. A comprehensive characterization of the raw biomasses including proximate, ultimate, and ash composition established the initial conditions governing their pyrolysis behavior. Biochars were produced under an inert atmosphere for pyrolysis temperatures ranging between 500 and 900°C. The products were analyzed using a suite of complementary techniques (N2 and CO2 sorption analysis, electronic microscopy, X-Ray diffraction, elemental analysis) to determine the evolution of key properties: porosity and surface area, carbonaceous structure (aromatization level), morphological features, elemental stoichiometry (H/C, O/C), and the transformation of inorganic constituents. Results demonstrate that increasing pyrolysis temperature generally drives carbonization, aromatization, and pore development, yet the magnitude and nature of these changes are profoundly feedstock-dependent [1,2]. Distinct property profiles emerged for each biomass class: algal-derived biochars exhibited notably high ash and inorganic content, lignocellulosic biochars displayed well-developed aromatic structures and porosity, and bagasse biochar showed an intermediate characteristic with significant silica content. The inorganic fraction underwent temperature-dependent transformations, significantly altering biochar reactivity and functionality. Based on these results, the valorization potential of the biochars is discussed with respect to their textural, chemical, and mineral properties. Targeted applications include adsorption of gaseous or aqueous pollutants [3,4], soil amendment for fertility improvement and carbon sequestration [2] as well as their use as catalysts or catalyst supports. This study underlines the importance of controlling both biomass selection and pyrolysis conditions to tailor biochar properties toward specific, high value-added environmental and energy-related applications [1].

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Catalytic and Inhibitory Effects Induced by Noncovalent Interactions between Cellulose and Lignin during Fast Pyrolysis

Fuat Sakirler (University of Massachusetts Lowell, United States) Doga Tekbas (University of Massachusetts Lowell, United States) Hsi-Wu Wong (University of Massachusetts Lowell, United States)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

Biomass fast pyrolysis has emerged as a highly promising technology for producing renewable fuels and chemicals. However, the inherent multiscale and multiphase nature of the process and the heterogeneous nature of biomass feedstocks typically lead to low selectivity toward each bio-oil molecule, posing significant commercialization challenges. A molecular-level understanding of the biomass pyrolysis reaction kinetics considering the interactions between the main constituents (i.e., cellulose, hemicellulose, and lignin) is essential to advance the macroscopic design, scale-up, and optimization of the process. In this work, microreactor experiments were conducted to determine the effects of lignin structures on the yields of cellulose-derived products during pyrolysis. We show that levoglucosan (LG) formation is inhibited by the β-O-4 lignin linkages or catalyzed by the 5-5 linkages, glycolaldehyde (GA) formation is catalyzed by the β-O-4 linkages or inhibited by the 5-5 linkages, and 5-hydroxymethylfurfural (5-HMF) formation is inhibited by either linkage. Density functional theory calculations reveal that these catalytic and inhibitory effects on cellulose fast pyrolysis are induced by noncovalent interactions between cellulose and lignin. The molecular-level picture of cellulose–lignin interactions uncovered in this work paves the way for further use of genetic engineering to grow new genotypes of biomass for selective production of value-added chemicals and machine learning approaches to obtain correlations between biomass structures and product yields for biomass fast pyrolysis.

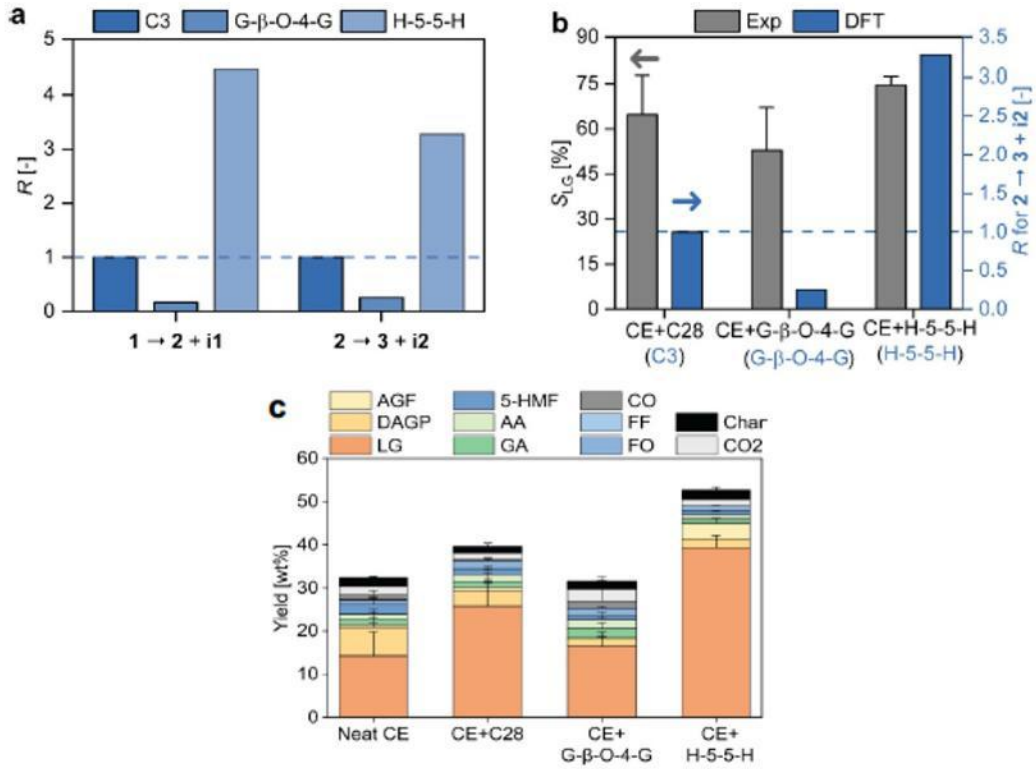


Figure caption: (a) DFT-calculated rate constant ratios (R) of the two elementary steps leading to LG formation in the presence of propane (C3, model compound for C28 as a control), G-β-O-4-G, or H-5-5-H at 500°C. (b) Comparison of experimental selectivity toward LG from CE+C28, CE+G-β-O-4-G, or CE+H-5-5-H against the DFT-calculated R values for the rate-limiting step (2 → 3 + i2) of LG formation. (c) Mass yields of CE-derived products from neat CE pyrolysis and co-pyrolysis of CE with C28 (CE+C28), G-β-O-4-G (CE+G-β-O-4-G), or H-5-5-H (CE+H-5-5-H). Mass yields are shown for LG, dianhydroglucopyranose (DAGP), 1,6-anhydroglucofuranose (AGF), GA, acetic acid (AA), 5-HMF, 2-(5H)-furanone (FO), furfural (FF), carbon monoxide (CO), carbon dioxide (CO2), and char.

Activated Carbon-Based Catalyst Supports for Dry Methane Reforming and Coke Formation

Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Beata Barczak (Gdańsk University of Technology, Poland)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

The performance of catalysts for dry methane reforming strongly depends on the properties of the catalyst support, particularly its surface area, pore structure, and accessibility of active sites. Biochar is an attractive precursor for catalyst supports due to its renewable origin, low cost, and the possibility of achieving a high surface area and well-developed porosity. The optimized activated carbons (ACs) exhibit textural properties that make them highly promising carbon-based catalyst supports for DMR. Moreover, it is expected that ACs used as catalyst supports will potentially facilitate coke mitigation by improving reactant diffusion and reducing the accumulation of carbonaceous deposits on the catalyst surface. During the methodology development, biochar was subjected to physical and chemical activation applied in different sequences. A synergistic effect resulting from the combination of both activation methods was observed, and the influence of their order on the structural and textural properties of the resulting carbon materials was investigated. The aim was also to prepare carbon catalyst supports for the DMR process and to examine their effect on coke deposition. The results demonstrate that the combined physical and chemical activation leads to a pronounced synergistic effect, producing AC with significantly higher specific surface areas and more developed hierarchical porosity compared to single-step activation. The coexistence of micro-, meso-, and macropores enhances both the dispersion of the active catalytic phase and mass transport within the material.

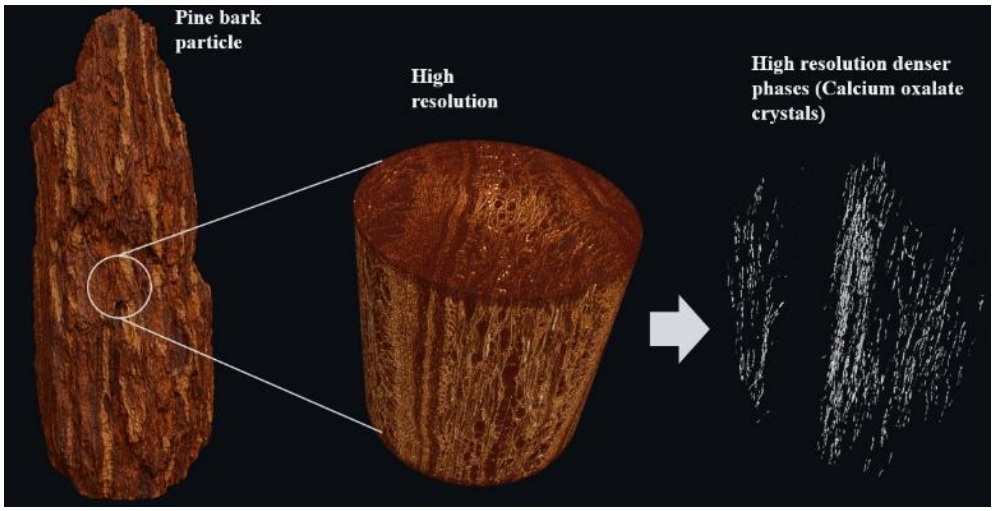
Spatial evolution of mineral phases within pine bark particles during pyrolysis under inert and weakly oxidizing atmospheres

Eduardo Arango Durango (Luleå Tekniska Universitet, Sweden) Ali Valizadeh (Luleå Tekniska Universitet, Sweden) Marcelo Dal Belo Takehara (Luleå Tekniska Universitet, Sweden) Henrik Wiinikka (Luleå Tekniska Universitet, Sweden) Kentaro Umeki (Luleå Tekniska Universitet, Sweden)

11:00-13:00 Session S1.1: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Anthony Dufour (CNRS, France) Shurong Wang (Zhejiang University, China)

ABSTRACT

Fluidized-bed (FB) pyrolysis represents a promising route for biocarbon production due to improved heat and mass transfer, uniform temperature distribution, and continuous solids handling, compared with conventional pyrolysis reactor configurations (e.g., fixed-bed, auger, and rotary kiln systems). At the same time, FB operation introduces a distinctive mechanical environment where particle–bed collisions promote attrition. Previous experiments with Ca–K-rich pine bark conducted under a weakly oxidizing flue-gas-like atmosphere (86.2 vol% N2, 10 vol% CO2, 3.8 vol% O2), showed that the depletion of ash-forming species such as K, P and Ca could not be explained solely by volatilization pathways. It was therefore proposed that additional removal via a coupled mechanism, whereby ash-forming phases become enriched at the particle surface during conversion (through migration and/or exposure) and are subsequently removed by attrition-driven loss of surface material (Arango-Durango et al., 2025). The present work examines this hypothesis by using particle-scale imaging to determine whether, when, and to what extent dense mineral phases migrate towards or are exposed to the external surface under inert and weakly oxidizing atmospheres. X-ray microtomography (XMT) was applied to individual pine bark particles before and after pyrolysis to quantify whether dense inclusions become preferentially located closer to the external surface. The primary XMT descriptor employed is the distance-to-surface distribution of high-density regions (before vs after conversion). A representative three-dimensional XMT rendering of a pine bark particle is provided in Figure 1 to illustrate the density-contrast features analyzed. Figure 1. High-resolution X-ray microtomography images showing the overall pine bark particle structure and the segmentation of calcium oxalate crystals (high-density phase). Complementarily, in situ experiments using a micro-electro-mechanical system (MEMS) chip-based heated microreactor inside a scanning electron microscope (SEM) will be used to track surface evolution during heating from ambient temperature to 1000 °C. The main microscopy output will be the surface area fraction of mineral-rich regions, obtained by image segmentation, as a function of temperature and time. SEM coupled with energy-dispersive X-ray spectroscopy (SEM–EDS) will be performed at the beginning and end of the in-situ sequence to assess changes in surface elemental signatures, focusing on major pine bark ash constituents (notably K, P, and Ca). The influence of atmosphere will be evaluated by comparing inert N2 against the weakly oxidizing N2/CO2/O2 mixture, testing whether selective surface oxidation modifies the formation, exposure, and evolution of mineral-rich surface features. By linking dense phase spatial distribution derived from XMT with time-resolved surface evolution observed by in situ microscopy under well-defined atmospheres, this study aims to clarify the mechanism governing ash-element behavior during biomass pyrolysis and to provide a basis for the development of mitigation strategies for applications sensitive to ash chemistry. References Arango-Durango, E., Pachchigar, S., Öhman, M., & Umeki, K. (2025). Exploring fluidized bed technology for biocarbon production with mitigation of ash-forming elements. Fuel. https://doi.org/10.1016/j.fuel.2025.134949



Advances in the investigation of cultural heritage materials through the coupling of pyrolysis with GCxGC-MS

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Han Bin (Dpt Archaeology & Anthropology, School of Humanities, University of Chinese Academy of Sciences, 100049 Beijing, China)

11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

Archaeological objects are made up of complex mixtures that may include binders or organic adjuvants of various origin (animal, plant, fossil), comprising chemical families with different properties (terpenes, fatty acids, amino acids, sugars) and which come from more or less complex technical manufacturing processes (heat treatments, mixing, fermentation, grinding). Therefore, it is appropriate to provide an analytical response with a very high resolving capacity to the challenges presented by their study, whether for archaeometry studies or for understanding the degradation phenomena observed on these objects.

As an analytical method, pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) has become a versatile technique commonly used in the domain of cultural heritage since the middle of the 20th century [1]. However, a one-dimensional GC separation is often insufficient for separating the individual constituents in complex mixtures. As a consequence, more resolutive techniques are needed, and comprehensive gas chromatography GCxGC provides an adapted answer to this challenge. The coupling of two capillary columns connected via a modulation system optimizes the complementary separation capabilities of columns of different polarities. The addition of a mass spectrometer as a detector adds another dimension to the separation capability. As a result, a comprehensive two-dimensional gas chromatography/mass spectrometry (GC×GC-MS) system offers much higher resolution, peak separation capacity, selectivity and lower detection limit for the analysis of volatile organic molecules, making it one of the most powerful analytical systems available for analysts today [2]. As expected, the coupling of pyrolysis with GCxGC-MS demonstrated promising applications for the investigation of cultural heritage materials [3]. With an experience of almost ten years, we can explore the benefits of using GCxGC-MS in conjunction with pyrolysis for the analysis of several cultural heritage artefacts: East Asian papers, Chinese inks, East Asian lacquers, archaeological collagen, beeswax, or bitumen oil paints. In particular, the advances in the investigation of cultural heritage materials can be seen in: (i) the identification of numerous fiber's plant markers for botanical origin assignment, (ii) the identification of inks components used in ancient Chinese recipes, (iii) the chromatographic separation of regioisomers of alkylphenols, and alkylcatechols in lacquer saps. Besides providing an improved depiction of these materials, Py-GCxGC-MS revealed as well the presence of other additives difficult to detect using Py-GC-MS alone (polycyclic aromatic hydrocarbons as markers of soots, diketopyperazines as markers of animal glues) and unexpected series of 2-methyl ketones in some of these materials (Asian lacquer artefacts, beeswax) raising interesting questions about the pyrolysis degradation mechanisms of these materials. Concomitantly, Py-GCxGC-MS reduced the necessity of using tetramethyl ammonium hydroxide (TMAH) as derivatization reactant when characterizing these materials. Research cases reported above thus demonstrate the potential of a Py-GCxGC/MS approach in the characterisation of cultural heritage materials, making it relevant for the study of complex samples in general, and extending beyond the field of cultural heritage.

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[3] Han, B. et al. J. Anal. Appl. Pyr. 122, 458 (2016).

Comparison of EGA and py-GCMS Data from naturally and artificially aged polyester urethane.

Elena Gómez-Sánchez (Deutsches Bergbau-Museum Bochum | Leibniz Research Museum for Geo-resources, Germany) Simon Kunz (Deutsches Bergbau-Museum Bochum | Leibniz Research Museum for Geo-resources, Germany) Roop Chand Guditi (Deutsches Bergbau-Museum Bochum | Leibniz Research Museum for Geo-resources, Germany)

11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

Evolved Gas Analysis Mass Spectrometry (EGA-MS), Double Shot pyrolysis GCMS (DS-py-GCMS) and Fourier Transform Infrared Spectroscopy (FTIR) were performed on polyester urethane (PU-ES) closed-cell foam samples after artificial ageing (70 °C and 98 %RH for up to 56 days) in 2017. A convolute of samples that had not been artificially aged in 2017, instead undergoing natural ageing until 2025, were then artificially aged for up to 49 days and analysed with the same techniques. Similar, but naturally aged material from the 1980s-90s was also available. The aim of the study was to verify proposed markers for degradation, namely adipic acid and 4,4'-methylenebisbenzeneamine (MDA) [1], which could enable an evaluation of the current state of degradation of a given material, as well as to identify further potential markers for this purpose. A systematic approach allowed bringing to light several repeatability issues in DS-py-GCMS [2]. These seemed to affect species with COOH groups. For example, MDI and adipic acid only occurred simultaneously in 25 % of all measurements of comparable material; in the rest of the measurements, either 4,4'-diphenylmethane diisocyanate (MDI) or adipic acid appeared. Several possible causes were identified for this, most importantly, high temperatures in combination with the appearance of highly reactive species such as MDI that seem to be further reacting with species appearing upon degradation [3, 4]. As a consequence, MDA seems not to be a suitable marker for degradation for carbamate hydrolysis, since it could be appearing as an artifact in the pyrolysis chamber due to secondary reactions of MDI.

The comparison of the EGA-MS results between the measurements performed after artificial ageing in 2017 and in 2025 highlighted chemical changes in the material due to natural indoor ageing. These changes are observed in the final stages of artificial ageing after 49 and 56 days, but not for smaller periods.

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[2] S. Kunz, S. Brunner, J. Köppen, E. Rettler, E. Bresolin, I.D. Gaudio, B. Staal, T. Gruendling, E. Gómez-Sánchez, Comparative study of the artificial and natural, indoor ageing of crosslinked, polyurethane ester closed-cell foams, Polymer Degradation and Stability 245 (2026) 111905. https://doi.org/10.1016/j.polymdegradstab.2025.111905.

[3] H. Ohtani, T. Kimura, K. Okamoto, S. Tsuge, Y. Nagataki, K. Miyata, Characterization of polyurethanes by high-resolution pyrolysis-capillary gas chromatography, J. Anal. Appl. Pyrolysis 12 (1987) 115–133.

[4] M. Matsueda, M. Mattonai, I. Iwai, A. Watanabe, N. Teramae, W. Robberson, H. Ohtani, Y.-M. Kim, C. Watanabe, Preparation and test of a reference mixture of eleven polymers with deactivated inorganic diluent for microplastics analysis by pyrolysis-GC–MS, J. Anal. Appl. Pyrolysis 154 (2021) 104993, https://doi.org/10.1016/j.jaap.2020.104993.

PY-GC-MS as a method for evaluating degradation of paper during material suitability testing

Michael Samide (Butler University, United States) Jason Garcia (Butler University, United States) Gregory Smith (Indianapolis Museum of Art at Newfields, United States)

11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

The Oddy test remains the standard approach to determine the suitability of a material for use in the display or storage of artwork. In this test, volatile pollutants emitted from a test material react with lead, silver, and copper metal coupons under conditions of elevated temperature and humidity. If corrosion is noticed after a 28-day incubation, the material is classified as unsuitable for use in a museum environment. While simple to perform, this test is limited due to the subjective nature of evaluating the metal coupons for corrosion as well as by its focus on only metal reactivity in the presence of a pollutant; a pollutant that may corrode metals may or may not have a similar deleterious effect on non-metal art materials. Newer methods like direct thermal desorption – gas chromatography – mass spectrometry (DTD-GC-MS) have been explored to establish a more objective approach to material suitability testing. Chemical information such as the identity and, with calibration, concentration of volatile organic compounds (VOCs) can be used to understand reactivity of emitted pollutants toward a variety of artists' materials. However, these methods often rely on some inherent knowledge of chemical reactivity – what we call "chemical intuition" – to decide if a detected VOC is a pollutant that will negatively impact an artwork. Efforts are underway to develop material-specific suitability tests to run in tandem with a traditional Oddy test. One example relies on the exposure of a paper surrogate to potential pollutants emitted from a test material for 14 days at elevated temperature and humidity. Under these conditions, the cellulose and hemicellulose components of the surrogate undergo catalyzed hydrolysis and liberate monosaccharide degradation products that are extracted from the paper and detected using ion chromatography or colorimetric assays. In this work, we will present the results of our efforts to use pyrolysis – gas chromatography – mass spectrometry (PY-GC-MS) to observe directly the degradation products formed from the exposure of a paper surrogate to potential pollutant molecules in a paper-based material suitability test. Monosaccharides formed from the degradation of the paper surrogate are converted into trimethylsilyl derivatives using BSTFA to increase volatility and ease of detection using a GCMS system. Three different analysis protocols will be discussed: (1) offline solution-phase derivatization of extracted monosaccharides using BSTFA; (2) direct derivatization of extracted monosaccharides using BSTFA in the PY furnace; (3) generation of volatile derivatized monosaccharides directly from the paper surrogate in the PY furnace without prior extraction. The goal of the work is to produce a rapid and quantitative method for analysis of monosaccharides to support material suitability testing for paper-based collections. Results from material suitability testing will be discussed and compared with a standard colorimetric analyses.

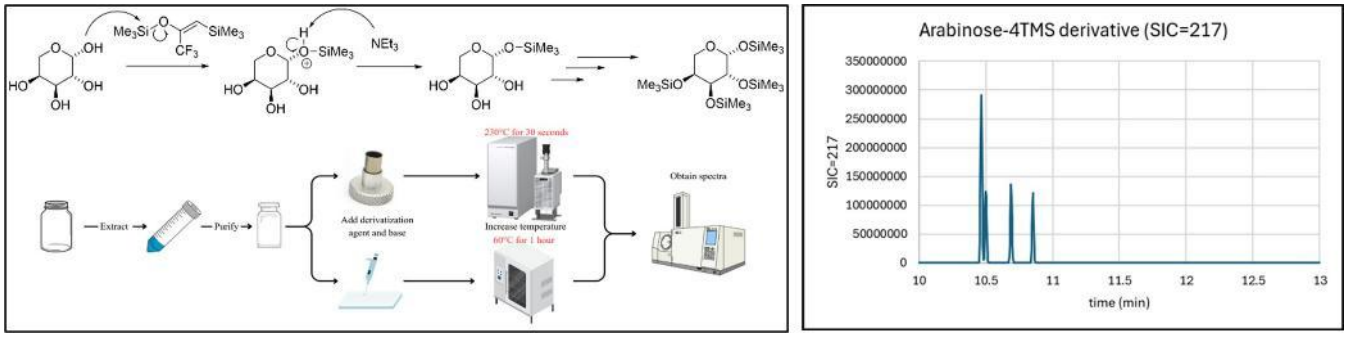


Figure 1: Analysis scheme for detection of arabinose from aged paper.

Influence of Progressive and Instantaneous Heating on the Pyrolysis Products of Silk

Cecilia Campi (Department of Chemistry and Industrial Chemistry, Università di Pisa, Pisa, Italy) Ilaria Degano (Department of Chemistry and Industrial Chemistry, Università di Pisa, Pisa, Italy) Ilaria Bonaduce (Department of Chemistry and Industrial Chemistry, Università di Pisa, Pisa, Italy)

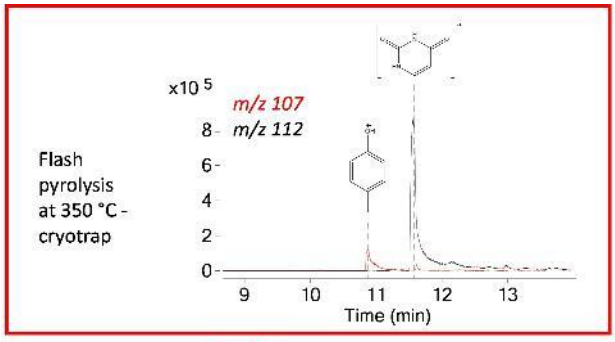
11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

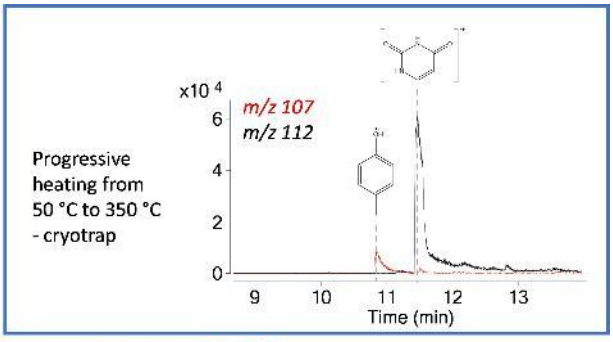
Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

In the field of cultural heritage, silk is a highly valued material, appreciated since the Chinese Empire. Silk is a proteinaceous fibre inherently delicate which becomes brittle and fragile with ageing. The preservation of silk artefacts requires not only the development of conservation and cleaning methodologies that minimize their impact on the material, but also a thorough understanding of the degradation processes involved. Building on previous applications of EGA-MS to proteinaceous materials [1], [2], this approach was applied to investigate the molecular modifications occurring during silk ageing. Upon progressive heating, the EGA-MS profile of silk shows a main degradation peak at approximately 330 °C, followed by a shoulder at around 390 °C. The first degradation peak is unexpectedly dominated by the m/z 107 ion, traditionally attributed to methylphenol. Although this ion may be associated with the pyrolysis of tyrosine, its high abundance is difficult to reconcile with the low tyrosine content of silk fibroin (~5%), suggesting a possible contribution from secondary pyrolytic reactions promoted by progressive heating during EGA-MS. Compared to aged silk, aged samples exhibited a marked decrease in thermal stability and a variation in the abundance of the ion m/z 107. To clarify the formation pathway of methylphenol, two complementary experiments were performed using Py-GC-MS coupled with a cryotrap: a single-shot flash pyrolysis at 350 °C and a progressive heating experiment from 50 °C to 350 °C at a rate of 10 °C/min (same used for EGA-MS experiments). The comparison of the relative abundance of the m/z 107 ion under the two experimental conditions demonstrates that methylphenol is not a secondary product formed during progressive heating but rather a primary pyrolysis product of tyrosine. Variations in the m/z 107 signal observed in the first EGA peak of aged silk can therefore be directly related to modifications of tyrosine occurring during ageing. This study demonstrates how Py-GC-MS coupled with a cryotrap under controlled progressive and instantaneous heating conditions enables the discrimination between primary and secondary pyrolysis products in silk, improving the interpretation of molecular pathways from EGA-MS data for proteinaceous materials.



Ratio between EIC 112/ EIC 107 :
9/1.3 = 6.9



Ratio between EIC 112/ EIC 107 :
6.1/0.9 = 6.8

[1] S. Orsini, C. Duce, and I. Bonaduce, "Analytical pyrolysis of ovalbumin," J. Anal. Appl. Pyrolysis, vol. 130, pp. 249–255, Mar. 2018, doi: 10.1016/j.jaap.2018.01.026.

[2] F. Sabatini, T. Nacci, I. Degano, and M. P. Colombini, "Investigating the composition and degradation of wool through EGA/MS and Py-GC/MS," J. Anal. Appl. Pyrolysis, vol. 135, pp. 111–121, Oct. 2018, doi: 10.1016/j.jaap.2018.09.012.

Analytical pyrolysis promotes organic residue analysis in China

Bin Han (University of Chinese Academy of Sciences, China)

11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (University of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

As an analytical method designed for polymer analysis, online pyrolysis had been explored for its practical application as early as 1950s and was quickly applied in cultural heritage and archaeology studies. Since then, pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) has been widely used for the characterization of organic materials used in artworks and archaeological samples. Also, Py-GC/MS is among the most frequently used techniques for archaeological organic residue studies due to its ability to provide information on their molecular structure. In archaeological research practice, pyrolysis is a way to permit the analysis of archaeological organic residue by GC/MS with minimum quantity and a simple sampling process. We have explored an approach based on the use of the coupling of pyrolysis, gas chromatography and mass spectrometry (Py-GC/MS) to screen potential biomarkers in organic residue to reveal their composition and further implications in social use and meanings in antiquity. For instance, potential vegetation biomarkers such as certain terpenes, lignin monomers, sesamin, miliacin can be easily screened by pyrolysis aiding material identification in archaeometry studies. A review of research cases in our group, as well as other groups for organic residue analysis in China, confirm the efficiency and usefulness of analytical pyrolysis for promotion of organic residue analysis in Chinese archaeological practice.

Optimizing Multifunctional Py-GC/MS Workflows for Historical Gold Varnishes: First Application to a 17th-Century Gilt Leather Panel

Valentina Pintus (Louvre Abu Dhabi, UAE) Khadija Lari (Louvre Abu Dhabi, UAE) Celine Bonnot-Diconne (Private Practice, France) Pablo Londero (Louvre Abu Dhabi, UAE) Elsa Bourguignon (Louvre Abu Dhabi, UAE)

11:00-13:00 Session S1.2: Analytical Pyrolysis: Cultural heritage

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Bonaduce (university of Pisa, Italy) Barbara M. Scholz-Boettcher (Carl von Ossietzky Universität Oldenburg, ICBM, Germany)

ABSTRACT

Historical “gold” varnishes—hereafter defined as oil- and resin-based transparent coatings applied over silver leaf to produce a gold-like appearance, and not as varnishes containing metallic gold—are characteristic surface finishes of gilt leather objects. In these artefacts, silver leaf is adhered to a leather-type support and subsequently coated with a yellow varnish whose optical properties create the visual effect of gold. These complex varnishes, composed of oils, resins, colorants, and minor additives, pose significant analytical challenges due to the difficulties in their exact identification as well as their extensive ageing, degradation, and the severe micro-sampling constraints imposed by cultural heritage materials.

While Pyrolysis–GC/MS (Py-GC/MS) has been applied to a wide range of heritage materials, its potential has never been systematically explored for historical “gold” varnishes of this type. This study presents the first comprehensive evaluation of a multifunctional Py-GC/MS workflow applied to “gold” varnish samples from a 17th-century gilt leather panel, The Triumph of David. The objective is to assess which pyrolytic configurations are best suited for characterizing both major and minor components in these highly complex coatings and to establish a methodological framework for future studies.

Selected varnish samples were analyzed using a suite of Py-GC/MS-based techniques, complemented by conventional GC/MS. The analytical strategy targeted lipidic, resinous, waxy, and proteinaceous components. Historical samples were systematically compared with gilt-leather gold-varnish model systems reproducing documented historical recipes. The Py-GC/MS configurations investigated included reactive Single-Shot (SS) Py-GC/MS, partially reactive Double-Shot (DS) Py-GC/MS, Evolved Gas Analysis (EGA)-MS, Heart-Cut EGA-GC/MS, and a recently developed SS Py-GC/MS mode employing Functional-Splitless injection for high-sensitivity detection of trace constituents. Each configuration was evaluated in terms of qualitative and semi-quantitative performance, sensitivity to minor compounds, sample-amount requirements, and practical considerations such as analysis time, data complexity, and robustness. This represents the first systematic comparison of these techniques applied specifically to historical “gold” varnishes. The results demonstrate that the multifunctional workflow provides unprecedented insight into the composition of historical “gold” varnishes. Reactive SS Py-GC/MS enabled rapid identification of major organic classes, while DS Py-GC/MS and EGA-based methods improved interpretation of complex degradation patterns and overlapping thermal behaviors typical of aged coatings. Notably, the Functional-Splitless SS Py-GC/MS configuration significantly enhanced detection of minor diagnostic compounds, such as specific resins and additives, demonstrating its value for the study of historical “gold” varnishes.

The integrated dataset allowed a more refined interpretation of the “gold” varnish composition on The Triumph of David, supporting attribution hypotheses and offering insights into workshop practices. This research establishes the necessity of multimodal pyrolytic approaches for the characterization of highly aged varnish systems under strict sampling constraints and provides practical guidance for future analytical studies of gilt leather and other historically layered coatings. Acknowledgements: We thank Laurianne Robine, Marie Radepont, and Sylvie Heu-Thao (Centre de Recherche sur la Conservation, Muséum national d’Histoire naturelle, Ministère de la Culture, CNRS, Paris, France) for providing gilt-leather gold-varnish models and for sharing their expertise.

Kinetic analysis of biochar formation by Py-GC/MS during fast pyrolysis of lignocellulosic biomass

Joselyne Uwizeye (IMT Mines Albi, France) Zoé Mercier (IMT Mines Albi, France) Marion Carrier (CNRS, France)

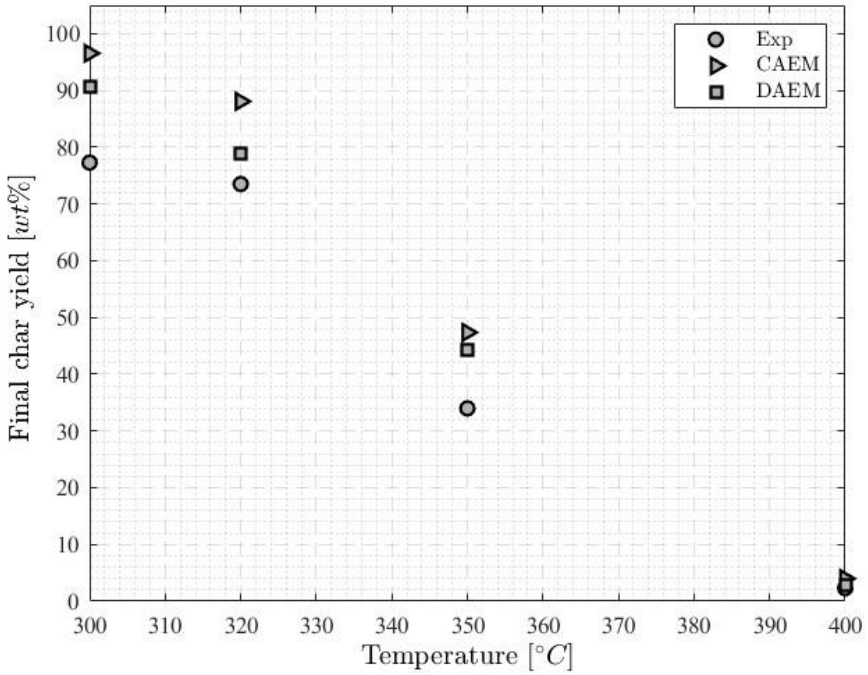
11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

This study investigated the apparent global kinetic parameters governing biochar formation during the fast pyrolysis of main biomass components isolated from Zea mays. The cellulose, hemicelluloses, and lignin fractions were obtained through an isolation process to allow individual component analysis. Controlled fast pyrolysis experiments were carried out in a micropyrolyzer coupled with GC-MS/FID at temperatures between 300 and 500°C, and the global kinetic parameters were determined using a single-step and first-order global reaction model. The Evolved Gas Analysis (EGA) was used to estimate pyrolysis times and determine the pre-exponential factors. The kinetic parameters obtained were E = 18.63 kJ mol^{-1} and A = 0.409 s^{-1} for lignins; E = 20.55 kJ mol^{-1}and A = 0.648^{-1} for hemicelluloses; and E = 105.98 kJ mol^{-1}, A = 6.04 × 106 s^{-1} for cellulose. Because of methodological differences, the direct comparison of our kinetic datasets with literature was not straightforward. However, numerical modelling using a new lumped and distributed activation energy model [1] allowed the validation of experimental final biochar yields (Figure 1) and indirectly the measured overall and global kinetics.



[1] Mercier, Z., Carrier, M. & Marias, F. Lumped and distributed activation energy modelling of biomass pyrolysis. Chemical Engineering Journal Advances 25, 100998 (2026).

Integrated Computational, Experimental, and Kinetic Modeling Study of the Pyrolysis Mechanisms of Hemicellulose Molecular Constituents

Bernardo Ballotta (School of Physics, Trinity College Dublin, Dublin, Ireland, Ireland) Corinna Maria Grottola (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (STEMS-CNR), Naples, Italy, Italy) Paola Giudicianni (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (STEMS-CNR), Naples, Italy, Italy) Michele Turco (School of Physics, Trinity College Dublin, Dublin, Ireland, Ireland) Jiaxin Ren (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Hugh Keelan (School of Physics, Trinity College Dublin, Dublin, Ireland, Ireland) Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Raffaele Ragucci (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (STEMS-CNR), Naples, Italy, Italy) Stephen Dooley (School of Physics, Trinity College Dublin, Dublin, Ireland, Ireland)

11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

The pyrolysis of lignocellulosic biomass represents a key technology for the sustainable production of biofuels and bio-based materials. However, the molecular-level understanding of biomass thermal decomposition remains incomplete, limiting the development of predictive kinetic models. Hemicellulose, and in particular xylan, plays a crucial role in biomass pyrolysis, yet its intrinsic reactivity and decomposition chemistry are still poorly understood. This work aims to elucidate the pyrolysis mechanisms of representative xylan molecular constituents, xylopyranose, xylobiose, and xylotriose, through a combined computational, experimental, and kinetic modeling approach. Reaction pathways will be systematically explored using the automated reaction discovery program AutoMeKin[1] coupled with semiempirical molecular dynamics, followed by high-level quantum chemical refinement of all stationary points. Accurate thermochemical and kinetic parameters will be obtained using density functional theory and DLPNO-CCSD(T)-F12 calculations, combined with RRKM/transition state theory to derive temperature-dependent rate coefficients relevant to fast pyrolysis conditions. Solvent effects will be evaluated using a polarizable continuum model to support condensed-phase kinetic applications. Experimentally, the thermal behavior of the selected mono-, di-, and tri-saccharides will be characterized using thermogravimetric analysis coupled with FTIR spectroscopy, complemented by Py-GC/MS micropyrolysis experiments to identify and quantify primary volatile products. Additional laboratory-scale pyrolysis tests will provide gas, liquid, and solid product characterization [2]. These datasets will enable direct validation of the computational reaction mechanisms and kinetic parameters. The experimental and theoretical results will be integrated into a semi-detailed chemical kinetic model describing the pyrolysis of xylan constituents [3]. The model will be hierarchically extended from xylopyranose to xylobiose and xylotriose and coupled with an existing gas-phase kinetic framework. Using molecular group additivity concepts, the model will provide a foundation for describing the pyrolysis of real xylan polymers and hemicellulose in softwood and hardwood biomasses. This integrated methodology will deliver a mechanistically consistent and predictive kinetic model, offering new insights into hemicellulose pyrolytic reactivity and supporting the development of more reliable biomass pyrolysis simulations.

[1] Martínez-Núñez, E.; Barnes, G. L.; Glowacki, D. R.; Kopec, S.; Peláez, D.; Rodríguez, A.; Rodríguez-Fernández, R.; Shannon, R. J.; Stewart, J. J.; Tahoces, P. G.; Vazquez, S. A. AutoMeKin2021: An Open-Source Program for Automated Reaction Discovery. J. Comput. Chem. 2021, 42, 2036–2048.

[2] Ferreiro, A. I.; Giudicianni, P.; Grottola, C. M.; Rabacal, M.; Costa, M.; Ragucci, R. Unresolved Issues on the Kinetic Modeling of Pyrolysis of Woody and Nonwoody Biomass Fuels. Energy Fuels 2017, 31, 4035–4044.

[3] Ranzi, E.; Debiagi, P. E. A.; Frassoldati, A. Mathematical Modeling of Fast Biomass Pyrolysis and Bio-Oil Formation. Note I: Kinetic Mechanism of Biomass Pyrolysis. ACS Sustainable Chem. Eng. 2017, 5, 2867–2881.

framework for reaction mechanism investigation of pyrolysis process for carbon-based fuels with reactive molecular dynamics simulation

Mo Zheng (State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, China) Xiaoxia Li (Institute of Process Engineering, Chinese Academy of Sciences, China)

11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

Carbon-based resources include traditional fossil energy sources (coal, oil shale, crude oil is its derived heavy oil), renewable/waste energy sources (biomass, waste plastics, municipal sludge) and light oils, etc. The radical reaction network triggered by the cleavage of covalent bonds in the molecular structure of carbon-based resources dominates the distribution characteristics of gas, liquid, and solid products. However, limited by experimental techniques to observe the real-time reaction process, most experimental studies can only determine the apparent synergistic effects by comparing pyrolysis behavior, product distribution and yields of characteristic compounds, which lacks in insights for building the detailed multi-channel reaction pathways among different feedstocks and pyrolyzates in solid and liquid phases. The combination of reactive force field (ReaxFF) that based on bond order concept and molecular dynamics (MD) can continuously describe the interatomic formation and bond breaking evolution of the reaction system without pre-designing the reaction pathways. In order to reach spatio-temporal scales of nanometers and nanoseconds for complex systems, the first graphics processing unit (GPU) enabled ReaxFF MD software, GMD-Reax, was created, both for the increase of system size and acceleration of ReaxFF MD running on desktop workstations. Any possible care has been taken in the implementation to have the ReaxFF algorithms mapped to the proper organization of GPU treads and data structures. In this work, the thermal characteristics of carbon-based fuels were evaluated under pyrolysis and catalytic pyrolysis conditions by using the large-scale ReaxFF MD simulation rooted in high-performance computing and cheminformatics-based reaction analysis. For example, the blend models containing six mixtures of polymers (polyethylene, polypropylene, polystyrene) and biomass (cellulose, hemicellulose and lignin) were constructed for the first time, which is close to the real utilization of waste materials. A unique ReaxFF MD simulation strategy for decoupling pyrolysis stage formation and char formation stage was carried out to obtain char-like structures with acceptable computational cost. ReaxFF MD simulation results indicate that the polymer would promote biomass pyrolysis at low temperature, while biomass would delay polymer decomposition at high temperature. Co-pyrolysis does not generate new species, but greatly affects the product yields through interactive reactions of hydrogen transfer and hydroxyl transfer, where more oxygen-containing oils are produced with the aid of polymer providing hydrogen atoms. Since oxygen-containing functional groups in biomass provide the initial cross-linking sites to produce large fragments, the formation of char precursors is reduced significantly with polymer addition. As compared to pyrolysis of only binary components, the observed qualitative synergistic results in co-pyrolysis of biomass-polymer mixtures provide important insights into the detailed reactions for co-pyrolysis process, which can complement experimental observations to modulate the nature and yield of the desired bio-oils and bio-chars.

Multiscale and AI-Enabled Investigation of Biomass/Plastic Fast Pyrolysis in Fluidized Bed Reactors

Xi Gao (Guangdong Technion-Israel Institute of Technology, China)

11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

The biomass/plastic fast pyrolysis fluidized bed reactor is a typical complex reaction system characterized by multiphase, multicomponent, and multiscale interactions. This presentation presents the research progress of our team in multiscale modeling, artificial intelligence, and experimental validation of thermochemical conversion reactors for biomass/plastic. Using high-speed photography and machine learning-based image processing methods, we investigated the multicomponent fluidization phenomena in biomass fast pyrolysis fluidized bed reactors. A machine learning-based drag force model was developed to study the fluidization behavior of biomass and quartz sand mixtures and their segregation. An interpretable pyrolysis kinetics model based on neural networks was constructed to optimize the parameters of the pyrolysis kinetics model. A machine learning-accelerated discrete particle simulation algorithm was developed to enable fast and accurate discrete particle simulations. The SuperDEM solver for non-spherical particle simulations was created, allowing large-scale parallel simulations of discrete particles and studying the fluidization phenomena of non-spherical particles. A multiscale modeling framework was established to couple complex reaction kinetics models, intraparticle transport-reaction models, and fluidized bed reactor models, enabling the simulation, optimization, and scale-up of biomass/plastic fast pyrolysis fluidized bed reactors.

Thermal Reactivity of the Cellulose Crystalline Core: Insights into Metal Cation Effects via Deuterium Labeling and TG-MS Analysis

Yasuko Maruichi (Kyoto University Graduate School of Energy Science, Japan) Yuta Masuda (Kyoto University Graduate School of Energy Science, Japan) Eiji Minami (Kyoto University Graduate School of Energy Science, Japan) Haruo Kawamoto (Kyoto University Graduate School of Energy Science, Japan)

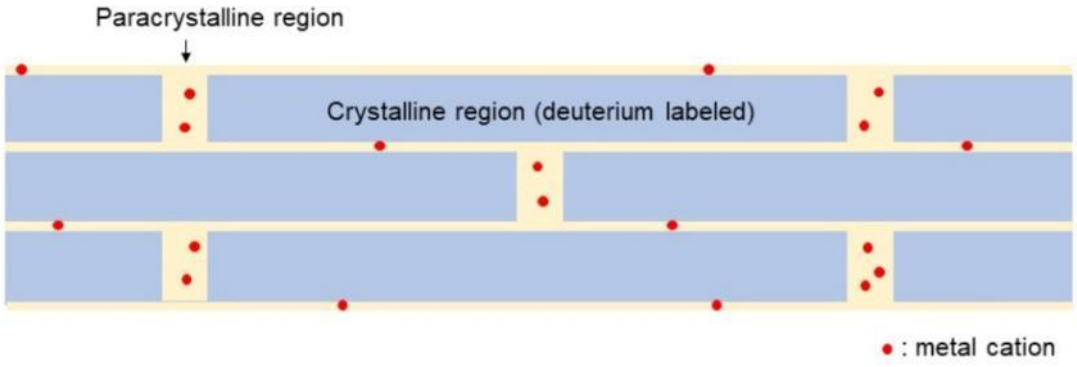
11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

Pyrolysis provides a promising saccharification method for cellulose, a main component of woody and herbaceous biomass, as it produces large amounts of levoglucosan (1,6-anhydro-beta-D-glucopyranose, LG), which can be hydrolyzed into glucose under mild conditions. However, the reaction mechanism and kinetic behavior of cellulose pyrolysis remain unclear due to variations in thermal reactivity among cellulose samples and the presence of a crystalline structure that includes paracrystalline regions. In contrast, our group has shown that metal-cation-exchanged cellulose exhibits distinct thermal reactivity, with alkaline earth metal salts promoting cellulose decomposition at temperature approximately 30℃ lower than those of alkali metal salts. In this study, a partially deuterated cellulose—where only regions inaccessible to water in aqueous suspension were deuterated—was employed to elucidate the thermal reactivity of crystalline region. This sample enabled a clear distinction between the reactivity and product selectivity of accessible and inaccessible regions using TG–MS analysis. This study further investigated how metal cations influence the pyrolysis behavior of cellulose. The deuterated cellulose sample was prepared by heating Whatman No.42 cellulose in deuterium oxide (D2O) at 220℃ for 5 minutes, then washing with purified water and freeze-drying. Metal-cation-exchanged cellulose was prepared by immersing the deuterated cellulose sample in a 0.05 M metal acetate solution (Na+, K+, Ca2+, Mg2+) at room temperature, followed by washing with purified water and drying at 105℃. These samples were analyzed by TG-MS. TG-MS analysis of deuterated cellulose sample revealed that D2O was released at higher temperatures than H2O, and that LG was preferentially formed in association with D2O. These results indicate that the accessible regions of cellulose have lower thermal stability, whereas LG originates primarily from the more stable inaccessible regions, likely located within the crystal core. In metal-cation-exchanged cellulose, a similar tendency was observed: D2O and LG were produced at higher temperatures than H2O. However, the onset temperatures of D2O and LG varied depending on the type of metal cation. To evaluate the effects of metal cations on the production temperature of each product—H2O, fragmentation products (FP) such as glycolaldehyde, CO2, D2O, LG, furfural (FF), and 5-HMF—"onset temperature" was defined as the temperature at which the signal intensity reached 3% of the maximum peak intensity". H2O, FP, and CO2 were produced at lower temperatures than D2O, indicating that these products originate from accessible regions. Their onset temperatures were nearly identical across different metal cations, expect for Mg2+. In contrast, LG, FF, and 5-HMF were produced at higher temperatures than D2O, suggesting that these compounds form after reactions in the crystalline core have progressed. Furthermore, their onset temperatures differed depending on the metal cation, with reactivity following the order: Mg2+ > Ca2+ > Na+ ≈ K+. Since the cation-exchange treatment was performed at room temperature, metal cations are localized only in the accessible regions of cellulose. These results indicate that metal cations in the accessible regions alter the thermal reactivity of the crystalline core. Figure caption: Image of cellulose containing paracrystalline regions and cations.



Strategy for revealing thermolysis mechanism of CL-20 cocrystals by ReaxFF MD simulations

Chunxing Ren (State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, China) Xiaoxia Li (State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, China) Mo Zheng (State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, China)

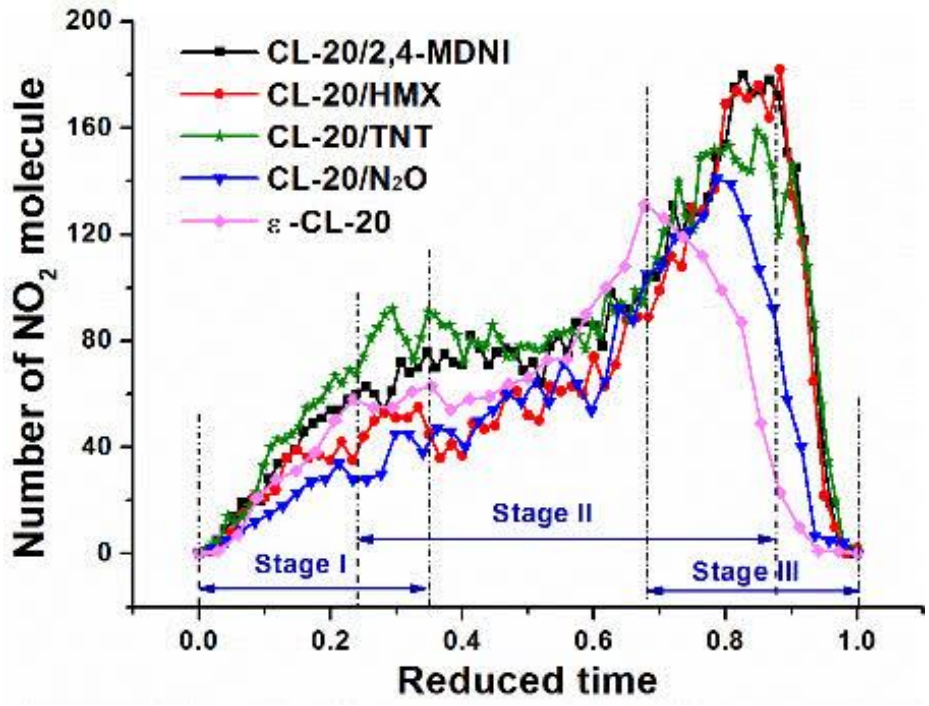
11:00-13:00 Session S1.3: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Ondrej Masek (The University of Edinburgh, UK) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain)

ABSTRACT

High energetic 2,4,5,8,10,12-hexanitro-2,4,6,8,10,12-hexaazaisowurtzitane (CL-20) has limited applications due to its low safety, which can be improved by synthesis of CL-20 cocrystals by cocrystallization strategy. Understanding the reaction mechanisms of thermal decomposition of CL-20 cocrystals and the interactions between components are fundamental for modulating material structure and properties properly by co-crystallization method. However, the thermal decomposition mechanisms of CL-20 cocrystals remain unclear due to the complexity of multi-component systems, rapid dynamic reactions under extreme conditions, and limitations of traditional experimental techniques (e.g., TG, DSC, and chromatography) that only provide several final products, weight loss, and apparent kinetic data. The reactive molecular dynamics using ReaxFF force field (ReaxFF MD) has been found useful to improve the understanding of microscopic chemical behaviors of multi-component energetic materials. Aimed at unraveling reaction mechanisms of CL-20 cocrystals thermolysis, thermal decomposition of CL-20 cocrystals is systematically investigated using ReaxFF MD simulations with varied heating history. A novel three-stage classification strategy was proposed based on the double peaks of NO2 evolution obtained by ReaxFF MD simulations of adiabatic thermolysis of CL-20 cocrystals, which facilitates to depict the similarities and differences of chemical behaviors and product distribution in thermolysis of varied CL-20 cocrystals. The similarities of chemical behaviors and product distribution in thermolysis of CL-20 cocrystals to that of pure CL-20 under are rooted in the CL-20 chemistry dominating over the whole process from the very initial response to thermal stimuli and primary decomposition to the secondary reactions. The chemical interactions between different components contribute significantly to the kinetic property differences among varied CL-20-involved reactive systems in energy-releasing process, decomposition of CL-20 molecules and stable product generation. The strategy of ReaxFF MD coupled with the three-stage framework provides an efficient approach of revealing the thermolysis mechanism of CL-20 cocrystals, which may be useful for evaluating the reaction properties of varied CL-20-based multi-component energetic systems.



Decomposition kinetics and product distribution of a very fast pyrolysis of algal biomass

Guozhao Ji (Dalian University of Technology, China)

15:30-16:30 Session S1.4: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Converting algal biomass to clean energy via a thermochemical pathway is an emerging technique for tackling environment and energy issues. Traditional kinetic studies on biomass pyrolysis employ a thermogravimetric analyzer (TGA) which heats the biomass sample at a rate of 0 ~ 2 K s−1, so TGA could only replicate the thermal behavior of the biomass sample in a fixed bed reactor. However, biomass samples can be heated at a rate over ~102 K s−1 in industrial reactors, including fluidized beds, spouted beds, or rotary kilns due to the direct contact between biomass samples and the solid heat carriers, thus TGA is incapable to reproduce these thermal behaviors. In view of the limitation of TGA in fast heating cases, this study has developed a fast-heating thermo-balance consisting of wire-mesh and wireless power supply technique to investigate the kinetics of fast pyrolysis. Seaweed is fast-growing and can be considered a promising feedstock for biofuel production. Therefore, this study selected seaweed as representative biomass waste and compared the pyrolysis behaviors under both slow and fast pyrolysis conditions. A key finding was the TGA-derived kinetic parameters were unable to describe the pyrolysis rate under fast pyrolysis conditions with significant overestimation. When compared to slow pyrolysis, fast pyrolysis can increase bio-oil yield by about 3–17%, but the N- and S-containing compounds in the bio-oil increase by about 1.1% and 0.15% respectively at a final temperature of 700°C. Fast pyrolysis produced about 16–53% more CO2 than slow pyrolysis above a final temperature of 500 °C. The polarity of compounds in biochar was reduced with increasing temperature and the presence of CaO was only found in biochar at a high temperature of 700 °C. The specific surface area of biochar was higher under fast heating pyrolysis (5.534–7.469 m2 g−1) than that under slow heating pyrolysis (4.076–6.414 m2 g−1).

Simultaneous pyrolysis-activation-doping of biomass for porous N-doped biochar

Wei Chen (Nanjing Agricultural University, China) Zhen Fang (Nanjing Agricultural University, China) Liang Wang (SINTEF Energy Research, Norway)

15:30-16:30 Session S1.4: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Biomass pyrolysis produces high-value chemical products and is important for developing energy applications. Nitrogen-doped biochar, which has a porous structure, active nitrogen/oxygen-containing groups, and catalytic sites, can be used directly as a high-performance functional carbon material such as a catalyst, adsorption, and energy storage material. How to prepare porous N-doped biochar is very important for the high-quality utilization of biomass. Chemical activation and nitrogen doping are the main upgrade methods for biochar. This study explored the preparation mechanism for nitrogen-doped biochar materials via one-step “pyrolysis-activation-doping” of biomass. The interaction of biomass pyrolysis, chemical activation, and NH3 modification was explored in depth, and the evolution mechanism of pore structure, nitrogen content, and active functional groups of porous N-doped biochar was discussed in detail. Results showed that there was a significant synergistic effect of KOH and NH3 on the development of pore structure and nitrogen doping. KOH reacted with active functional groups in biomass and removed large amounts of O-containing groups to generate abundant active vacancies. NH3 reacted with biomass and formed lots of NH2* and NH*, which occupied active vacancies quickly, thus enriching large amounts of nitrogen in biochar product (10.4 wt.%). NH3 and KOH also etched biochar fragments to form large quantities of pores, thus obtaining N-doped biochar materials with high specific surface area and developed mesoporous structure (2800 m2/g). Thus, one-step “pyrolysis-activation-doping” of biomass can easily prepare for the porous N-doped biochar with a developed porous structure and high nitrogen content.

In-situ Pyrolysis Vapor Recirculation in a Continuous Auger Reactor: Characterization of Bio-oil from Pyrolysis of Pine Bark

Yusuf Tolunay Kilic (Luleå University of Technology, Sweden) Marcelo Dal Belo Takehara (Luleå University of Technology, Sweden) Kentaro Umeki (Luleå University of Technology, Sweden)

15:30-16:30 Session S1.4: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Thermochemical conversion of lignocellulosic biomass via pyrolysis offers a versatile pathway for producing renewable energy carriers and chemicals. However, the utilization of bio-oil is often hindered by its high oxygen and water content, chemical instability, and complex heterogeneity. While previous studies (1-3) have explored external bio-oil recirculation to enhance biochar yield and quality, the role of internal in-situ vapor recirculation remains poorly understood in continuous pyrolysis systems. This study addresses this gap by systematically investigating how controlled vapor–solid interactions influence product yield distribution and bio-oil quality. The experiments were performed in a laboratory-scale continuous auger reactor with pine bark (500 g/h) at the highest treatment temperatures (HTTs) of 600, 700, and 800C. The reactor's five independently controlled heating zones and multiple selectable vapor outlet ports allowed the manipulation of temperature profiles and vapor flow trajectories. Three configurations (Figure) were evaluated: a conventional parallel-flow (PF) and two counter-flow (CF). In PF, vapors travel co-currently with the biomass. In CFs, the flow is reversed to pass through cooler upstream zones, promoting in-situ condensation of heavy vapors onto incoming biomass and promoting secondary pyrolysis reactions. In the experiments, bio-oil was recovered in a three-stage condensation system, and non-condensable gas composition was analyzed online (microGC). The mass and carbon balance closures were performed to assess the impact of flow configurations on product yield and properties. To investigate the effect on bio-oil composition and properties, the collected bio-oils were fractioned into water-soluble and water-insoluble (heavy oil) phases by using MgSO4-assisted fractionation. The fractions were characterized by GC–MS/FID to identify and semi-quantify volatile species, such as acids, furans, and phenols. NMR spectroscopy provided deep structural insights: one-dimensional 13C NMR was applied to determine the distribution of carbon functional groups, while two-dimensional 1H–13C HSQC NMR was used to resolve overlapping signals and track changes in molecular motifs, including carbohydrate-derived units and lignin-derived methoxy groups. The results demonstrate that in-situ vapor recirculation offers an in-situ upgrading for bio-oil, enhancing carbon retention and controlled selectivity among biochar, bio-oil, and gas in continuous pyrolysis systems.

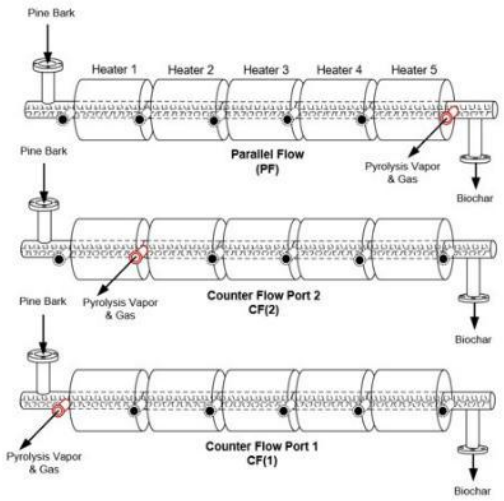


Figure. Schematic representation of reactor configurations used in the study.

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Understanding the ageing of polyurethane foams in art and design: a thermoanalytical approach

Greta Biale (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Alessandro Rughi (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Adele Ferretti (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Francesca Modugno (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Ilaria Degano (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy)

15:30-16:30 Session S1.5: Analytical Pyrolysis: Cultural heritage, Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Synthetic polymers have influenced contemporary artists since the beginning of last century; among these materials, polyurethanes (PU) are widely present in 20th century artworks and design objects, mainly as flexible and rigid foams. Adopted by artists from the late 1960s for their distinctive properties, such as lightness and softness, polyurethane foams exhibit limited durability and can degrade within a few decades after production. The wide variety of possible compositions and formulations for these materials makes the degradation of PU foams a critical conservation issue for 20th century art and design collections, that requires suitable tools to evaluate, monitor, and ultimately mitigate it through appropriate conservation strategies. This is one of the aims of the PRIN2022 interdisciplinary project PERSPECTIVE - PolymEr Research Studies for PreventivE Conservation Through non invasIVe analytical strategiEs (https://perspective.cnr.it) for plastic heritage. Within the framework of the project, this work focuses on the application of thermoanalytical techniques to provide a comprehensive evaluation of PU items, including polymers and additives such as consolidant formulations and UV absorbers tested/used in the conservation of PU artworks [1]. Reference PU samples, unaged and subjected to artificial ageing, were analyzed by means of evolved gas analysis-mass spectrometry (EGA-MS) and double shot pyrolysis-gas chromatography-mass spectrometry (DS-Py-GC-MS) to characterize their thermal degradation behavior, optimize the DS-Py-GC-MS temperatures, and determine the composition of the material. Part of the reference PU samples were treated with two different consolidant dispersions and a light stabilizer. The analysis allowed the characterization not only of the diisocyanate and polyol fractions of the PU, but also of the light stabilizer and the consolidant dispersions tested by the restorers. Differences in the thermal degradation profiles due to ageing and to the different additives used were highlighted by comparing the EGA profiles of the various samples. The different PU samples (unaged, artificially aged, both treated and untreated with consolidant dispersions and light stabilizer) were then subjected to accelerated UV degradation using the online micro UV Irradiator system (UV-1047Xe, Frontier Laboratories) and subsequently analyzed by EGA-MS and DS-Py-GC-MS to evaluate changes in the untreated (Figure) and differently treated PU samples. The use of the light stabilizer proved effective, while the two different consolidant dispersions showed distinct thermal degradation behaviors due to their chemical compositions, and thus different performance in terms of consolidation. The optimized protocol, based on thermoanalytical techniques, was applied to polyurethane artworks from the Triennale Design Museum of Milan and proved effective in monitoring the degradation of PU heritage objects through micro-invasive sampling.

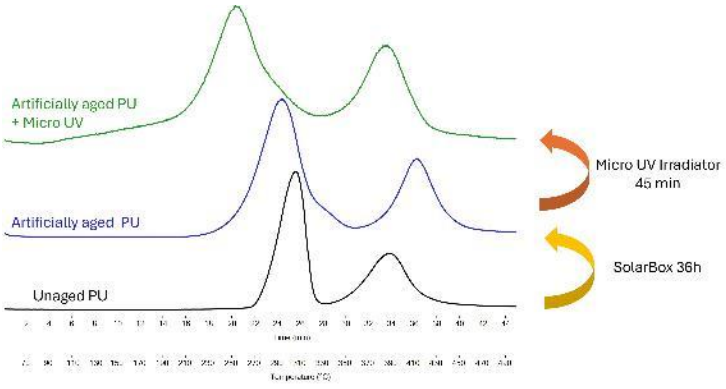


Figure EGA-MS profiles of unaged and artificially aged reference PU samples.

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Acknowledgements The Centre for Instrument Sharing of the University of Pisa (CISUP); Grazia De Cesare from the Academy of Fine Arts of L'Aquila (Italy), and Rafaela Trevisan from the Triennale Design Museum of Milan (Italy). Funding was provided by the Italian Ministry of University and Research (MUR), PRIN2022 project "PERSPECTIVE" coordinated by Francesca Rosi (CNR-SCITEC, Perugia).

Layer-Specific Identification of Organic Binders in 17th–18th Century Korean Dancheong by Pyrolysis-GC/MS

Jia Yu (National Institute of Cultural Heritage, Korea, South Korea)

15:30-16:30 Session S1.5: Analytical Pyrolysis: Cultural heritage, Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Dancheong is a traditional Korean polychromy technique applied to wooden architecture since at least the 4th century, serving both protective and decorative functions on temple and palace buildings. Despite long-term outdoor exposure, dancheong painting layers were produced using organic binders such as animal glue and starch pastes (wheat or rice). Previous studies have mainly focused on patterns and inorganic pigments, while the identification of organic binders remains a challenge due to their low concentration and extensive degradation. As contemporary artisans have limited experience with traditional natural binders, scientific investigation of these materials is necessary for informed conservation and restoration. This study investigates the original dancheong painting technique through the analytical characterization of organic binders. Based on historical documents and interviews with artisans, mock-up samples were prepared using animal glue, wheat and rice starch pastes, and a commercial acrylic emulsion. Their analytical characteristics were examined using Fourier-transform infrared spectrocopy (FTIR), evolved gas analysis (EGA), pyrolysis–gas chromatography/mass spectrometry (Py–GC/MS), and enzyme–linked immunosorbent assay (ELISA). EGA confirmed the presence of organic binders in paint layers, while Py–GC/MS identified diagnostic markers specific to each binder type: pyrrole-based compounds for animal glue, furan- and glucosan-related compounds for starch pastes, and acrylic monomers (ethyl acrylate, butyl acrylate, and butyl methacrylate) for the synthetic binder. Application of these diagnostic markers to multiple 17th–18th century dancheong samples consistently indicated the use of animal glue in the painting layers and starch paste in the ground layer (gachil), in agreement with historical descriptions. In heavily degraded samples, binder-related signals were detected at trace levels, demonstrating the sensitivity of Py-GC/MS for aged architectural paint layers. Our findings show that Py-GC/MS can be effectively applied to the identification of trace organic binders in architectural surface decorations that have been exposed for over 200–300 years. These results contribute to the accurate restoration of traditional dancheong techniques and expand the application of pyrolysis analysis in cultural heritage science. * Acknowledgment: This research was supported by the National Research Institute of Cultural Heritage, Korea (NRICH-2605-A83F-1-1).

Py-GC/MS investigation of the formation of various anhydrosugars from carbohydrates for efficient green chemical synthesis

Kristine Meile (Latvian State Institute of Wood Chemistry, Latvia) Galina Dobele (Latvian State Institute of Wood Chemistry, Latvia) Vilhelmine Jurkjane (Latvian State Institute of Wood Chemistry, Latvia) Aivars Zhurinsh (Latvian State Institute of Wood Chemistry, Latvia)

15:30-16:30 Session S1.5: Analytical Pyrolysis: Cultural heritage, Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Use of biomass as the feedstock for pyrolysis is aimed at promoting a bioeconomy, where value-added products are obtained from renewable resources, instead of fossil ones. The scientific objectives of our work are related to the thermochemical destruction of carbohydrates and the equilibrium between monosaccharide derivatives and their isomers as pyrolysis products under various pre-treatment conditions, as well as the extraction of the resulting products. We aim to elucidate the mechanisms of the formation of various anhydrosugars as a potential source of green chemicals. Levoglucosan (LG) or 1,6-anhydro-β-D-glucopyranose is the main product of cellulose depolymerisation and dehydration during pyrolysis. LG has a unique chiral structure, and it can find applications in various chemical and pharmaceutical synthesis. We propose to expand the array of complementary anhydrosugar products in lignocellulose pyrolysis with a biorefinery approach to increase added value to the pyrolysis process. The main anhydrosugar-type by-products of LG in pyrolysis include 1,6-anhydro-β-D-glucofuranose (AGF), 1,4:3,6-dianhydro-α-D-glucopyranose (DAG), and levoglucosenone (LGO). The yields of these anhydrosugars are influenced by the carbohydrate feedstock, pre-treatment, use of catalysts, and the pyrolysis temperature. Commercially available standard carbohydrates, as well as lignocellulosic materials were used in the Py-GC/MS experiments with a Frontier Lab Micro Double-shot Pyrolyser Py-2020iD directly coupled with Shimadzu GC/MS—QP 2010 instrument (capillary column RTX-1701 (Restec, USA), 60 m × 0.25 mm × 0.25 μm film). The screening of the pyrolysis products obtained from glucose, fructose, cellobiose, cellobiosan, levoglucosan, cellulose, starch, and birch wood at 500 ℃ showed the influence of the carbohydrate structure on the formation of LG, AGF, DAG, and also furan derivatives as pyrolysis by-products. Furthermore, the pyrolysis experiments were done with the carbohydrates treated with sulfuric acid in 0.2-4 % concentration range (sulfuric acid m / feedstock m) to evaluate the catalytic effect of acids. In the absence of acid, LG as a feedstock showed thermochemical stability, while the yield of LG from the pyranoses increased in the following order: glucose < cellobiose < cellulose. Addition of acid significantly increased the yield of LG in case of glucose, but not significantly in case of its oligomer and polymer - cellobiose and cellulose, respectively. Moderate addition of sulfuric acid promoted the formation of AGF, but maximum acidity was in favour of the formation of DAG, while the yields of LG and AGF significantly dropped. At 4% sulfuric acid addition, the main pyrolysis products of all carbohydrates were furfural and levulinic acid. Two types of birch lignocellulose (with sulfuric acid and phosphoric acid pre-treatment) were tested at 350 ℃ and 500 ℃, and the ratio of carbohydrate pyrolysis products was influenced both by the temperature and the pretreatment. Sulfuric acid was more favourable for the formation of LG and AGF, but phosphoric acid pre-treatment promoted the formation of LGO and DAG. Optimising the pre-treatment and pyrolysis conditions could enable the production of several valuable green chemicals in the same process. Acknowledgements to ERDF PostDoc Latvia project No. 1.1.1.9/LZP/1/24/005.

From Gas-Phase Chemistry to Carbon Formation and Deposition: Validation of a Kinetic Framework for Light Hydrocarbons Pyrolysis

Lorenzo Giardini (Politecnico di Milano, Italy) Luna Pratali Maffei (Politecnico di Milano, Italy) Alberto Cuoci (Politecnico di Milano, Italy) Alessio Frassoldati (Politecnico di Milano, Italy) Tiziano Faravelli (Politecnico di Milano, Italy) Matteo Pelucchi (Politecnico di Milano, Italy)

15:30-16:30 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Hydrocarbon pyrolysis is an increasingly attractive route for low-emission hydrogen production, offering the advantage of coupling hydrogen generation with the formation of value-added carbon materials. In this context, a key challenge lies in accurately describing the evolution of the gas-phase composition, particularly under operating conditions relevant to the formation of structured carbon phases. The predictive capability of kinetic models strongly depends on their ability to capture the formation and consumption of key intermediates governing both hydrogen yield and carbon precursor availability. In addition, experimental challenges in fully resolving gas-phase composition and carbon forms (amorphous, surface) [1] further motivate the development of accurate mechanistic kinetic models. This work presents the validation of an integrated kinetic framework combining detailed gas-phase chemistry with a dedicated model for carbon deposition and growth via non-catalytic Chemical Vapor Deposition (CVD) and carbon nanoparticle formation. The framework consistently links homogeneous pyrolysis chemistry with heterogeneous carbon formation pathways, enabling a unified description of gas-phase reactions and solid carbon growth. The CRECK gas-phase kinetic mechanism[2,3] is tested both independently and through systematic comparison with established literature mechanisms[4], focusing on key intermediates such as acetylene, benzene, and polycyclic aromatic hydrocarbons, which play a central role as precursors to solid carbon formation. Validation is performed against experimental data obtained in ideal reactor configurations, assessing the effects of temperature, residence time, pressure, and C/H ratio on feedstock conversion, hydrogen yield, and gaseous product distribution. This analysis enables evaluation of the robustness and consistency of the gas-phase description across relevant conditions. Building upon the validated gas-phase framework, a solid-phase kinetic module is introduced to describe carbon deposition and growth via gas-surface reactions. Theoretical studies[5,6] indicate growth mechanisms analogous to soot and pyrocarbon formation in non-catalytic CVD environments. Reaction classes and rate rules are formulated by analogy with established PAH growth mechanisms[7] and supported by kinetic scaling relationships, ensuring thermodynamic and mechanistic consistency. The modular structure allows progressive inclusion of surface reactions while preserving coherent coupling with the gas-phase chemistry. The combined validation of gas-phase kinetics and solid deposition modeling demonstrates the capability of the framework to consistently link hydrocarbon pyrolysis chemistry to carbon formation pathways. The results highlight the strong sensitivity of carbon growth behavior to gas-phase precursor chemistry and operating conditions. Overall, this work represents a step toward predictive multiscale kinetic models for methane pyrolysis reactors, supporting experimental interpretation and the development of modeling tools for process optimization in hydrogen and value-added carbon production.

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Effect of coal macromolecular network fragments on char during coal pyrolysis

He Yang (Dalian University of Technology, China) Yu Yang (Dalian University of Technology, China) Zhengxian Song (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China) Yang Li (Dalian University of Technology, China) Haoquan Hu (Dalian University of Technology, China)

15:30-16:30 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Understanding the influence of fragments of coal macromolecular network (metaplast and tar) on char during coal pyrolysis is beneficial for studying the mechanism of coal conversion and realizing the regulation of coal pyrolysis products. The solvent extraction and swelling treatment of rapid pyrolysis char were carried out to reduce the content of metaplast. The metaplast extracted with tetrahydrofuran (THF) solvent contained abundant aromatic compounds with a low degree of polycondensation, and its orientation distribution in char was disordered. After solvent extraction and swelling, the reactivity of the residues was enhanced, making more residues convert into liquid and gas products during the re-pyrolysis. Solvent extraction and swelling only increased the specific surface area of the char from 4 m^2/g to 5 m^2/g and 7 m^2/g, respectively, indicating that metaplast cannot directly influence pyrolysis by occupying pores. In re-pyrolysis, the relative growth rates of 4×4 and larger aromatic sheets in the extraction and swelling residues were decreased from 66.35% (char without solvent treatment) to 52.21% (char after extraction treatment) and 36.4% (char after swelling treatment), respectively. It indicates that metaplast can promote the polycondensation. After solvent treatment, the orientational concentration of aromatic cores in the char increased during re-pyrolysis, whereas that in the untreated char did not. It indicates that the metaplast was more likely to being trapped by the char's skeletal framework through cross-linking reactions or pore adsorption and was further polycondensed with the volatiles to form amorphous aromatic cores within the char matrix. In addition, the rapid-pyrolyzed chars prepared at different temperatures were re-pyrolyzed under atmospheres containing different tar model compounds. For char prepared at 600 ℃, the proportion of ≥3×3 aromatic rings increased from 28% in N_2 atmosphere to 35% and 39% under 1-methylnaphthalene and quinoline atmospheres, respectively, bigger than those in toluene (31%) and o-cresol (29%) atmospheres. Moreover, the proportion of large-sized aromatic cores in the 600 °C rapid-pyrolyzed char was significantly higher than that in the 800 °C rapid-pyrolyzed char under all atmospheres. 1-Methylnaphthalene, with its bicyclic structure serving as the growth unit for polycondensation, exhibits the most pronounced promotion effect due to its side-chain methyl group facilitating radical cross-linking. Quinoline reduces the activation energy of polycondensation through strong adsorption of its nitrogen-containing ring to the char surface, demonstrating the second-strongest effect. Toluene-1 and o-cresol, however, exhibit relatively weak regulatory effects on the degree of macromolecular polymerization in char due to limitations of their monocyclic structures and spatial steric hindrance from their side chains. They condense within pores to form microcrystalline structures with some stacking but insufficient extension. Metaplast and tar exhibit similar reaction characteristics with the char macromolecular framework: the larger aromatic ring structures undergo polycondensation at lattice edges, while smaller aromatic cores condense within the pores.

A comprehensively experimental and kinetic modeling investigation of C6 ketone isomers pyrolysis and oxidation: Insight into effects of isomerism

Xinyue Sun (China University of Mining and Technology, China) Hongyan Wang (China University of Mining and Technology, China) Jingpei Cao (China University of Mining and Technology, China) Xiaoyan Zhao (China University of Mining and Technology, China)

15:30-16:30 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Ketones have garnered considerable interest as promising biofuels or fuel additives due to their high-octane number and knock resistance. Beyond their utility as fuels, ketones are also significant intermediates formed during the combustion of oxygenated fuels (e.g., ethers, alcohols) and large n-alkanes. Therefore, a precise understanding of ketone combustion kinetics governs the optimization of combustion efficiency and the control of pollutant formation (such as aldehydes, CO, soot, etc.). A fundamental understanding of the relationship between molecular-structure and combustion kinetic necessitates advanced ketone-based biofuel design. 2-hexanone and 3-hexanone, with the combination of a carbonyl group and moderate alkyl chain lengths, are promising candidates for balancing energy content and anti-knock performance. However, studies on the combustion chemistry of 2- and 3-hexanone remain scarce. To elucidate the decisive role of oxygen-functional group position in combustion chemistry, an isomer-specific kinetic model was established. It integrates high-level CBS-QB3 quantum calculations with jet-stirred reactor experiments at 1.0 atm and 723-1048 K. As the first isomer-specific kinetic model for C6 ketones, it incorporates pressure-dependent rate constants derived from master equation analysis and rigorously calculated H-abstraction barriers. The pyrolysis products, including C0-C4 hydrocarbons and oxygenated intermediates closely linked to fuel consumption, were identified and quantified using GC-MS and online GC-FID/TCD analyses. Results demonstrate that 3-hexanone exhibits higher pyrolysis reactivity than 2-hexanone, attributable to its symmetric structure featuring two low-BDE α-C-H sites for favorable H-abstraction and distinct unimolecular scission pathways. Among them, 2-hexanone preferentially forms acetone and C3-C4 hydrocarbons, whereas 3-hexanone generates more ethylene and specific ketenes. The identified effect of functional group position provides a broader framework for oxygenated fuels (ketones, alcohols and ethers), supporting a generalized principle that higher molecular symmetry correlates with enhanced pyrolysis reactivity. The fundamental insights gained in this study enhance the understanding of branched ketone combustion chemistry and support their potential application as clean fuels or fuel additives.

Pyrolysis of C5 Cyclic Hydrocarbons and Derived High-Energy-Density Fuels: Kinetic Modeling and Aromatics Formation Mechanisms

Hongyan Wang (China University of Mining and Technology, Xuzhou, Jiangsu 221116, , China) Jingpei Cao (China University of Mining and Technology, Xuzhou, Jiangsu 221116, , China)

17:00-18:00 Session S1.4: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

To explore the decomposition behaviors of C5 cyclic hydrocarbons and extend this understanding to high-energy-density liquid fuels, the pyrolysis of basic C5 rings (cyclopentane, cyclopentene, and cyclopentadiene) and four derived C5-containing high-density fuels was investigated. Experiments were conducted using a flow tube reactor across a wide pressure range (1.0–30.0 atm), supported by high-level theoretical calculations. First, a universal kinetic model for the basic C5 fuels was proposed, revealing that unsaturation significantly impacts reactivity and pathway selection. Saturated rings favor ring-opening to generate small hydrocarbons, whereas increased unsaturation promotes the formation of monocyclic and bicyclic aromatic hydrocarbons (MAHs and BAHs) via cyclopentadienyl resonance-stabilized radicals (RSR). Building on this foundation, the study examined four typical high-density fuels: tetracycloheptane (QC), ethylnorbornane (EthNB), tetrahydrodicyclopentadiene (exo-TCD), and tetrahydrotricyclopentadiene (THTCPD). Adopting a "hierarchical structure" strategy with the C5 and aromatics mechanism as the core, comprehensive kinetic models were developed and validated. The results indicate that specific carbon-ring structures dictate the initial fuel consumption pathways; for instance, the norbornane structure predominantly undergoes open-ring isomerization. Regarding aromatics formation, MAHs are primarily generated through the multi-step dissociation of fuel radicals, whereas PAH formation is dominated by the bi-molecular addition reactions of CPDyl and CPD. This PAH growth mechanism is largely independent of specific fuel chemistry, with the exception of the highly strained QC, which exhibits distinct pathways involving acetylene and toluene due to its unique cage structure.

Pyrolysis of marine biomasses with different heating technologies: The case of study of Posidonia Oceanica fibrous spheres

Domenico Licursi (Department of Chemistry and Industrial Chemistry - University of Pisa, Italy) Riccardo Gallorini (Department of Civil and Industrial Engineering - University of Pisa, Italy) Sara Fulignati (Department of Chemistry and Industrial Chemistry - University of Pisa, Italy) Luca Rosi (Department of Chemistry "Ugo Schiff" - University of Florence, Italy) Anna Maria Raspolli Galletti (Department of Chemistry and Industrial Chemistry - University of Pisa, Italy) Claudia Antonetti (Department of Chemistry and Industrial Chemistry - University of Pisa, Italy)

17:00-18:00 Session S1.4: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Posidonia Oceanica is an abundant plant of the Mediterranean area, and its debris wastes naturally accumulate up to the coast. Their management should be carefully evaluated, expecially considering that unpleasant inconveniences during the bathing season may occur. In the perspective of identifying new exploitation opportunities, in this work, fibrous spheres of Posidonia Oceanica have been thermally treated by slow-pyrolysis, comparing the traditional heating with the microwave (MW)-assisted one. For this investigation, similar processing conditions (e.g. heating rate, set-point temperature and residence time) were proposed, thus characterizing the corresponding streams. The use a nitrogen flow in the conventional heating approach reduced the residence times of the evolved vapours in the hot zones of the reactor, favoring the formation of typical probe intermediates, such as levoglucosan, originating from the thermal degradation of the holocellulose. The degradation of biomass components was more advanced in the MW system, due to the absence of nitrogen flow. Some modifications of the MW apparatus were considered, in particular the addition of a dephlegmator unit, which further promoted cracking and aromatization reactions. Remarkably, when the Posidonia Oceanica-derived biochar was employed in blend with the fresh biomass, the efficiency of the MW heating greatly improved, exploiting the biochar as an efficient MW absorber, thus enabling the gasification regime and, consequently, the selective formation of CO and H2. Life Cycle Assessment (LCA) evaluations confirmed the similar environmental impact of both technologies on the laboratory scale, where MW-assisted pyrolysis still presents some drawbacks for the development on a larger scale, mainly related to the energy supply/management. MW technology still has significant potential of improvement on these aspects, and it is reasonable that it will be more competitive respect to the conventional heating technology, already in the next future.

Acknowledgements

The authors thank the project NEST "Network 4 Energy Sustainable Transition" (code PE0000021) funded by the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.3 – Call for tender No. 1561 of 11.10.2022 of MUR, funded by the European Union – NextGenerationEU.

Effect of Hydrothermal Carbonization Conditions on Carbon Partitioning and Catalytic Pyrolysis of Fish-Based Biomass

Tatwadhika R. Siddhartha (Ghent University, Belgium) Stef Ghysels (Gent University, Belgium) Philippe Heynderickx (Ghent University Global Campus, South Korea) Frederik Ronsse (Ghent University, Belgium)

17:00-18:00 Session S1.4: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Frederik Ronsse (Ghent University, Belgium) Marco Mattonai (University of Pisa, Italy)

ABSTRACT

Hydrothermal carbonization (HTC) of fish-based biomass was investigated to elucidate the effects of reaction temperature (180, 220, and 240 °C) and residence time (2 and 4 h) on product yield, elemental composition, and carbon partitioning, with emphasis on biocrude fractions and downstream thermal behavior. At 180 °C, HTC was dominated by hydrolysis and condensation reactions, resulting in hydrochar formation and extensive solubilization of organic carbon into the aqueous phase, without formation of a distinct biocrude phase. Increasing the temperature to 220 and 240 °C promoted partial liquefaction and the appearance of a separable biocrude fraction, while the overall hydrochar yield decreased with increasing temperature. Residence time showed only a minor influence on hydrochar yield, indicating that carbon redistribution approaches a quasi-equilibrium within the shorter residence time under the conditions studied. Elemental analysis revealed strong differentiation between product streams: hydrochars exhibited low carbon content (~19 wt%) with nitrogen retention, whereas the biocrude fractions were highly enriched in carbon (~71–74 wt%) and hydrogen, reflecting preferential partitioning of reduced, hydrophobic compounds at higher HTC severity. Thermal conversion of HTC-derived biocrude was examined using a tandem micro-reactor (TMR) coupled with GC–MS/FID. Pyrolysis at 300 °C predominantly released oxygenated and nitrogen-containing volatiles, while pyrolysis at 500 °C resulted in extensive cracking and secondary reactions, producing lighter hydrocarbons and aromatic species. The introduction of zeolite catalysts in the secondary reactor qualitatively shifted the vapor composition toward increased aromatic hydrocarbons and reduced oxygenated compounds, highlighting the role of catalytic vapor-phase upgrading. These results demonstrate that HTC temperature governs carbon partitioning and bio-oil formation, while residence time plays a secondary role, and that coupling HTC with catalytic pyrolysis provides a versatile pathway for valorizing fish-derived biomass into upgraded hydrocarbons, aromatic chemicals, and functional carbon materials.

Detailed Characterization of Leather Solid Wastes Using Analytical Py-GC/MS and TG-IR to Evaluate Resource Recovery Potential

Ravikrishnan Vinu (Indian Institute of Technology Madras, Chennai 600036, India) Velusamy Mozhiarasi (CSIR-Central Leather Research Institute (CSIR-CLRI), Chennai 600020, India) Pragadeshwar Babu (Indian Institute of Technology Madras, Chennai 600036, India) Santhosh Srinivasan (Indian Institute of Technology Madras, Chennai 600036, India) Dirk Weichgrebe (Institute of Sanitary Engineering and Waste Management (ISAH), Leibniz Universität Hannover, 30167 Hannover, Germany, Germany) Subhan Pal (Indian Institute of Technology Madras, Chennai 600036, India)

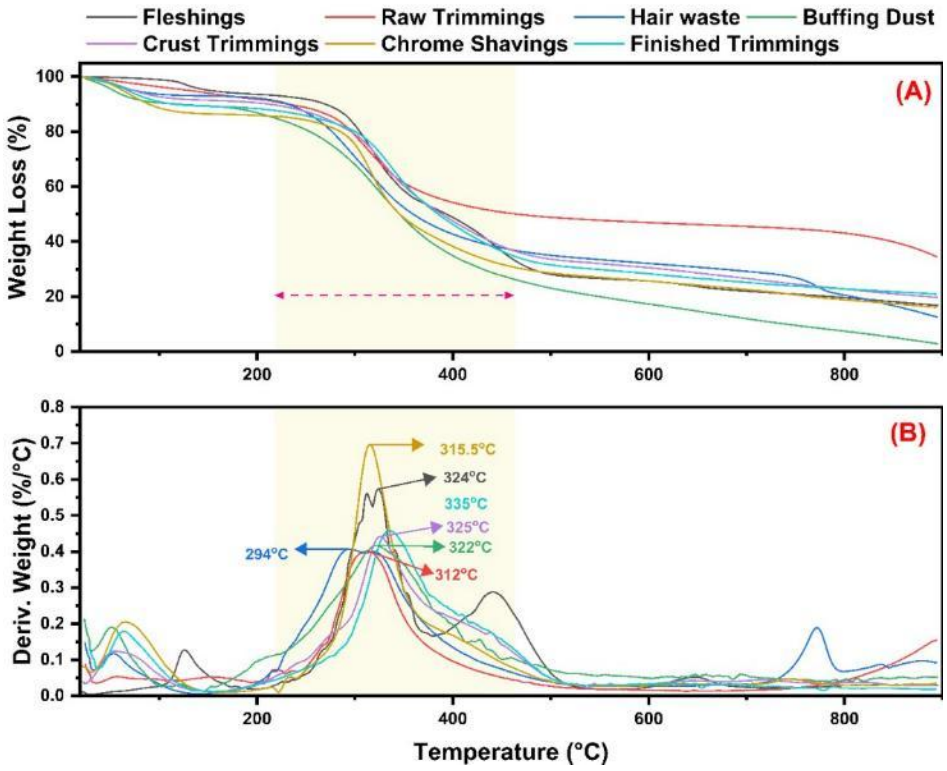
17:00-18:00 Session S1.5: Analytical Pyrolysis: Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Among various industrial sectors, leather is one of the significant contributors to export revenues and ranks among the top 10 foreign exchange earners for many developing countries, particularly India. Large quantum of leather solid wastes is produced during leather manufacturing, i.e. ~ 50-60 wt.% of process solid wastes are generated while processing 1 ton of raw hides/skins to finished leather, posing significant environmental challenge. In this study, various leather solid wastes (LSW) generated during different stages of leather processing were collected, and detailed characterization was performed to understand their elemental and biochemical composition, thermal decomposition behaviour, and the presence of various functional groups. Thermogravimetry hyphenated with infrared spectroscopy (TG-IR) analysis was performed at 10 oC/min upto 900 ˚C, and analytical pyrolysis coupled with gas chromatograph/mass spectrometry (Py-GC/MS) was performed in thermal desorption (TD) (100-300oC at 10 oC/min) and fast pyrolysis (600 oC) modes to evaluate the evolution key functional groups in the vapor phase at different temperatures, and the specific organics during devolatilization of the samples. Squalene was consistently detected in the thermal desorption profiles of all the leather samples below 300 ˚C, indicating its prevalent presence in the thermal decomposition products. In addition, nitrogen-containing compounds like pyrrole derivatives constituted 10-30% in both TD and pyrolysis. C10-C30 hydrocarbons were the major pyrolysates from the samples. More interesting results on product distribution at different temperatures and from different LSW will be discussed during the presentation. The study demonstrates that leather solid wastes could be a potential feedstock for recovering valuable hydrocarbons that can be utilized for fuel/chemicals production, upon subsequent upgradation, targeting commercial use.



Characterization of modified lignin for applications in sustainable biobased formulations

Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Vanesa López (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Tamara Nóvoa (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Marcelo Osorio (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Caroline Santos (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Mauro Gonzalez (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Vanesa Regueira (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Alba Mallo (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Maria del Mar Castro (Fundación Centro Tecnológico de Investigación Multisectorial, Spain) Rosalía Noguerol (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

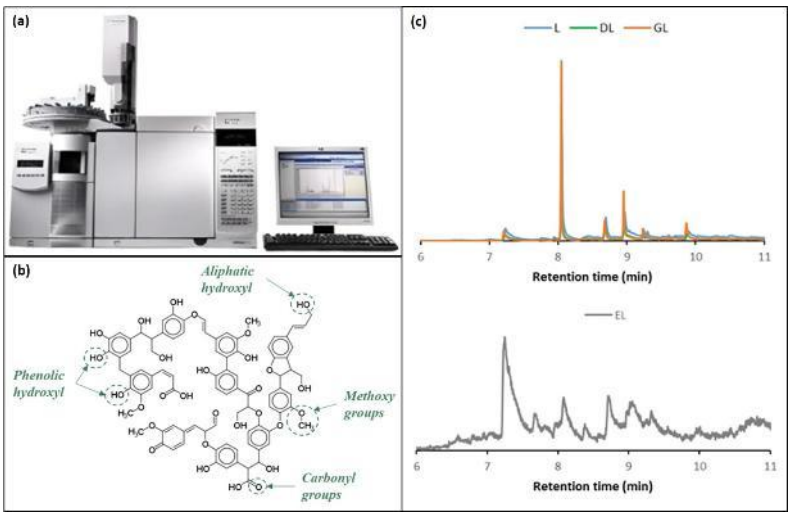
17:00-18:00 Session S1.5: Analytical Pyrolysis: Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Lignin is currently considered as one of the main sustainable alternatives to the petrochemical raw materials. It has been established as a very promising carbon-based raw material, given that it is an abundant, non-food biomass obtained from very diverse sources, including residual. However, its industrial use remains limited due to the complexity of its molecular structure preventing the final materials from achieving desirable properties and functionalities. Therefore, the chemical modification of lignin is being used as a key strategy to increase its reactivity and overcome these challenges. The present work aims to carry out the characterization of lignin modified through different chemical reactions introducing specific functional groups. The objective is to paving the way for accurate and efficient characterization that can be extrapolated to further lignin derivatives and types, such as nanolignins. The chemical modification of lignin depends primarily on the accessibility and activation of its core functional groups. But, the inherent complexity of lignin's macromolecular structure significantly controls the success of these reactions. Steric hindrance often impedes reagents from reaching internal reactive sites, leading to incomplete transformations. Also, the high stability of certain inter-unit linkages can induce resistance in modification attempts. For that reason, the characterization techniques are fundamental for evaluating whether a given reaction has worked instead of following standardized protocols to guarantee success. While various analytical methods are used to confirm the addition of functional groups and improvements in physical properties, Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) remains a relatively underexplored but valuable tool for tracking these structural changes. In the present it is presented the results of four different types of lignin samples (unmodified, demethylated, glyoxylated and epoxidated lignin) analyzed by PY-GC-MS.



The results indicated that guaiacyl-type units and other oxygenated aromatic compounds dominated the pyrolysis products, consistent with the characteristic pyrolysis fingerprint of softwood lignin. The epoxidized lignin showed the lowest number of pyrolysis derivative products. Nevertheless, the most distinct variations between samples were observed in the relative proportions of side-chain and demethylated-linked pyrolysis products. For instance, the glyoxylated and epoxidized lignins presented the highest total side-chain contents. Specifically, epoxidized lignin was associated with higher proportion of guaiacol, whereas glyoxylated lignin was primarily associated with a higher yield of 4-methylguaiacol. This distinction is attributed to the high selectivity of epoxidation for side-chain hydroxyl groups. In contrast, while glyoxylation primarily targets aromatic rings, it is also prone to secondary reactions along the aliphatic side chains. In contrast, demethylated lignin was characterized by a significantly lower proportion of side-chain products. Instead, it yielded a higher proportion of catechol that was not detected for epoxidized and glyoxylated lignin samples. In fact, this may suggest the fundamental structural differences introduced by the demethylation process. Finally, the findings of the present study demonstrate the potential of analytical pyrolysis as significant for assessing the chemical modifications in lignin. Further investigation will be undertaken to develop innovative methodological approaches aiming to supplement existing tools, to provide deeper understanding of lignin modification processes and to facilitate its introduction as sustainable material into bio-based applications.

High-Performance Software for Deconvolution and Annotation of Py-GC/MS Data for Lignocellulosic Biopolymer Characterization

Oleksandr Ilchenko (Swedish University of Agricultural Sciences, Sweden) Junko Takahashi-Schmidt (Swedish University of Agricultural Sciences, Sweden) Totte Niittylä (Swedish University of Agricultural Sciences, Sweden) Hans Stenlund (Umeå University, Sweden)

17:00-18:00 Session S1.5: Analytical Pyrolysis: Natural materials

Location: ROOM A1 – FIRST FLOOR

Chairs: Jeannette Jacqueline Lucejko (Università di Pisa, Italy) Valentina Pintus (Louvre Abu Dhabi, UAE)

ABSTRACT

Pyrolysis coupled with Gas Chromatography-Mass Spectrometry (Py-GC/MS) is an important technique for the rapid chemical profiling of complex organic macromolecules, particularly within lignocellulosic biopolymers. Despite its utility, the widespread adoption of Py-GC/MS is hindered by a significant data-processing bottleneck; current workflows are typically labor-intensive, demand specialized expertise, and struggle with the effective deconvolution of complex, overlapping pyrograms. This project introduces a high-throughput, user-friendly, and open-source software solution designed to automate and accelerate Py-GC/MS data processing. By integrating efficient peak deconvolution, robust compound annotation, and user-defined classification for carbohydrates and lignin (including S/G/H unit ratios), the software makes sophisticated chemical screening accessible to a broader range of researchers. The software architecture is optimized for high-performance screening, utilizing multithreading and streamlined code to process large-scale datasets efficiently. The workflow begins with critical preprocessing steps, including noise reduction, baseline correction, and sample alignment. Data analysis is driven by automatic peak detection and chromatogram windowing, followed by peak deconvolution with Multivariate Curve Resolution-Alternating Least Squares (MCR-ALS). The software offers a choice of distinct initial estimation strategies: Principal Component Analysis (PCA), Singular Value Decomposition (SVD), or Vertex Component Analysis (VCA). Peak quality is further validated through a signal-to-noise ratio (SNR) filtration algorithm and automated unimodal peak area integration. Compound annotation is achieved using a refined, class-categorized specific library. To resolve the common challenge of composite spectra, the software applies directional weight filtering and comprehensive mass spectrum comparisons to enhance identification accuracy. This tool transforms a time-consuming process into a rapid, automated screening tool. Equipped with an intuitive Graphical User Interface (GUI), the software enables the characterization of large sample sets in a much shorter time than traditional methods, providing valuable insights into biopolymer composition.

Resolving Formic Acid Pyrolysis: Integrating Automated Generation with High-Fidelity Theory

Alon Grinberg Dana (Technion - Israel Institute of Technology, Israel)

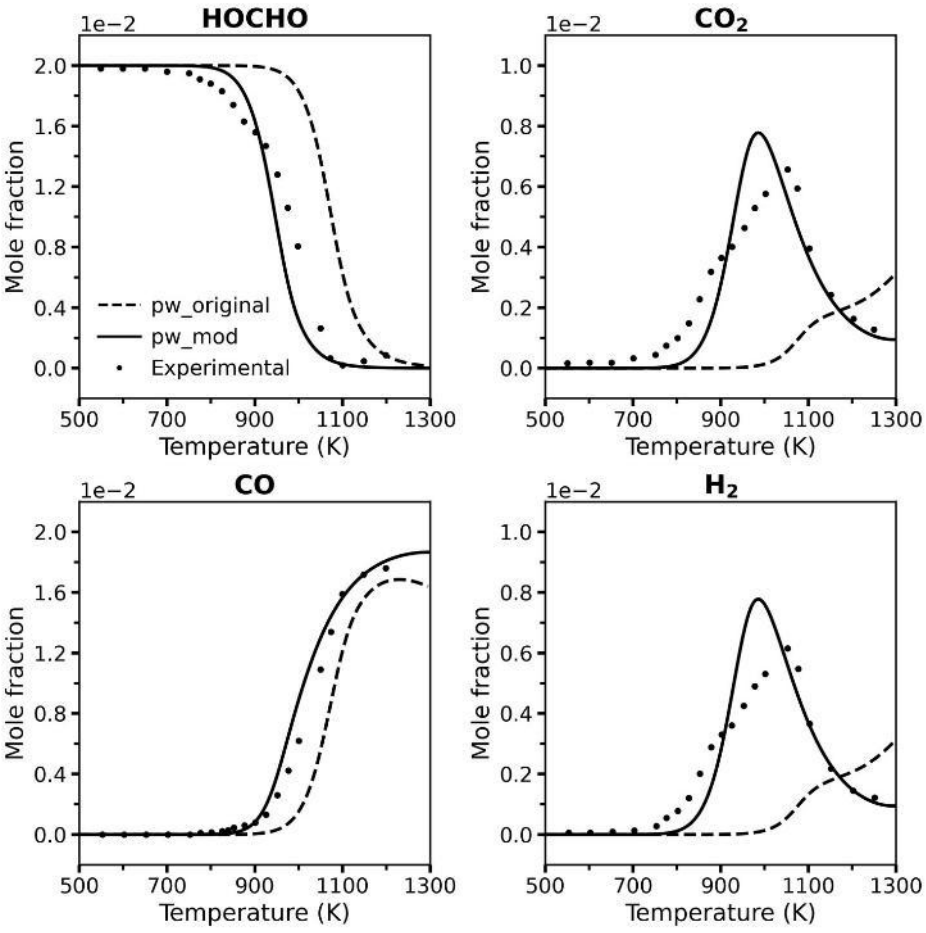
17:00-18:00 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Formic acid (HOCHO) is a fundamental oxygenated fuel and a promising liquid organic hydrogen carrier, yet accurate predictive modeling of its gas-phase kinetics remains a significant challenge. Despite its structural simplicity, the pressure-dependent competition between its dehydration (HOCHO → CO+H2O) and decarboxylation (HOCHO → CO2+H2) channels are frequently misrepresented in kinetic models. This lecture identifies specific gaps in current modeling approaches and presents a robust resolution through a two-stage investigation. We first evaluate the baseline capabilities of automated kinetic generation. We demonstrate that a "Vanilla" model generated by the Reaction Mechanism Generator (RMG) successfully captures oxidation speciation and laminar flame speeds without manual tuning, in contrast to recent claims in literature. We isolate a critical breakdown under pyrolysis conditions, traced to an inaccurate pressure-dependent branching ratio on the CH2O2 potential energy surface. To resolve this bottleneck, we recomputed the relevant potential energy surfaces using CCSD(T)-F12 theory. Finding that rigorous theory alone still underestimates low-temperature decomposition rates compared to historical data, we developed a hybrid model that integrates the theoretical network with independent targeted experimental rate coefficient constraints. The resulting mechanism successfully reproduces challenging non-monotonic speciation profiles observed in pyrolysis while retaining high accuracy in oxidation, establishing a physically consistent framework for formic acid kinetics. Figure caption: A comparison of the present work model (solid lines) and the non-refined model (dadhed lines) with JSR experimental data (symbols) for key species under pyrolysis conditions at 1 atm, with a 2 s residence time.



A Robust NLSM-Based Kinetic Approach for Pyrolysis Valorization: Application to Polymers, Biopolymers, and Biomass

Nada Kouraa (Mohammadia School of Engineers, Mohammed V University in Rabat, Rabat, Morocco, Morocco) Souad Abderafi (Mohammadia School of Engineers, Mohammed V University in Rabat, Rabat, Morocco, Morocco) Lokmane Abdelouahed (Normandie Univ, INSA Rouen, UNIROUEN, Rouen, France, France)

17:00-18:00 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Pyrolysis, as a thermochemical process, decomposes solid waste in the absence of oxygen, thus helping to limit its environmental impact. This process converts the material into valuable products, such as syngas, bio-oil, and biochar. However, the wide chemical and structural diversity of these residues results in varied thermal and kinetic behaviors, necessitating a unified methodological approach for their study and valorization. This study presents a comparative analysis of the pyrolysis of three major waste categories: biomass (argan residues and beech wood), biopolymers (cellulose, hemicellulose and lignine), and synthetic polymers (polystyrene, low-density polyethylene, high-density polyethylene, and polypropylene). Thermogravimetric analysis (TGA/DTG) is used to characterize thermal decomposition under different heating rates. The experimental data are then processed using the kinetic method based on nonlinear least squares minimization (NLSM), allowing for the estimation of the activation energy and the pre-exponential factor for each type of material. The NLSM method relies on the numerical integration of the kinetic equations describing thermal decomposition, followed by an iterative optimization process to automatically adjust the kinetic parameters, including the activation energy and the pre-exponential factor. The goal of this optimization is to minimize the discrepancy between experimental TGA/DTG curves and those calculated by the model, thus ensuring a faithful representation of the actual thermal behavior of the materials. This approach eliminates the need for subjective manual adjustment and provides robust identification of kinetic parameters from experimental data. The use of a unique kinetic method, based on optimization, ensures a consistent and reliable comparison of the thermal and kinetic behavior of the different materials studied. The results highlight significant differences between biomass, biopolymers, and synthetic polymers, emphasizing the influence of macromolecular structure, compositional heterogeneity, and physicochemical interactions on thermal degradation mechanisms. This approach allows for the comparison of the thermal and kinetic behavior of different solid materials, providing a robust methodological framework for studying their energy or chemical valorization.

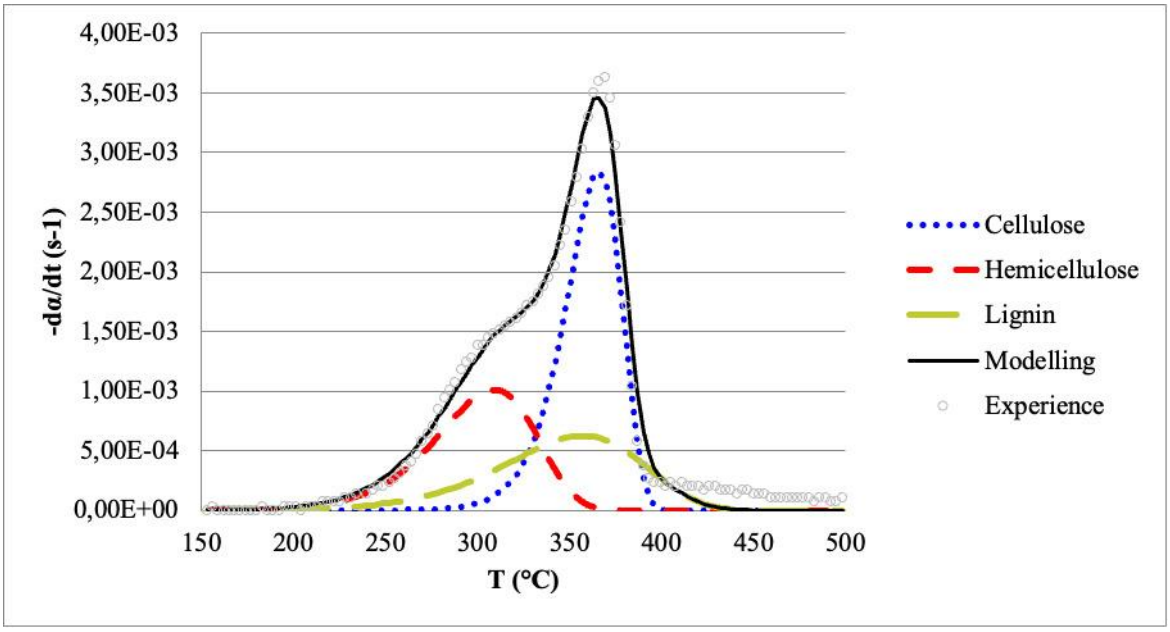


Fig. 1. DTG curves fitted with NLSM method for beechwood for 15 °C.min-1

Cellulose carbonization pathways studied using reactive force field methods

Olli Pakarinen (VTT Technical Research Centre of Finland Ltd., Finland) Antti Paajanen (VTT Technical Research Centre of Finland Ltd., Finland) Elli Virtanen (VTT Technical Research Centre of Finland Ltd., Finland) Lukas Fliri (Aalto University, Finland) Chamseddine Guizani (VTT Technical Research Centre of Finland Ltd., Finland) Michael Hummel (Aalto University, Finland) Jukka Vaari (VTT Technical Research Centre of Finland Ltd., Finland)

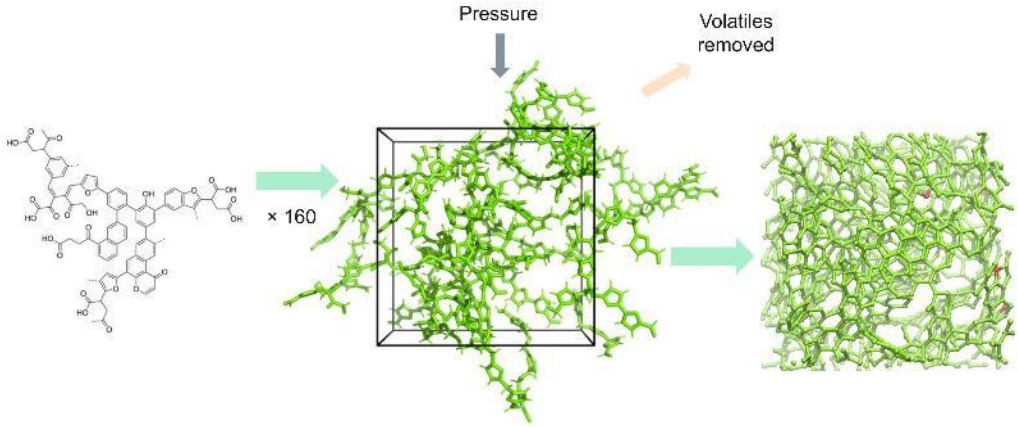
17:00-18:00 Session S1.6: Fundamental pyrolysis reactions, kinetics/modelling

Location: ROOM C1 – FIRST FLOOR

Chairs: Matteo Pelucchi (CRECK Modeling Lab, Politecnico di Milano, Milano, Italy, Italy) Valérie Vitzthum (Lorraine University, France)

ABSTRACT

Carbon materials are important for our everyday life, as they are essential for a range of products from electrical devices to fiber-reinforced plastics. Currently used carbon materials are almost solely produced from non-renewable precursors, and there is a growing need for sustainable alternatives. One such alternative is cellulose, which is both renewable and abundantly available. Unfortunately, cellulose-based carbon materials remain notably inferior to fossil-based ones, largely because carbon structure formation in cellulose pyrolysis is not adequately understood. In our ongoing work, we study the chemical and structural pathways of cellulose carbonization using atomistic simulations based on the ReaxFF reactive force field [1]. We both evaluate the capability of the method to reproduce known reactions and products of cellulose pyrolysis and predict chemical changes that occur at different stages of its carbonization. Our modelling work is linked to an experimental campaign to understand the transformation of cellulose into an intermediate thermostable condensed phase (TSCP) and ultimately carbon [2, 3]. Our first modelling studies focused on the mechanism and kinetics of cellulose chain scission at high temperatures and heating rates, which are accessible using (unbiased) molecular dynamics (MD) simulations [4, 5]. We found that direct MD simulations could not reproduce the formation of the TSCP, which is the initial carbonization intermediate and has polyfuranic nature [3]. We could, however, access the early reactions that precede TSCP formation, particularly the crosslinking of cellulose chains with levoglucosan (LGA) end groups [2]. Our findings support the view that LGA end groups participate in the char forming pathway. Starting from a glucose-derived humin as a model for the TSCP, based on NMR evidence [3, 6], we have now carried out simulations of the further stages of carbonization at higher temperatures, including the deoxygenation, dehydrogenation and gradual graphitization of the polyfuranic intermediate (Fig. 1).



We study the process at an elevated pressure, a crucial modelling feature to observe carbon production and to prevent excessive fragmentation and vaporization. Another key feature is the periodic removal of volatiles, enabling us to predict the evolution of elemental ratios and the residual carbon mass. Comparison with experimental thermogravimetric and elemental analysis shows that the simulations capture adequately the removal of oxygen and the carbon yield, but likely underestimate the removal rate of hydrogen. We describe the underlying chemical transformations with focus on competing fragmentation and polymerization events, and the formation of carbon rings and their fused polycyclic forms. We backtrack the formation of six-membered carbon rings, showing which initial structures are most likely to contribute to the carbon residue. Figure 1. From the humin-like structure of the TSCP (left) [6] to molecular dynamics simulations with elevated pressure and volatile removal (middle, right) that predict chemical transformations underlying cellulose carbonisation

[1] van Duin, J. Phys. Chem. A 105 (2001) 9396–9409

[2] Fliri, J. Anal. Appl. Pyrol. 175 (2023) 106153

[3] Fliri, J. Anal. Appl. Pyrol. 181 (2024) 106591

[4] Paajanen, Cellulose, 24(7) (2017) 2713–2725

[5] Paajanen, Cellulose 28(14) (2021) 8987–9005 [6] van Zandvoort, Green. Chem. 17 (2015) 4383–4392

Abstracts:
Orals Day 2
Tuesday, 9th June 2026

Heating rate and solid residence time effects on carbon transformation pathways in slow and fast pyrolysis of woody and herbaceous residues

Corinna Maria Grottola (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy) Davide Amato (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Roberto Solimene (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Piero Salatino (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy) Paola Giudicianni (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy)

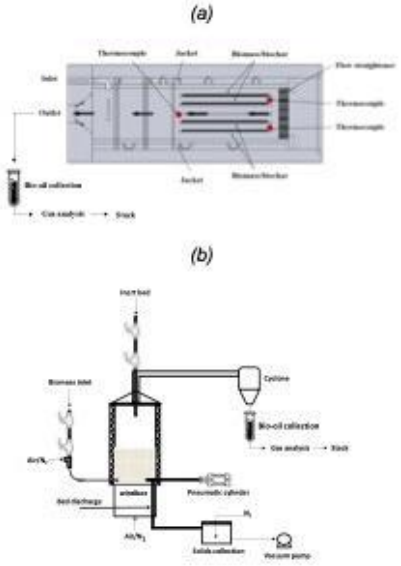
09:30-10:10 Session S2.1: Applied pyrolysis: biomass valorisation; Fundamental pyrolysis reaction, kinetics/modeling

Location: ROOM A – GROUND FLOOR

Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

Pyrolysis is a strategic enabling technology in biorefinery concepts, offering a flexible multi-product platform for the simultaneous production of biochar, bio-oil and gaseous fuels. However, the mechanisms governing biochar stabilization during pyrolysis are still predominantly interpreted in terms of final temperature, while the role of heating rate (HR) and solid residence time (t) at the final temperature remains insufficiently elucidated. These parameters directly influence the devolatilization dynamics, secondary reactions, degree of aromatization and establishment of “turbostratic” order, and the interaction between organic carbon and mineral matter, particularly in feedstocks with markedly different ash contents such as forestry and herbaceous residues [1]. This study aims at investigating the effect of HR and t at different final temperatures in both slow and fast pyrolysis regimes (~0.1–1 °C/s and ~100–1000 °C/s, respectively) on the chemical and physical properties of the biochar, with a focus on those related to its persistence. Poplar and giant reed, differing in the content of both organic components and ash, were selected as representatives of different classes of residual biomasses, namely woody and herbaceous biomasses. The biomass samples underwent pyrolysis tests experiencing different thermal histories (HR and t) representative of the operating conditions typical of slow and fast pyrolysis in the temperature range 500-700 °C. The experimental campaign was carried out in a thermogravimetric analyzer and in bench-scale batch reactors (Figure 1).



The chemical and structural properties of the produced biochars (H/C ratio, chemical functionalities, structural order) [2] were analysed and discussed in relation to their implications for biochar persistence. In parallel, the liquid and gaseous products were characterised through chromatographic techniques [3] to provide deeper insight into the transformation pathways of organic carbon within the solid matrix. By addressing the combined effects of solid residence time and heating rate on biochar physicochemical properties linked to persistence, this study contributes to a more mechanistic understanding of pyrolysis within integrated biorefineries and supports the rational design of processes that optimize both energy co-products and long-term carbon sequestration performance. Figure 1 – Reactors for (a) slow and (b) fast pyrolysis tests

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[1] Giudicianni et al., 2020. Inherent metal elements in biomass pyrolysis: a review. Energy fuels, 35(7), 5407-5478.

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[3] Gargiulo et al., 2022. Insights about the effect of composition, branching and molecular weight on the slow pyrolysis of xylose-based polysaccharides. J Anal. Appl. Pyrolysis, 161, 105369.

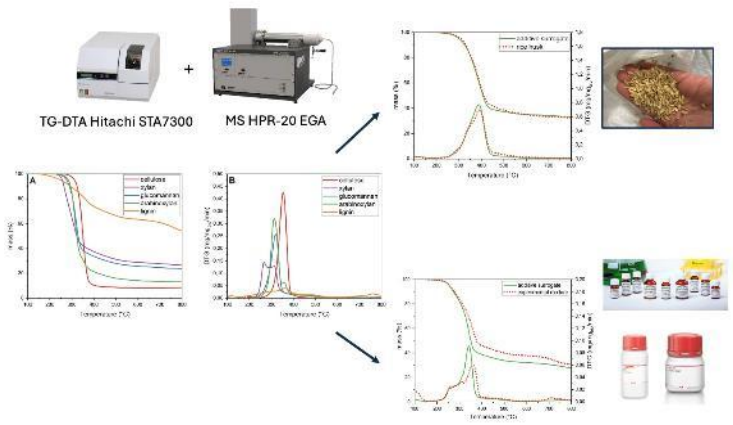
Can the pyrolysis kinetics of cellulose, hemicellulose and lignin serve as building blocks to describe the behavior of physical mixtures and real biomass?

Eleonora Benedetto (LaDipartimento di Energia, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, Italy) Veronica Piazza (Dipartimento di Energia, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, Italy) Alessandro Guarnieri (Dipartimento di Energia, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, Italy) Luca Carlomaria Pariani (Dipartimento DCMIC, Politecnico di Milano, p.zza Leonardo da Vinci 32, 20133 Milano, Italy, Italy) Paola D'Arrigo (Dipartimento DCMIC, Politecnico di Milano, p.zza Leonardo da Vinci 32, 20133 Milano, Italy, Italy) Alessio Frassoldati (Dipartimento DCMIC, Politecnico di Milano, p.zza Leonardo da Vinci 32, 20133 Milano, Italy, Italy) Tiziano Faravelli (Dipartimento DCMIC , Politecnico di Milano, p.zza Leonardo da Vinci 32, 20133 Milano, Italy, Italy) Luca Lietti (Dipartimento di Energia, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, Italy) Alessandra Beretta (Dipartimento di Energia, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy, Italy)

09:30-10:10 Session S2.1: Applied pyrolysis: biomass valorisation; Fundamental pyrolysis reaction, kinetics/modeling
Location: ROOM A – GROUND FLOOR
Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

The pyrolysis of lignocellulosic biomass plays a key role in the development of sustainable thermochemical routes for the production of renewable fuels, chemicals, and carbonaceous materials. However, the intrinsic complexity of this feedstock poses significant challenges to the development of kinetic models capable of predicting devolatilization behavior and product speciation for real biomasses. Lignocellulosic biomass is composed of cellulose, hemicellulose, and lignin, found in highly variable proportions. While the pyrolysis of these individual components has been widely investigated, it is still debated whether in mixtures these constituents behave independently, or synergistic effects are present. This unresolved issue impacts the ultimate goal of describing the pyrolysis behavior of real biomass pyrolysis, questioning whether it can be described as the simple superposition of the kinetics of its main components, considered as independent sub-reactive systems. This study starts with the experimental investigation of rice husk pyrolysis by thermogravimetric analysis coupled with mass spectrometry (TG–MS), providing detailed information on devolatilization behavior and product speciation. The rice husk sample was then characterized through chemical fractionation allowing the quantification of its constituents.



The pyrolysis behaviours of the single constituents were then combined as the weighted sum of their contributions according to the fractionation results and directly compared with the experimental evidence obtained for rice husk. The comparison shows that the additive approach satisfactorily reproduces both the overall devolatilization profile and the main trends in product speciation, with only minor discrepancies. However, the limits of validity of this hypothesis are still unclear. For this reason, physical mixtures of single biomass components were used as a tool to investigate the boundaries of additive behavior and to identify possible systems in which interactions become relevant. Binary and ternary mixtures of cellulose, hemicellulose, and lignin were studied by TG–MS and the experimental behavior of the mixtures was systematically compared with the predicted one, obtained as the weighted sum of the individual component contributions. The results indicate that the additivity assumption holds for most of the investigated systems, especially for mixtures involving only cellulose and hemicelluloses, which show devolatilization profiles and product yields very close to the additive predictions. Deviations become more evident in mixtures containing lignin and are particularly pronounced for the cellulose–lignin system, which exhibits increased char formation, a shift of the main devolatilization peak toward higher temperatures, and a reduced volatile release. The ternary mixture shows trends consistent with those observed in the binary systems, confirming that the main source of non-additive behavior lies in the cellulose–lignin interaction region. Overall, this work provides a quantitative assessment of whether the kinetics of cellulose, hemicellulose and lignin can be used as independent building blocks to describe the pyrolysis behavior of real biomasses and single components mixtures. Experiments showed discrepancies between the two scenarios, suggesting the onset of different physicochemical phenomena. Further measurements with advanced mixtures (e.g. pelletization, ball milling) are ongoing. These results can help in defining the domain of applicability of the additive hypothesis in kinetic models and support their reliable use for predictive simulations of complex lignocellulosic feedstocks.

Expanding the pyrolysis toolkit: Automated comparative analysis of complex materials using Py–GC×GC–TOF MS and advanced chemometrics

Anthony Buchanan (SepSolve Analytical, UK) Laura McGregor (SepSolve Analytical, UK) James Ogden (SepSolve Analytical, UK)

09:30-10:30 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Pyrolysis coupled with gas chromatography–mass spectrometry (Py–GC–MS) is widely used for the characterisation of solid and insoluble materials that are difficult to introduce directly into GC–MS systems, including polymers, paper, and other complex matrices. However, pyrograms generated from these materials are often highly complex, with extensive coelution observed when using one-dimensional gas chromatography (1DGC). In addition, detailed manual comparison of individual peaks becomes impractical, particularly when screening recycled materials of diverse composition. In this study, pyrolysis coupled with comprehensive two-dimensional gas chromatography and time-of-flight mass spectrometry (Py–GC×GC–TOF MS) is applied to improve the separation of complex materials. The additional chromatographic dimension enhances resolution of coeluting compounds and provides clearer grouping of compound classes, enabling more straightforward sample characterisation. To efficiently handle the high data density, we employ tile-based chemometric methods, which divide the 2D chromatograms into manageable segments (“tiles”) for automated, statistically robust comparison. This method highlights meaningful compositional differences between samples, reduces the need for labor-intensive manual inspection, and allows systematic analysis of subtle variations across multiple materials. By combining Py–GC×GC–TOF MS with chemometric analysis, this methodology offers a systematic approach for characterising, comparing, and assessing the quality of complex solid materials, including tyres, plastics, and paper. It is particularly valuable for evaluating recycled or waste-derived materials, supporting sustainable material management.

Assessment of Conventional and Biodegradable Microplastics in Agricultural Soils applying Py-GC/MS

Encarnación López Rodríguez (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Jesús Marín Sáez (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Roberto Romero González (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Antonia Garrido Frenich (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain)

09:30-10:30 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Microplastics (MPs), defined as plastic particles ranging from1 µm to 5 mm, are found scattered across various environments, impacting resident biota. Their hazard lies not only in their physical dimensions but also in their chemical additives used during manufacturing. Agriculture significantly contributes to the proliferation of these pollutants through the intensive use of mulching films, irrigation systems, and greenhouse coverings. To mitigate MP accumulation, the European Union, through Commission Delegated Regulation (EU) 2024/2787 [1], promotes replacing conventional mulching plastics with biodegradable materials. However, bioplastics often fail to degrade completely under natural conditions, leading to the emergence of biodegradable microplastics (BMPs). This study investigates the presence of MPs in agricultural soils from Almería (Spain), which hosts the highest concentration of greenhouses in Europe. A wide range of both conventional polymers and biopolymers was determined, including polytetrafluoroethylene (PTFE), polymethyl methacrylate (PMMA), polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), nylon-6 (N6), polycarbonate (PC), polyethylene terephthalate (PET), polyurethane (PU), polystyrene (PS), as well as polylactic acid (PLA), polybutylene adipate terephthalate (PBAT), polycaprolactone (PCL) and poly-3-hydroxybutyrate (P3HB). A pre-digestion step using Fenton reagents (H_2O_2 and $FeSO_4 \cdot 7H_2O$) was employed to reduce organic matter, followed by density separation with $ZnCl_2$. A double density separation was performed to ensure accurate MP recovery. After separation, samples were filtered through cellulose nitrate filter (1 µm). Finally, filters were homogenized using a cryomill and submitted for analysis. After that, a novel analytical method was applied using thermoanalytical techniques as an alternative to traditional spectroscopic methods like FTIR or Raman. The approach employs pyrolysis and gas chromatography coupled with mass spectrometry (Py-GC/MS) in Selected Ion Monitoring (SIM) mode to identify and quantify the MPs evaluated. The optimized method was fully validated evaluating selectivity, linearity, recovery and precision. Validation performance was adequate for most compounds with values ranging from 0.05 to 0.25 mg. Finally, the method was applied to the analysis of 20 agricultural soils from different origins: greenhouse and extensive fields. Samples showed a clear trend, finding a high prevalence of PP and PE, suggesting a connection between agricultural practices and the MPs found. In addition, some biopolymers were also found, such as PLA, highlighting the importance of monitoring such compounds. This publication is part of project PID2022-137122OB-I00, funded by MICIU/AEI/10.13039/501100011033/ and ERDF, EU. Encarnación López Rodríguez acknowledge grant FPU21/00858, funded by MICIU/AEI/10.13039/501100011033 and ESF+. Jesús Marín Sáez acknowledges the Andalusian government, the Counselling of University, Investigation and Innovation (CUII) and European Social Fund plus (Andalusia ESF+ 2021–2027) for financial support (POST_2024_00151). [1] European Commission. Delegated Regulation (EU) 2024/2787 of 23 July 2024 amending Regulation (EU) 2019/1009 of the European Parliament and of the Council regarding the inclusion of mulch plastics in category 9 of constituent materials. 2024. https://doi.org/10.2873/23399

Evolved Gas Analysis (EGA-MS) for polyethylene quantification in compostable bioplastics shopping bags

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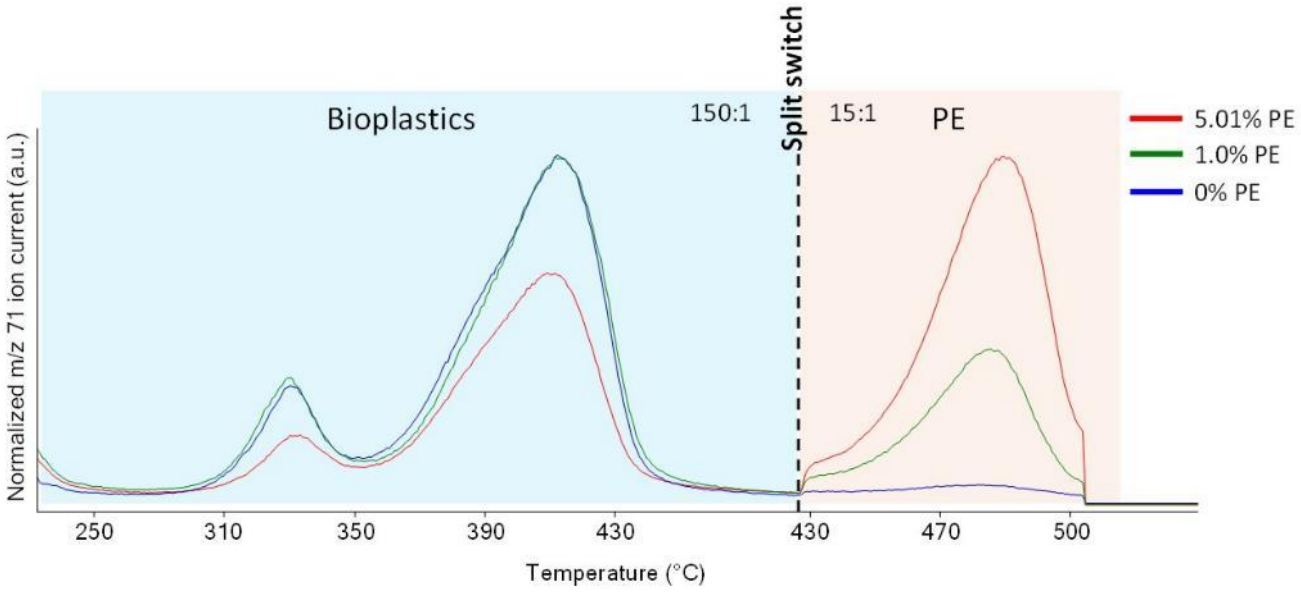
09:30-10:30 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

A new analytical procedure for the quantification of small amount of polyethylene (PE) in compostable bioplastics blends using evolved gas analysis coupled with mass spectrometry (EGA-MS) is here reported. In recent years, the production of compostable bioplastics has become a key aspect for the ecological transition. Bioplastics are increasingly replacing conventional plastic items, in particular disposable plastic products such as shopping bags or packaging1. Bioplastics are produced as blends of many components and small amount of non-biodegradable polymers, mainly PE, are added to improve properties and reduce production costs. European standards, as EN 13432:2002, establish that the maximum allowed amount of PE in compostable bioplastic blends is 1% in weight of the final product2. Quantification of PE in bioplastic formulation is fundamental to ensure conformity with regulations, but no standardized analytical protocol is available. Recent literature showed that analytical pyrolysis coupled with gas chromatography and mass spectrometry (Py-GC/MS)3 is a suitable technique to quantify small amounts of PE in complex blends. However, the technique is time-intensive and can rarely match the time pressure of bioplastic production plants or industrial composting facilities. In this study, we propose a faster method based on EGA-MS. It allows the quantification of small amounts of PE to be done thanks to an innovative strategy based on a mid-run split switch, which increases the signal of PE despite its low content (Figure 1). The method was developed using bioplastic blends with known amounts of PE, specifically produced for this study. Once developed, the method was tested on commercially compostable shopping bags, and the results were compared with those obtained by Py-GC/MS. We also improved this methodology by switching the mass spectrometer off when bioplastics exit the system and then turning it on only for PE analysis: this allows us to preserve the instrument and to make the analysis faster. Both the methods are robust, efficient, and suitable to perform rapid quantification of PE even for large sample numbers. Figure 1: Ion thermogram at m/z 71 for sample 0% PE, 1.0% PE, 5.01% PE



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PyroFriction - New low-temperature biomass pyrolysis technology

Marek Klaptocz (Ekotrend Sp. z o.o., Poland)

09:30-10:30 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Ekotrend has developed a new low-temperature biomass pyrolysis technology using PyroFriction technology, i.e. liquid-phase pyrolysis employing a cavitation pump. The process is carried out at a temperature of approximately 300–350 °C; however, the actual process temperature, which cannot be directly measured, is most likely several tens of degrees higher due to intense friction forces and the collapse of cavitation bubbles. The technology is capable of processing any type of biomass with a moisture content below 20% and a particle size below 5 mm. To date, production-scale tests have been conducted using straw, wood sawdust, pistachio shells, pomegranate peels, and sunflower husks. There is also potential for processing plastic waste; however, this is not currently the subject of research. The process is supported by commercial catalysts such as zeolite 4A, as well as naturally occurring mineral substances present in the feedstock. The main products of the process are high-quality bio-oil and biochar, and the relatively low process temperature results in a negligible amount of gaseous products. After 12 years of experience, the company is preparing to convert a demonstration plant with a capacity of 1 tonne of biomass per hour into a fully commercial installation with higher throughput.

Exploring the role of Acid-modified and Metal (Ni, Co, Ni/Co) impregnated Chilean Natural Zeolite during Catalytic Co-Hydropyrolysis of Biomass/Plastics

Bastián Puentes-Navarro (Universidad del Bío-Bío, Chile) Serguei Alejandro-Martín (Universidad del Bío-Bío, Chile) Laura Azocar-Ulloa (Universidad Católica de la Santísima Concepción, Chile)

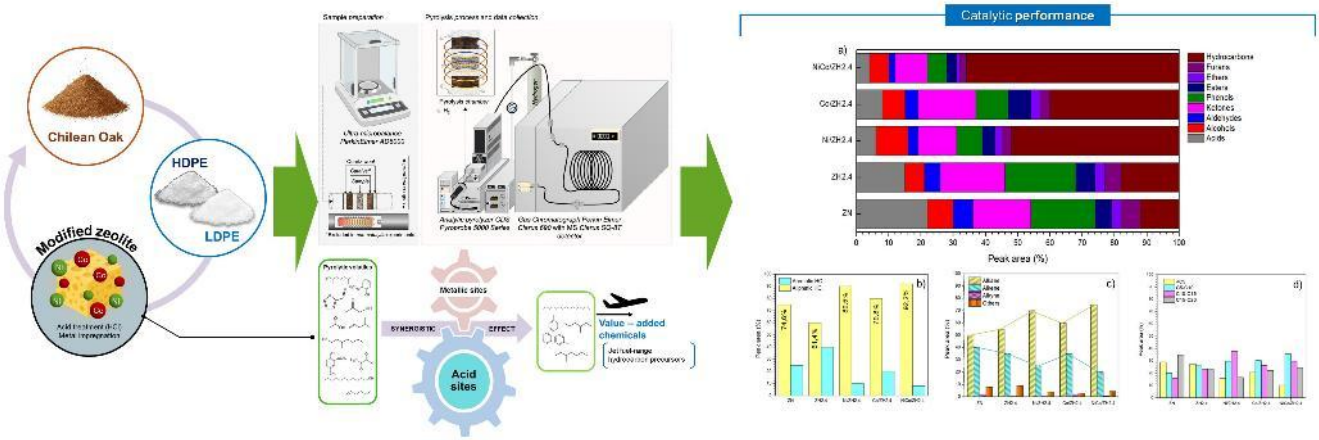
09:30-10:30 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Nowadays, catalytic co-hydropyrolysis of biomass and plastic is considered an enjoyable process for obtaining value-added precursors for obtaining sustainable aviation fuel production. Thus, some potential catalysts derived from a Chilean natural zeolite after an acid treatment (HCl, 2.4 M) and metal impregnation with Ni, Co, and Ni/Co were evaluated for upgrading evolved volatile pyrolysis streams. Then, the aim was to explore how acid modification and metal incorporation influenced the structural, acidic, and textural properties of the obtained catalysts and their influence on the chemical distribution of evolved gases during co-hydropyrolysis of Chilean Oak and HDPE/LDPE, using an analytical pyrolysis system coupled to gas chromatography–mass spectrometry (Py-GC/MS). The Py-GC/MS system provides rapid screening of gaseous chemical composition, enabling assessment of catalytic effects through detailed identification of chemical species, including hydrocarbons, oxygenates, aromatics, and fuel-range fractions. Such a setup (Py-GC/MS) enabled reliable comparisons of catalyst contributions, accounting for negligible mass-transfer limitations and secondary reactions, and allowing data recollection for mechanistic interpretation of catalytic performance. The acid treatment of the Chilean natural zeolite (ZN) led to a notable increase in surface area (from 213 to 439 m^2/g) and enhanced mesoporosity, resulting in a higher Si/Al ratio (+33%), as confirmed by N_2 physisorption and XRF. Moreover, the modification also removed aluminium (extra-framework and framework) and decreased the concentrations of inorganic impurities (Na, Ca, Fe, Mg, K), thereby improving acid site accessibility. SEM-EDX analysis revealed increased surface roughness, enlarged pores, and homogeneous distribution of the impregnated metals on the modified zeolite (ZH2.4). XRD analysis confirmed that the crystalline structure was not affected by acid treatment and metal impregnation. Thus, monometallic catalysts showed NiO and Co_3O_4 reflections. In contrast, the bimetallic NiCo/ZH2.4 catalyst additionally exhibited characteristic peaks of the mixed spinel phase $NiCo_2O_4$, suggesting structural integration of Ni and Co. Furthermore, the H_2-TPR profiles of NiCo/ZH2.4 exhibited an intense and readily accessible reduction feature, likely due to hydrogen spillover and the formation of mixed-metal phases. Additionally, NH_3-TPD experiments confirmed that metal incorporation modified the surface's acidity: Ni promoted medium-strength acidity, Co preserved strong acid sites, and NiCo/ZH2.4 presented a balanced acid distribution favourable for bifunctional acid–metal reactions. Py-GC/MS runs at 550°C showed that NiCo/ZH2.4 catalyst substantially enhanced hydrocarbon production, specifically alkanes, while reducing oxygenated compound families. This catalyst exhibited the highest selectivity toward Jet Fuel–type hydrocarbon fractions, evidencing a strong acid–metal synergy. Thus, registered results indicate that applied pre-treatments (acid modification and bimetallic impregnation) successfully improve catalytic performance in biomass/plastic co-hydropyrolysis. Finally, among all samples, the NiCo/ZH2.4 catalyst exhibited remarkable physicochemical properties and product selectivity, consolidating its potential for sustainable aviation fuel production using mixed waste feedstocks in thermochemical processes.



Ex-situ catalytic pyrolysis of paper sludge to bio-BTX on a staged free-fall reactor using three commercial catalysts

Yanping Chen (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China) Na Li (School of Mechanical and Power Engineering, Nanjing Tech University, China) Zhenlei Zhang (Engineering and Technology Institute Groningen, University of Groningen, Netherlands) Anton Bijl (Alucha Works B.V., Netherlands) Giacomo Iannetti (Engineering and Technology Institute Groningen, University of Groningen, Netherlands) Eyerusalem Gucho (Alucha Works B.V., Netherlands) Jingmei Li (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China) Hero Jan Heeres (Engineering and Technology Institute Groningen, University of Groningen, Netherlands) Songbo He (Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China)

09:30-10:30 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Paper sludge (PS) is a solid waste generated in large quantities by the papermaking industry. PS contains fine minerals and lignocellulosic biomass, which can be recycled to recover circular minerals and produce bio-based chemicals. This contribution presents our latest study on the ex-situ catalytic pyrolysis of PS to bio-based benzene, toluene, and xylene (bio-BTX) in a newly developed staged free-fall reactor using three commercial catalysts, including E-cat, Pt/Al2O3, and H-ZSM-5. The pyrolysis liquid products were analyzed in detail by GC-TCD, GC-FID, GC×GC-FID, elemental analysis, Karl Fischer (KF) titration, total acid number (TAN), and gel permeation chromatography (GPC). The fresh, used, and regenerated catalysts were characterized by BET, NH_3-TPD, TGA, and XRD. Reaction-regeneration cycles were performed to investigate the catalyst reusability after regeneration. Results showed that H-ZSM-5 catalyst exhibited the highest BTX carbon yields of 4.14 C.%, compared to 1.84 C.% for Pt/Al2O3, 1.46 C.% for E-cat, and 0.39 C.% for no catalysts. TAN of the oil phase decreased from 171 mgKOH gsample-1 for Pt/Al2O3 to 108 mgKOH gsample-1 for H-ZSM-5, in accordance with the decreased concentration of the free fatty acids in the oil phase from 14.6 wt.% for Pt/Al2O3 to 0.5 wt.% for H-ZSM-5 catalyst. This indicates that H-ZSM-5 can effectively convert oxygenated intermediates, e.g., free fatty acids, into BTX. A techno-economic assessment (TEA) showed that the bio-BTX yield was one of the most important factors influencing the economic viability. This study presents an industrially feasible technical method for the ex-situ catalytic pyrolysis of PS to produce BTX and supports the development of sustainable catalysis in the field of circular carbon conversions.

Influence of additives, fillers and pigments via thermo-catalytic pyrolysis of polypropylene and polyethylene over HZSM-5 zeolites.

Kateřina Klemencová (VSB-TUO, CEET, IET, Czechia) Barbora Grycová (VSB-TUO, CEET, IET, Czechia) Amer Inayat (VSB-TUO, CEET, IET, Czechia) Pavel Leštinský (VSB-TUO, CEET, IET, Czechia)

09:50-10:30 Session S2.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Shogo Kumagai (Tohoku University, Japan) Alba Dieguez-Alonso (TU Dortmund University, Germany)

ABSTRACT

The rising production of plastic waste has driven the search for effective utilization routes. Pyrolysis offers a promising solution to converting waste plastic into available high-value products, fuels or chemicals. To increase the quality and durability of plastics, various additives are used, such as pigments, stabilizers, fillers and others, which positively affect the properties of plastics. However, at the end of the plastic life cycle, additives may positively or negatively affect the yield and quality of pyrolysis products. In this study, the most common plastics and additives were selected, and the influence of naturally occurring additives on the yield and quality of products during thermo-catalytic pyrolysis over HZSM-5 was evaluated. Waste plastics commonly contain a combination of different additives, so this study also examines the influence of the additive's combination. In the thermo-catalytics pyrolysis of waste plastic mixtures, additives can lead to catalyst deactivation through the reduction of acid-site activity. Nevertheless, additive combinations may relieve these negative effects while allowing controlled enhancement or suppression of aromatic compound formation. The exception is carbon black, which significantly increased the formation of monoaromatic hydrocarbons.

Impact of Intra-Particle Heat Conduction on Waste Plastic Pyrolysis

Feichi Zhang (Karlsruhe Institute of Technology, Germany) Muhao Li (Karlsruhe Institute of Technology, Germany) Pia Bleile (Karlsruhe Institute of Technology, Germany) Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Thorsten Zirwes (University of Stuttgart, Germany) Dieter Stapf (Karlsruhe Institute of Technology, Germany)

09:50-10:30 Session S2.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Shogo Kumagai (Tohoku University, Japan) Alba Dieguez-Alonso (TU Dortmund University, Germany)

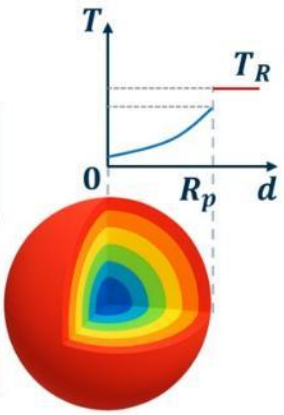
ABSTRACT

In 2024 alone, global plastic production reached approximately 430.9 million tonnes, yet less than 10% is recycled globally. While mechanical recycling is effective for clean, single-polymer streams, it performs poorly for mixed and contaminated plastics, which are typical for e.g. municipal waste. Chemical recycling, particularly pyrolysis, has therefore emerged as a necessary alternative, offering a practical compromise between economic viability and product quality. However, scaling pyrolysis reactors to industrial capacities remains challenging, largely due to the prohibitive cost of large-scale experimentation. As a result, numerical simulation has become indispensable for reactor design and process optimization, although many existing models rely on oversimplified representations of polymer conversion. A critical but frequently overlooked factor in plastic pyrolysis modeling is the inherently low thermal conductivity of polymers. In industrial applications, shredded plastic particles typically range from millimeters to centimeters in size and effectively behave like thermal insulators. Consequently, overall conversion is governed not only by intrinsic reaction kinetics but also by intra-particle heat conduction. Despite this physical reality, most computational studies employ homogeneous (0D) particle models that assume uniform internal temperature. This assumption neglects the dominant, rate-limiting role of internal heat transfer and can lead to substantial errors for predicting reactor performance. In this work, we address this limitation by systematically quantifying the predictive error of the 0D assumption through direct comparison with a particle-resolved model (1D) that explicitly captures internal temperature gradients. The results show that the conventional 0D model consistently overestimates both particle heating and conversion rates. Moreover, this discrepancy is not constant: it increases markedly with particle size, reactor temperature, and external heat transfer coefficient, conditions typical of industrial reactors, under which the assumption of thermal uniformity breaks down entirely. We propose a novel correction framework to bridge the gap between the computational efficiency of lumped-capacitance (0D) models and the physical fidelity of particle-resolved simulations. By analyzing the 0D model's error relative to the Pyrolysis number (Py) and Biot number (Bi), we derive a correction factor that accounts for intra-particle thermal lag. This factor reduces the heating rate predicted by the 0D model to align with particle-resolved solutions. The magnitude of this correction is modeled by fitting the discrepancy between the two approaches as a function of Py and Bi. This new model allows the 0D approach to replicate the accuracy of particle-resolved simulations while requiring a fraction of the computational cost. This advancement is particularly valuable for three-dimensional Euler-Lagrange simulations of large-scale reactors, where resolving the internal temperature profiles for millions of particles is computationally prohibitive. Ultimately, the proposed methodology offers a broadly transferable framework for the accurate modeling of other thermally-driven particle conversion processes where internal gradients are significant, such as biomass pyrolysis and solid fuel combustion, thereby facilitating more reliable virtual prototyping of next-generation recycling technologies.

Particle-resolved model (1D)

$$\frac{\partial \tilde{m}_p}{\partial t} = \dot{\tilde{r}}(r_p, t) = -A \cdot exp\left(-\frac{E_a}{R\tilde{T}_p}\right) \cdot \tilde{m}_{p,0}^{(1-n)} \tilde{m}_p{}^n$$

$$\rho_P \, \tilde{c}_P \frac{\partial \tilde{T}_p}{\partial t} = \frac{1}{r_p^2} \frac{\partial}{\partial r_p}\left(\lambda_p r_p^2 \frac{\partial \tilde{T}_p}{\partial r_p}\right) - \frac{\Delta H_R \cdot \dot{\tilde{r}}(t, r_p)}{\tilde{V}_p}$$



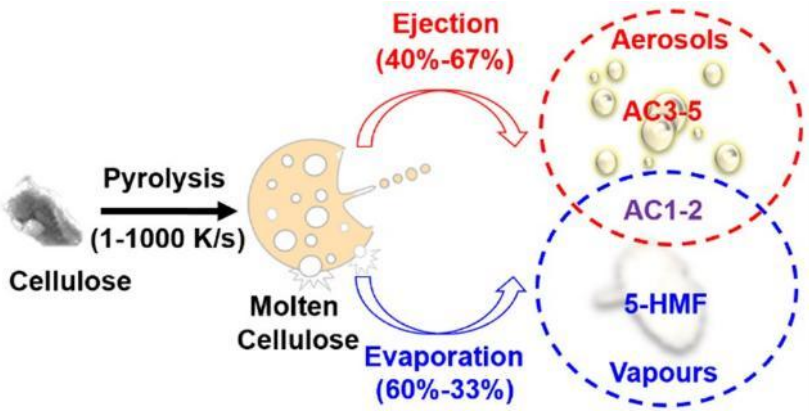
Important Role of Thermal Ejection in Condensable Volatiles Formation during Cellulose Pyrolysis

Yun Yu (Curtin University of Technology, Australia) Hongwei Wu (Curtin University of Technology, Australia)

11:00-12:40 Session S2.1: Applied pyrolysis: biomass valorisation; Fundamental pyrolysis reaction, kinetics/modeling
Location: ROOM A – GROUND FLOOR
Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

Thermal ejection may play a key role in the formation of primary volatiles from biomass fast pyrolysis. As the first in the field, this study proposes a new method based on the tracers that are only present in the ejected aerosols or the evaporated vapours, in order to determine the true yields of the ejected aerosols and the evaporated vapours in the condensable volatiles (so-called tar) produced from cellulose pyrolysis in a wire mesh reactor at 600 °C and 1 – 1000 K/s. The results show that some non-volatile compounds (i.e., cellotriosan, cellotetraosan and cellopentaosan) are only present in the ejected aerosols with similar collection efficiencies, while volatile compounds such as 5-hydroxymethylfurfural are only present in the evaporated vapours with high collection efficiencies (>90%). Consequently, the true yields of the ejected aerosols and the evaporated vapours can be determined using those key compounds as "tracers". The results show that the true yield of the ejected aerosols from cellulose pyrolysis continuously increases from 29% at 1 K/s to 57% at 1000 K/s, accompanied by the continuous decrease in the true yield of the evaporated vapours from 43% at 1 K/s to 28% at 1000 K/s. The total primary tar yield of cellulose pyrolysis still increases with the heating rate (from 72% at 1 K/s to 86% at 1000 K/s), with the contribution of the ejected aerosols increasing from 40% at 1 K/s to 67% at 1000 K/s. The data clearly demonstrate the key role of thermal ejection in the formation of condensable volatiles during cellulose pyrolysis, greatly influencing the yield and composition of tar generated from cellulose pyrolysis. Overall, the results of this study provide significant insights into the formation mechanisms of primary volatiles during cellulose/biomass pyrolysis.



Gas-phase thermal stability of levoglucosenone derived from biomass pyrolysis

Shinji Kudo (Kyushu University, Japan) Ren Akai (Kyushu University, Japan) Jun-Ichiro Hayashi (Kyushu University, Japan)

11:00-12:40 Session S2.1: Applied pyrolysis: biomass valorisation; Fundamental pyrolysis reaction, kinetics/modeling
Location: ROOM A – GROUND FLOOR
Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

Levoglucosenone (LGO) is a highly functionalized biomass-derived platform molecule that can be produced from cellulose via catalytic pyrolysis or secondary upgrading of a primary product from its non-catalytic pyrolysis, levoglucosan. Owing to its enone structure, LGO has attracted considerable attention as a precursor for a wide range of value-added chemicals including polymers. While various catalytic systems have been proposed to enhance LGO formation, reported studies generally rely on slow pyrolysis conditions. In contrast, fast heating and high-temperature continuous pyrolysis often result in significantly lower LGO yields. From the viewpoint of reactor design and process intensification, understanding the thermal stability of LGO in the gas phase is essential for improving its recovery under fast pyrolysis conditions. In this study, the gas-phase thermal stability of LGO was systematically investigated using a continuous-flow reactor. A flow-type reaction system consisting of an evaporation zone and a reaction zone was employed. Liquid LGO was vaporized and continuously supplied to the reaction zone under a controlled flow of inert carrier gas. The reaction temperature and residence time were varied over a wide range to evaluate their effects on LGO recovery. At temperatures below 200 °C, LGO was almost completely recovered regardless of residence time, indicating high thermal stability under mild conditions. However, LGO recovery decreased markedly with increasing temperature and residence time. At 300 °C, the recovery dropped below 80% within tens of seconds, while at 400 °C, nearly complete loss of LGO occurred within only a few seconds. Similar trends were observed when the inert gas nitrogen was replaced by steam, hydrogen, or carbon dioxide as the carrier gas, suggesting that the observed LGO loss was not strongly dependent on gas atmosphere. Notably, negligible amounts of permanent gases were detected below 400 °C, and coke deposition on the reactor wall was minimal. Instead, a substantial fraction of LGO was converted into condensable products that were not detectable by general GC analysis. Gel permeation chromatography revealed the presence of products with molecular weights higher than that of LGO, indicating the formation of heavy liquid species. These results suggest that LGO predominantly undergoes gas-phase addition or polymerization reactions rather than thermal cracking. Given the high reactivity of the enone moiety, intermolecular reactions between the α and β carbon atoms of LGO molecules are likely responsible for the rapid loss of LGO in the gas phase, although the details have yet to be clarified. Based on kinetic analysis of the obtained data, the results demonstrate that appropriate control of temperature and residence time is critical to suppress gas-phase reactions of LGO. The findings provide important guidelines for reactor design and operating conditions, indicating that high-yield continuous production of LGO is achievable even under fast heating and continuous pyrolysis, provided that gas-phase degradation is effectively minimized.

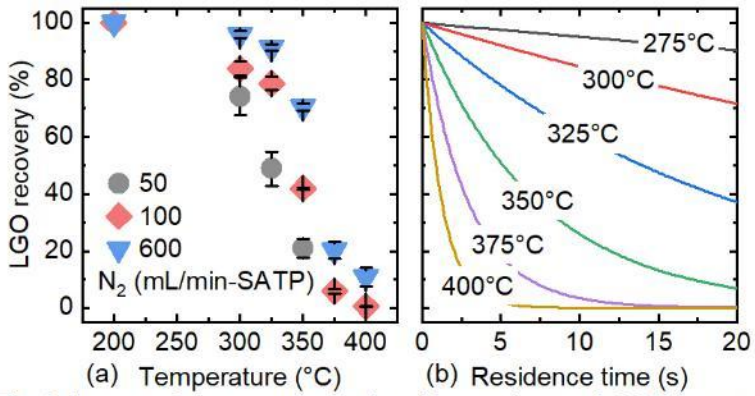


Fig. Influence of temperature and residence time on LGO recovery: (a) experimental results and (b) LGO recovery calculated using kinetic analysis results. LGO 3 μmol/min.

Production of hydrogen-rich syngas from catalytic reforming of biomass gasification tar coupled with in-situ CO2 capture

Cui Quan (Xi'an Jiaotong University, China) Shaoxuan Feng (Xi'an Jiaotong University, China) Ningbo Gao (Xi'an Jiaotong University, China)

11:00-12:40 Session S2.1: Applied pyrolysis: biomass valorisation; Fundamental pyrolysis reaction, kinetics/modeling
Location: ROOM A – GROUND FLOOR
Chairs: Haruo Kawamoto (Kyoto University, Japan) Aneta Magdziarz (AGH University of Krakow, Poland)

ABSTRACT

Biomass gasification for hydrogen production has received widespread attention in recent years as a sustainable energy technology. However, the biomass gasification process produces tar. This can seriously affect subsequent gas cleaning and utilization. In this study, toluene was used as a tar model compound. The effects of different catalyst carriers, reforming temperatures, S/C ratio, and in-situ CO2 capture on the yield of toluene steam reforming were investigated. The results showed that under the same working conditions, the hydrogen yield of the SiC carrier catalyst was much higher than that of the SiO2 and Al2O3 carriers. This is due to the excellent thermal conductivity and suitable acid-base properties of the SiC carrier. CaO could effectively adsorb CO_2 and increase the hydrogen yield. The hydrogen yield reached 90.63% with the addition of 0.3g of CaO, which was 13.7% higher than that without the addition of CaO. In addition, to investigate the structural changes and chemical state of the catalysts the differences between the catalysts before and after use were analyzed using a variety of characterization methods. This study provides critical insights into the design of efficient catalysts and processes for overcoming the challenges associated with biomass-derived tar.

What are we breathing at home? - Household Micro- and Nanoplastics: Composition, Differences, potential Sources & Determinants

Barbara Scholz-Böttcher (Institute for Chemistry and Biology of the Marine Environment (ICBM), Carl von Ossietzky Universität Oldenburg, Germany) Amanda Durkin (Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Netherlands) Lisa Charlotte Balding (Institute for Chemistry and Biology of the Marine Environment (ICBM), Carl von Ossietzky Universität Oldenburg, Germany) Bente van Santbrink (Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Netherlands) Virissa Lenters (Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Netherlands) Runyu Zou (Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Netherlands) Ulrike Gehring (Institute for Risk Assessment Sciences, Department of Population Health Sciences, Utrecht University, Netherlands) Roel Vermeulen (Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, Netherlands)

11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Micro- and nanoplastics (MNPs) are omnipresent, even in the most remote places on Earth. At the same time, reports of MNPs in the human body are increasing exponentially. The main exposure routes are ingestion and, above all, inhalation. People spend most of their time indoors, predominately in their homes. Characterization of indoor air exposure to MNPs is essential to contextualize internal human measurements and assess their environmental plausibility. Accordingly, exposure levels, composition, spatial and behavioral determinants require detailed evaluation. Passive sampling was performed in 105 households in Utrecht, the Netherlands and surrounding areas within a 50 km radius. Petri dishes were placed in elevated positions for dust collection twice within a period of three months. Samples, replicates and blanks were analyzed for MNP composition and mass with reactive Py-GC/MS after Fenton oxidation. Accompanying questionnaires captured sociodemographic, behavioral, and household factors, and environmental data were linked to sampling locations. Spatial and household-level determinants of MNP deposition rates were examined using multivariable mixed-effects linear regression.

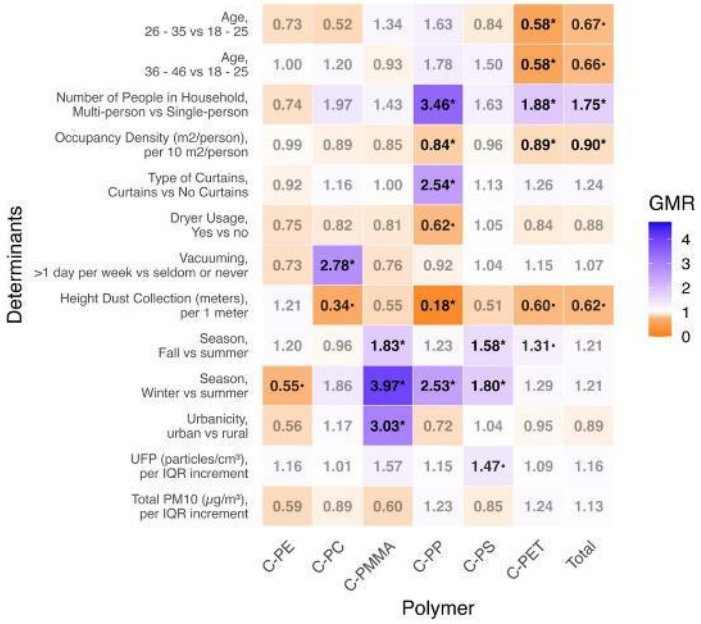


Figure 1. Heatmap (multiple regression) of geometric mean ratios (GMRs) for associations between determinants of exposure and MNP concentrations. *significant ($p < 0.05$), .marginally significant ($p < 0.1$) associations.

All samples contained MNPs reported as clusters related to the respective quantifiable homo polymers and accordingly include copolymers on a proportional basis. Most prominent was the polyethylene terephthalate cluster (C-PET), with rates between 0.37 and 170 µg/m²/day (mean 27.2) which accounted for almost 80% of total polymer deposition. It was followed by the clusters of polypropylene (C-PP) and polyethylene (C-PE) representing a significantly lower proportion of total polymer deposition with 6% each. Less prominent clusters were polystyrene (C-PS), polymethyl methacrylate (C-PMMA), polycarbonate (C-PC) and polyamide (C-PA6). A subset of samples (n=40) was analyzed for tire wear particles. Very few samples had levels which exceeded the LOD, suggesting a minor role, if any, of tire abrasion in the household

dust samples examined. The polyvinylchloride cluster was excluded from the results due to severe interferences of natural fibres. Prior to pyrolysis, the prepared sample filters were inspected microscopically. This revealed a significant proportion of fibres. Most likely the high proportions of C-PET, and C-PP to a lesser extent, were attributed to household and clothing textiles. Multivariable linear regression (Figure 1) was used to assess associations for specific polymer clusters with potential determinants of exposure. Higher deposition was observed in multi-person households and in autumn and winter compared to summer. However, more living space per person, was associated with lower deposition. Specific household sources and sinks were identified: curtains in the living room were associated with higher C-PP deposition; vacuuming, with higher C-PC; and dryer use, with lower C-PP. Higher levels of C-PMMA and C-PS were associated with environmental conditions, including urbanicity and ultrafine particle concentrations, respectively. Besides identification of some key determinants, qualitative and quantitative data will be related to published outdoor and indoor deposition. In addition, the observed pattern is compared and discussed with that from a selection of previously published human samples.

Unravelling the chemical complexity of artificially aged tire wear particles by Py-GCxGC-ToFMS

Géraldine Dumont (OBiAChem, University of Liège, Belgium – Flemish Institute for Technological Research, , Belgium) Marco Mattonai (Department of Chemistry and Industrial Chemistry – Center for Instrument Sharing, University of Pisa, Italy, Italy) Jacopo La Nasa (Department of Chemistry and Industrial Chemistry – Center for Instrument Sharing, University of Pisa, Italy, Italy) Milica Velimirovic (Flemish Institute for Technological Research, Belgium, Serbia) Jan Jordens (Flemish Institute for Technological Research, , Belgium) Pierre-Hugues Stefanuto (OBiAChem, University of Liège, , Belgium) Jean-François Focant (OBiAChem, University of Liège, , Belgium) Francesca Modugno (Department of Chemistry and Industrial Chemistry – Center for Instrument Sharing, University of Pisa, Italy, Italy) Siebe Lievens (Academic Center of Excellence in Separation Science and Sensing (ACESSS) – OBiAChem, University of Liège, , Belgium)

11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Plastics and microplastics are ubiquitous in the global environment, drawing increasing attention due to their adverse environmental impacts. Particles originating from tyre abrasion represent a substantial share of the microplastic pollution, mainly pronounced in traffic-dominated and urban environments. Following their release, several environmental processes encompassing for instance mechanical abrasion, and physicochemical degradation such as UV-irradiation. The latter mechanisms can lead to pronounced changes in the chemical fingerprint and functional characteristics of tire wear particles (TWPs), hence their overall impact has not been elucidated. This knowledge gap is predominantly originating from the complex analytical approach required to tackle these heterogeneous samples. Conventional pyrolysis coupled to gas chromatography mass spectrometry (Py-GC-MS) is seen as the go to strategy to characterize TWPs by identifying its polymer-specific marker compounds. However, due to the sample complexity, Py-GC-MS faces limitations in resolving power, restricting research to unravel the full chemical fingerprint of TWPs. Comprehensive two-dimensional gas chromatography hyphenated with analytical pyrolysis and time-of-flight mass spectrometry (Py-GCxGC-ToFMS) can present a potential solution to overcome the conventional shortcomings. In the current study, human-produced TWPs were artificially aged using a weathering chamber with UV-irradiation, and every week a subsample was taken for four weeks. The pristine and aged TWPs were subsequently analysed using Py-GCxGC-ToFMS, revealing a temporal alteration pattern in the relative abundance of characteristic pyrolysis compound groups obtained in the 2D pyrograms. This outcome supports the hypothesis that UV-irradiation can induce degradation of TWPs altering their chemical composition, and in turn complicating accurate quantification. In conclusion, such non-targeted screening approaches are of major importance for tracing degradation products and acquiring reliable TWP data for environmental mitigation strategies. The authors acknowledge the COST Action ICPLASTIC CA23131 ISO compatible, efficient and reproducible protocols/equipment for mICro-nanoPLASTIC detection through machine-learning – ICPLASTIC, supported by COST (European Cooperation in Science and Technology), and the Fonds de la Recherche Scientifique (FNRS) for financial support of the current study.

Quantification of Polyvinyl Chloride in Atmospheric Particulate Matter Using Pyrolysis GC/MS: Matrix Effects and Marker Behavior

Hitoshi Mizuguchi (Tokushima University, Japan) Yuta Moriguchi (Tokushima University, Japan) Tomoya Ogawa (Tokushima University, Japan) Hiroto Takeda (Tokushima University, Japan) Taiga Maekawa (Tokushima University, Japan) Masaki Takeuchi (Tokushima University, Japan) Toshio Takayanagi (Tokushima University, Japan) Norio Teramae (Tohoku University, Frontier Laboratories Ltd., Japan) Atsushi Watanabe (Tohoku University, Frontier Laboratories Ltd., Japan) Chuichi Watanabe (Frontier Laboratories Ltd., Japan)

11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Environmental pollution caused by microplastics has become an issue of increasing public concern. In recent years, atmospheric microplastics have increasingly been reported, attracting growing scientific and public interest, and the development of analytical methods to track their behavior is now an urgent task. In our previous studies, atmospheric particulate matter was collected on quartz fiber filters, and a portion of the collected samples was directly introduced into a pyrolysis gas chromatography–mass spectrometry (Py-GC/MS) system to quantify trace amounts of polymer components. Using this approach, we successfully demonstrated the quantitative determination of polymer species such as polypropylene, polystyrene, and styrene–butadiene rubber. However, in the quantitative analysis of polyvinyl chloride (PVC), the large hydrogen chloride signal typically observed during pyrolysis is strongly influenced by matrix components and therefore does not function reliably as evidence for the presence of PVC. Although many researchers use naphthalene as a marker compound, this issue may be addressed by clarifying the behavior of hydrogen chloride generated during the pyrolysis of PVC in matrices inevitably introduced during atmospheric sampling as well as in real atmospheric particulate matter, and by elucidating how these matrices affect the responses of marker compounds such as naphthalene. In this study, the peak behavior of hydrogen chloride in atmospheric particulate matter collected on quartz fiber filters was analyzed, and the validity of the quantitative method was evaluated through spike-and-recovery experiments using real atmospheric samples. In this presentation, we will present the results of this study, including the analytical results of PVC contents in size-classified atmospheric particulate matter (PM>10, PM2.5–10, and PM2.5).

Splitless analytical pyrolysis of museum foraminifera tests: historical insights on oceanic plastic pollution

Marco Mattonai (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Laura J. Cotton (Natural History Museum Denmark, Copenhagen University, Denmark, Denmark) Ronnie N. Glud (Department of Biology, University of Southern Denmark, Denmark, Denmark) Francesca Modugno (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Moriaki Yasuhara (State Key Laboratory of Marine Environmental Health, City University of Hong Kong, Hong Kong SAR, China, Hong Kong) Elvis G. Xu (Department of Biology, University of South Denmark, Denmark, Denmark)

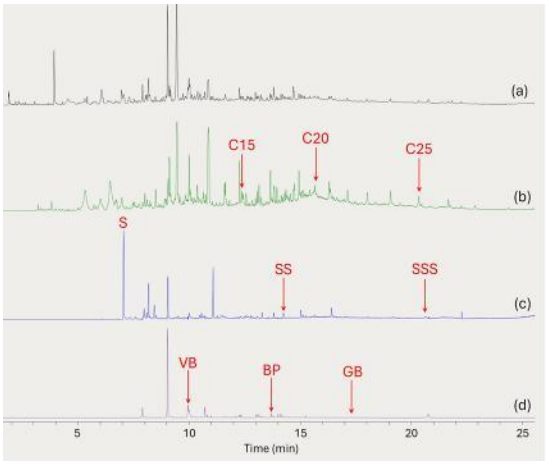
11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

In this study, we quantified plastic content in foraminifera tests to evaluate their suitability as tools for time-resolved plastic pollution studies in the marine environment. Foraminifera are unicellular marine organisms capable of producing shell-like agglomerates known as tests using seawater particles. Suspended plastic particles might be incorporated into these tests and protected from environmental degradation. This makes foraminifera tests potential bio-archives of plastic pollution, with a better spatial resolution compared to marine sediments. However, information on the plastic content in either fresh or historical foraminifera tests is lacking in the literature. Here, four historical foraminifera tests (1911–1952) from different oceans were retrieved from a museum collection and plastic contents were quantified by analytical pyrolysis-GC-MS. The tests were ground and analyzed without further pretreatment. A new tool that allows splitless injection of pyrolyzates into the chromatographic system was used to increase instrumental sensitivity. In addition, matrix-matched calibration was performed using a plastic reference mixture with calcium carbonate as solid dispersant. Peaks from the organic linings of the tests were detected in the pyrograms and constituted potential interferents for some of the pyrolysis markers of polymers. Therefore, a careful selection was made of polymers for which reliable quantitative data could be provided, and discussion of the results was limited to these polymers. Results revealed the presence of polyethylene, polystyrene, and polyethylene terephthalate, in amounts consistent with plastic production history and age of the samples (Figure 1). While the sample pool is not big enough to draw definitive conclusions, these results indicate that fresh and historical foraminifera tests are promising resources to build time-resolved plastic pollution patterns in marine environments.



µg/g	1911	1915	1952	1952
PE	<LOD	2.4	78.7	47.7
PS	<LOD	<LOD	<LOQ	0.9
PET	9.6	<LOD	40.6	45.0

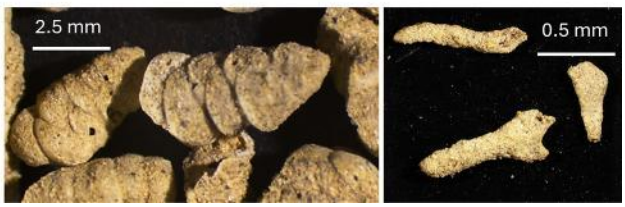


Figure 1. Left – Total ion pyrogram of a test sample (a) and extracted ion pyrograms showing pyrolytic markers for polyethylene (b), polystyrene (c) and polyethylene terephthalate (d). Right, top – quantitative results. Right, bottom – microscopy images of the samples.

Molecular characterisation of the environmentally labile fraction of biochars by hydropyrolysis

Will Meredith (University of Nottingham, UK) Colin Snape (University of Nottingham, UK) Clement Uguna (University of Nottingham, UK) Ahmed Khairy (University of Nottingham, UK) Philippa Ascough (University of Glasgow, UK)

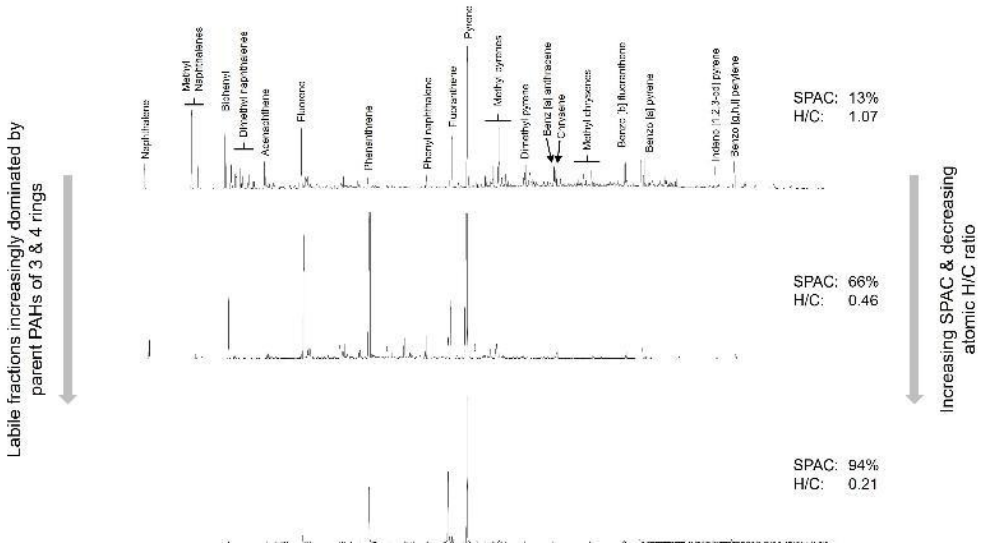
11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Hydropyrolysis (hydrogen pyrolysis or HyPy) is a comprehensive method for the isolation and quantification of the carbonaceous fraction of biochar that is environmentally stable over extended (centennial) timescales (McBeath et al 2015). It has been shown to strongly correlate with both widely used bulk compositional metrics such as atomic H/C ratio, and also novel indirect parameters such as solid-state electrical conductivity (Hagemann et al., 2025). It has the advantage of being able to isolate a fraction of consistent thermal stability which is also defined on a molecular basis as being composed of >7 aromatic rings. In addition, the fraction which is potentially environmentally labile can also be recovered and subsequently characterised by gas chromatography mass spectrometry. This fraction, composed of smaller aromatic clusters, together with alkyl moieties and breakdown products of the lignocullulosic material derived from the biochar feedstock, can, together with the quantification of the residual stable ployaromatic carbon fraction (SPAC) allow for the feedstock and process conditions of the biochar to be assessed. It may also provide a methodology for assessing the extent of alteration of biochars once they have been exposed to environmental degradation. Here we describe the characterisation of the labile fraction of a range of wood biochars produced under different process conditions, and hence of markedly different stability, as assessed by both their SPAC content and atomic H/C ratio. As shown in the Figure, for relatively low temperature biochars with a consequent low degree of condensation (H/C ratio of 1.07) and SPAC of 13% the labile fraction consisted of a high abundance of PAH compounds of between 2 and 7 rings, together with their alkyl substituted homologs, and some phenolic species. With increasing temperature, and consequent increased degree of condensation (H/C = 0.46; SPAC 66%), the recovered products were restricted to just the parent PAHs, although still spanning the 2-7 ring size range. For highly stable biochars (H/C = 0.21; SPAC = 94%), the concentration of products was much reduced, and comprised only of 3 and 4 ring structures. It is thought that rather than being cleaved from the biochar structure itself these were condensation products, thermally desorbed from the biochar during HyPy that had condensed onto the char surface during production. In addition we also report on the characterisation of the labile fraction of biochars that had been part of an agricultural field trail 13 years ago, to assess how the labile fraction may change after environmental exposure. References McBeath AV, Wurster CM, Bird MI. 2015. Influence of feedstock properties and pyrolysis conditions on biochar carbon stability as determined by hydro¬gen pyrolysis.



Biomass Bioenergy 73, 155–73. Hagemann N, Schmidt HP, Buchelia TD, Grafmueller G, Vosswinkel S, Herdegen V, Meredith W, Uguna CN and Snape CE. 2025. Proxies for use in biochar decay models: Hydropyrolysis, electric conductivity, and H/Corg molar ratio. PLoS One 20, e0330206.

Py-GC-MS method development and validation for micro- and nanoplastics in human breast milk and bile

Federica Nardella (Vrije Universiteit Amsterdam, Netherlands) Martin van Velzen (Vrije Universiteit Amsterdam, Netherlands) Kas Houthuijs (Vrije Universiteit Amsterdam, Netherlands) Virissa Lenters (Vrije Universiteit Amsterdam, Netherlands) Sicco Brandsma (Vrije Universiteit Amsterdam, Netherlands) Henk Roest (Erasmus MC Transplant Institute, Netherlands) Frederic Béen (Vrije Universiteit Amsterdam; KWR Water Research Institute, Netherlands) Luc van der Laan (Erasmus MC Transplant Institute, Netherlands) Marja Lamoree (Vrije Universiteit Amsterdam, Netherlands)

11:00-13:00 Session S2.2: Analytical Pyrolysis: Environment

Location: ROOM A1 – FIRST FLOOR

Chairs: Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Clemens Schwarzinger (Johannes Kepler University Linz, Austria)

ABSTRACT

Micro- and nanoplastics (MNPs) are increasingly recognized as emerging contaminants with potential implications for human health. However, detecting and quantifying MNPs in human biological matrices remains a substantial analytical challenge due to their particle nature, the complexity of the matrix, and the high risk of cross-contamination arising from their pervasive presence. Among human samples, biological fluids such as breast milk and bile represent particularly relevant matrices for human exposure assessment: breast milk reflects maternal transfer pathways and early-life exposure, while bile plays a key role in the excretion of exogenous substances entering the body via ingestion. Despite their importance, these matrices are highly complex and diverse, characterized by varying and often high contents of proteins, lipids and other endogenous compounds. These factors demand analytical approaches that provide high specificity and sensitivity, together with robust contamination control. Pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS) offers a powerful and reliable strategy for MNP analysis, as it provides polymer-specific chemical fingerprints derived from characteristic thermal degradation pathways. However, the complexity of biological fluids can introduce co-pyrolysis effects, leading to altered marker profiles or interferences with pyrolysis products originating from matrix constituents. The main aim of this study was the development and validation of Py-GC-MS methods tailored for the analysis of MNPs in human biological fluids such as breast milk and bile. Given the heterogeneity of the target matrices, we developed matrix-specific digestion procedures designed to efficiently remove organic material while preserving polymer integrity. Each digestion workflow was optimized to guarantee high recoveries and minimal matrix effects. For each targeted polymer, pyrolysis markers were selected to reduce interferences and co-pyrolysis artefacts. The final protocols were successfully validated, following international validation guidelines, for human bile and human breast milk, demonstrating reliable performance for six commonly encountered polymers: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), polyvinyl chloride (PVC), and polymethyl methacrylate (PMMA). Application of the validated methods to samples collected from donors confirmed their suitability for the detection and quantification of MNPs in real human matrices. This work highlights the essential role of Py-GC-MS in advancing MNP exposure assessment, offering a versatile and sensitive analytical approach. The developed methods provide a crucial foundation for future studies investigating human uptake, distribution, and potential health impacts of MNPs pollution.

Upgrading of Slow Pyrolysis Oil via Mild and Deep Hydrodeoxygenation for Green Marine Fuels

Ecrin Ekici (Institute of Catalysis Research and Technology, Karlsruhe Institute of Technology, Germany) Dicle Yalic (Institute of Catalysis Research and Technology, Karlsruhe Institute of Technology, Germany) Klaus Raffelt (Institute of Catalysis Research and Technology, Karlsruhe Institute of Technology, Germany) Nicolaus Dahmen (Institute of Catalysis Research and Technology, Karlsruhe Institute of Technology, Germany)

11:00-12:40 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

The seeking of alternative routes for green marine fuel production has accelerated due to recent regulations that aim to reduce toxic gas emissions, particularly sulfur oxides (SO_x). Bio-oil can be considered a promising alternative to fossil-based marine fuels because of its carbon neutrality and naturally low sulfur content. However, it cannot be used directly in engines due to its poor fuel quality. The high oxygen content of bio-oil reduces its calorific value and stability, while its high acidity causes corrosion problems in engines. Therefore, an upgrading step is necessary to improve the fuel properties of bio-oil and make it suitable for blending or co-refining with conventional marine fuels. Hydrodeoxygenation (HDO) is one of the most effective upgrading methods, aiming to remove oxygen from bio-oil under hydrogen flow in the presence of a catalyst. In this study, slow pyrolysis oil is produced from cherry plum waste and then upgraded through HDO under different conditions using nickel oxide and noble metal catalysts. The bio-oil is pyrolyzed in a continuously operated screw reactor at 500°C under constant 10 NL/min N2 flow with 5 min solid residence time. The char, oil, and gas yields are 29.4 wt.%, 38.6 wt.%, and 32 wt.%, respectively. In this study, three different conditions are applied: 1) Mild HDO was performed at 250 °C and 80 bar; 2) Deep HDO was carried out at 330 °C and 80 bar; 3) two-step HDO process, first applying the mild HDO conditions and following deep HDO. The upgraded products were characterized by several analyses such as GC-FID, GC-TCD, and CHNS to evaluate the influence of reaction severity and catalyst type on the physicochemical properties of the resulting fuels. This study demonstrates that reaction severity is the primary driver of bio-oil upgrading, while catalyst type mainly controls product selectivity and gas formation pathways. Increasing temperature from 250 °C to 330 °C strongly enhanced deoxygenation. The O/C ratio decreased from 0.29 to 0.21 after mild stabilization and to 0.05 after deep HDO. Deoxygenation is lower for the two-step HDO compared to direct deep HDO (ca. O/C = 0.19). The lowest gas yields (~12 wt.%) were obtained with the two-step HDO, indicating more controlled oxygen removal. Under mild conditions, oxygen is mainly removed via decarboxylation, leading to CO2 formation (ca. 3 vol%) with about 1 vol% methane production. Under deep HDO, hydrogenation–hydrogenolysis and decarboxylation are the main pathways, while very low CO formation (~0.1 vol%) indicates negligible decarbonylation. The two-step process restores CO2 as a dominant oxygen-removal pathway and limits excessive cracking, resulting in moderate C1–C3 formation. Overall, mild HDO alone is insufficient for producing fuel-grade oils but is essential for stabilizing highly reactive oxygenated species. Deep HDO is required for significant oxygen removal, but when applied directly it sacrifices liquid yield through excessive gas formation. A staged HDO strategy that first stabilizes and then deeply deoxygenates bio-oil provides the best balance between oxygen removal, liquid yield, and product quality, making it a promising route for producing marine-fuel-range liquids from bio-oils.

Catalytic hydrotreatment efficiency on HTL biocrudes from two microalgae strains, Chlorella sorokiniana and Chlorella vulgaris, evidenced by FT-ICR MS

Jasmine Hertzog (Université de Lorraine, LCP-A2MC, F-57000 Metz, France, France) Ruben Checa (IRCELYON, 69626 Villeurbanne, cedex, France, France) Bruno da Costa Magalhães (IRCELYON, 69626 Villeurbanne, cedex, France, France) Vincent Carré (Université de Lorraine, LCP-A2MC, F-57000 Metz, France, France) Frédéric Aubriet (Université de Lorraine, LCP-A2MC, F-57000 Metz, France, France) Pavel Afanasiev (IRCELYON, 69626 Villeurbanne, cedex, France, France) Dorothée Laurenti (IRCELYON, 69626 Villeurbanne, cedex, France, France) Christophe Geantet (IRCELYON, 69626 Villeurbanne, cedex, France, France)

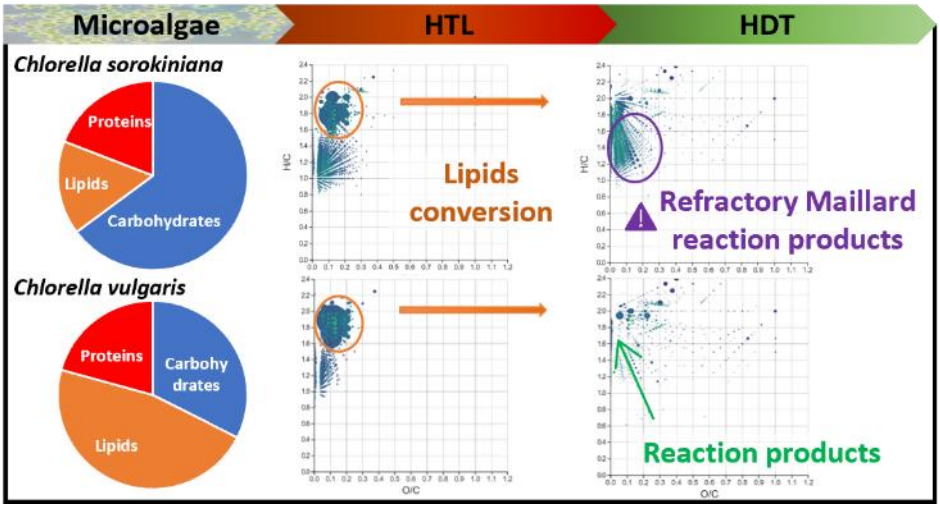
11:00-12:40 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Two microalgae strains, Chlorella sorokiniana and Chlorella vulgaris, were subject to hydrothermal liquefaction (HTL). The resulting HTL biocrudes were then upgraded via hydrotreatment (HDT), using a sulfided NiW/Al2O3 catalyst, with samples collected after 0, 2.5, 5, and 8 hours of reaction. The heavy fractions from these distinct HTL biocrudes and HDT bio-oils were subsequently characterized by Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS). These analyses yielded thousands of distinct molecular formulae, corresponding to CHON, CHN, CHO, and CH compound classes. The lipids present in algae were converted by HTL into long chain acids and CHN, CHO, CHNO compounds. Through deoxygenation and denitrogenation reactions, a large amount of alkanes and aromatics were obtained. However, a significant population of refractory species was identified, mainly in Chlorella sorokiniana HDT oils. This strain is defined by its higher content of carbohydrates that yield Maillard reaction products, along with algal proteins. These high-mass species were formed during HDT and are therefore better characterized by FT-ICR MS than by gas chromatography (GC). Furthermore, analysis of the treated bio-oil obtained after a short HDT time exhibited the lowest unsaturation level, likely due to reaction between the fatty chains and amino acids. In summary, the FT-ICR MS approach combined with multivariate statistical analyses, proved to be highly complementary to GC analyses. It enabled to decipher the molecular complexity of the heavy fraction of the HTL biocrudes and HDT bio-oils, clarified the influence of the microalgae strain on the HDT efficiency, and provided meaningful insight into the reactions occurring during the early stages of the upgrading process.



Investigation of bones waste catalytic pyrolysis for bio-based compounds production

Razvan Nicolae State (National University of Science and Technology POLITEHINCA Bucharest, Romania) Gabriela Ionescu (National University of Science and Technology POLITEHINCA Bucharest, Romania) Aneta Magdziarz (AGH University of Krakow, Poland) Cosmin Marculescu (National University of Science and Technology POLITEHINCA Bucharest, Romania)

11:00-12:40 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

This study investigates the catalytic pyrolysis of chicken wing bones residues to improve yield and quality of the by-products. The work focuses on the use of novel catalysts produced from chicken bone waste, supporting the valorization of cooked poultry residues. Biochar obtained from the pyrolysis of chicken bones was further modified with HZSM-5 zeolite and nickel to enhance catalytic activity. Experiments were performed using chicken wings bones residues as feedstock. The main goal was to evaluate catalyst efficiency, product distribution, and the potential reuse of the catalysts. When biochar-based catalyst was used, the average yields were approximately 42% biochar, 31% bio-oil, and 22% gas. For HZSM5, mean yields were about 45% biochar, 29% bio-oil, and 21% gas. Gas analysis showed that, for both catalysts, the main components were hydrogen, carbon monoxide, carbon dioxide, methane, acetylene, ethylene, and a high fraction of butane, with smaller amounts of other light hydrocarbons. When biochar-based catalyst was used, the dominant compound classes in the bio-oil were carboxylic acids, amides, nitriles, aromatic compounds, and nitrogen-containing aromatics. In contrast, bio-oils obtained with HZSM5 contained a broader range of compounds, including alkanes, alkenes, aromatic compounds, amides, carboxylic acids, nitriles, amines, and esters. Overall, the results show that chicken bone-derived catalysts are effective in catalytic pyrolysis and offer a promising route for the sustainable conversion of cooked bone waste into valuable products.

Pressure effect on catalytic pyrolysis of eucalyptus over hierarchical BETA zeolite

Alicia Margarita Montero-Csanady (Rey Juan Carlos University, Spain) Maria Inés Ávila (Rey Juan Carlos University, Spain) Jennifer Cueto (IMDEA Energy Institute, Spain) Laura Briones (Rey Juan Carlos University, Spain) Angel Peral (Rey Juan Carlos University, Spain) Jose Maria Escola (1 Rey Juan Carlos University 2 Instituto de Investigación de Tecnologías para la Sostenibilidad, Spain) David Pedro Serrano (1 Rey Juan Carlos University 2 IMDEA Energy Institute, Spain) Gema Gómez-Pozuelo (Rey Juan Carlos University, Spain) Juan Angel Botas (1 Rey Juan Carlos University 2 Instituto de Investigación de Tecnologías para la Sostenibilidad, Spain)

11:00-12:40 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Eucalyptus is an invasive biomass species due to its fast growing and self-proliferation, which makes it a renewable and abundant resource. Its low ash content and composition make it an interesting source of high value-added products such as phenolic compounds. Catalytic pyrolysis of eucalyptus is especially remarkable for its ability to enhance selectivity towards oxygenated compounds. It has been demonstrated that hierarchical zeolites lead to the decomposition of heavy oligomers coming from the biomass, improving the bio-oil quality and boosting the proportion of phenolic compounds in the bio-oil1. Previous studies show that increasing the pressure in catalytic pyrolysis enhances the selectivity of zeolites towards compounds of interest for bio-oil upgrading2. In this context, this study is focused on the effect of pressure on the catalytic performance of both commercial (H-BETA) and hierarchical (h-H-BETA) BETA zeolites in eucalyptus pyrolysis. The experiments were carried out under nitrogen atmosphere in a fixed-bed reactor operating at 550 ºC for thermal eucalyptus decomposition and 450 ºC for catalytic vapour upgrading, using a catalyst/biomass ratio of 0.2 and operating pressures of 1 and 6 bar. The resulting char, bio-oil* (water-free basis), water, permanent gases, and coke (the latter just for catalytic tests) were analysed using different techniques to assess conversion efficiency and products selectivity. By comparison, in the non-catalytic test (NC), increasing the pressure reduced the bio-oil* yield and increased the char yield, due to the slower vaporization rate of liquid products coming from primary thermal degradation reactions, leading to the formation of secondary char. In the case of the catalytic tests the bio-oil* yield was reduced because of the increased water and coke production. Gas production is enhanced by the increasing pressure in both thermal and catalytic tests, due to the severe cracking and decarboxylation reactions. Consequently, in thermal reactions, the increased pressure provoked a decrease in the detected matter quantified by GC-MS of the bio-oil*. The pressure showed a strong influence on the light compounds in the bio-oil*, leading to the cracking of the lightest species and promoting the formation of non-condensable gases such as CO and CO_2. These trends indicate a higher degree of cracking affecting a fraction of the oligomers derived from pyrolysis, resulting in a more homogeneous distribution of lower molecular weight compounds. Although increasing pressure is not favourable in thermal reactions, its positive effect can be observed in catalytic reactions, where an improvement in bio-oil* quality in terms of a higher selectivity towards the target compounds in the detected fraction occurs. The higher pressure boosted the production of AR and O-AR with the use of H-BETA. This effect was improved with the h-H-BETA zeolite, showing an increase in the concentration of the above compounds and promoting lignin oligomers conversion to O-AR which exhibit numerous industrial applications.

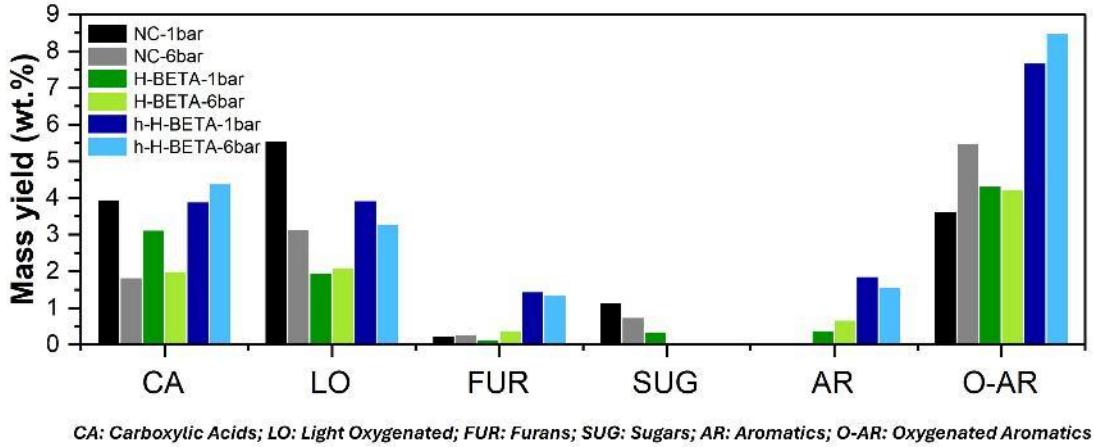


Figure 1. Bio-oil* family compounds obtained in the eucalyptus catalytic pyrolysis over commercial and hierarchical H-Beta zeolites at different pressures.

1. Ávila, M. I. et al. Catal. Today 456, 115343 (2025). 2. Artillo, F. et al. Ind. Crops Prod. 194, 116313 (2023).

Role of active phases based on Fe, Zn and MgCl2 for in-situ upgrading of bio-crude during hydrothermal liquefaction of tannery sludge

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11:00-12:40 Session S2.3: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Hydrothermal liquefaction (HTL) of tannery sludge (TS), carried out in hot pressurized water (ca. 200–375°C and 40–200 bar), enables the conversion of TS into bio-crude, as target product, together with a gaseous, solid, and aqueous co-products, while not aiming at a complete oxidation of the organic matrix, potentially preventing the oxidation of chromium to its more harmful hexavalent form [1]. However, HTL-derived bio-crude often contains high O, N, and S content, leading to poor fuel properties. To mitigate these limitations, Fe, Zn and $MgCl_2$ were in-situ added during HTL to improve bio-crude quality [2]. Experiments were conducted in a 500 mL batch autoclave reactor at 350°C for 10min with 20% (percentages are by weight) of dry sludge and active phase loadings of 5–50%, (1–10% of loaded slurry). The feedstock and HTL products were characterized by ash content, elemental analysis, and higher heating value (HHV). For Zn-assisted HTL (the only case reported, for brevity), the gas phase was analyzed by micro-GC at 20% and 50% of Zn loadings to determine the gas composition and estimate the aqueous-phase product yield. This enabled the evaluation of the gas-phase HHV and the associated energy recovery (ERG), which contributes to the total energy recovery (ERTOT) of the HTL process. Table 1 reports HTL product yields, and the characterization of bio-crude and gas obtained from Zn-assisted tests. Raising the Zn concentration up to 25%, the bio-crude and gas yield slightly increase and the aqueous phase yield decreases, while a subsequent increase in Zn concentration leads to a decrease in these phases in favor of the solid residue.

Zn [%]	Y_S^{db} [%]	Y_G^{db} [%]	Y_{BC}^{db} [%]	Y_{AP}^{db} [%]	Bio-crude characterization						
					C [%]	H [%]	N [%]	S [%]	O [%]	HHV_{BC}^{db} [MJ/kg]	ER_{BC} [%]
0	56.0	5.0	25.1	13.9	62.1 ±0.5	9.2 ±0.1	2.0 ±0.1	1.5 ±0.1	25.2 ±0.6	30.5	45.8
5	54.6	5.9	25.9	13.6	60.8 ±0.5	8.9 ±0.2	2.0 ±0.1	1.7 ±0.2	26.6 ±0.7	29.4	45.6
10	56.2	8.9	24.2	10.7	64.6 ±1.4	9.1 ±0.3	2.2 ±0.1	1.3 ±0.03	22.8 ±2.3	31.5	45.6
15	57.3	5.1	24.6	13.0	63.6 ±0.5	9.0 ± 0.2	2.0 ±0.1	1.3 ±0.2	24.1 ±0.6	30.9	45.5
20	57.9	7.9	26.2	8.0	65.8 ±0.2	9.5 ±0.2	2.4 ±0.01	1.0 ±0.02	21.3 ±0.5	32.7	51.3
25	58.4	9.1	27.8	4.7	62.8 ±0.9	9.0 ±0.4	2.0 ±0.1	0.9 ±0.03	25.3 ±1.2	30.3	50.4
50	63.8	7.0	26.6	2.6	61.4 ±0.8	8.4 ±0.2	2.0 ±0.1	1.5 ±0.1	26.7 ±1.1	28.9	46.0

Gas phase characterization								
Test	Gas phase compounds yield (N-free, wt%)					Energy properties		Total energy recovery
Zn [%]	H_2	CO_2	CO	$C_1 - C_6$	CH_4	HHV_G^{db} [MJ/kg]	ER_G [%]	ER_{TOT} [%]
20	0.4	6.5	0.02	0.9	0.1	13.8	6.6	57.9
50	1.0	5.5	0.03	0.3	0.2	23.9	10.1	56.1

Compared to the TS (34.4% C, 4.8% H, 2.7% N, 3.2% S, 13.9% O, and HHV of 16.7 MJ/kg), the C and H content of bio-crude increases and N and S content decreases, with HHV almost doubled. Compared to the test without active phases, C and H contents increased with Zn loading, peaking at 20% and decreasing thereafter. The nitrogen content remains nearly unchanged compared to the test without active phase. Sulphur content generally decreases with increasing active phase concentration, likely due to ZnS formation during HTL, which promotes deoxygenation reactions [3]. The HHV increases with Zn concentration, peaking at 32.7 MJ/kg and 51.3% energy recovery at 20% Zn, before decreasing at 50% Zn.

Regarding the gas phase characterization, hydrogen production was higher at 50% Zn than at 20% Zn. The HHV values of 13.8 MJ/kg and 23.9 MJ/kg were obtained for the 20% and 50% Zn tests, corresponding to ERG increases of 6.6% and 10% relative to bio-crude alone and resulting in ERTOT of 57.9% and 56.1%, respectively. Table 1. Yields (Y) on dry basis (db) and properties of the bio-crude and gas phase obtained with Zn-assisted HTL tests. S=solid; G=gas; BC=bio-crude; AP=aqueous phase.

References

[1] F. Di Lauro, M. Balsamo et al., Fuel, 399 (2025) 135595. [2] C. Prestigiacomo, J. Zimmermann et al., Fuel Processing Technology, 237 (2022) 107452. [3] Q. Zhou, S. Yang et al., Applied Catalysis B: Environmental, 282 (2021) 119603.

Bifunctional magnetic Co3O4-B/C catalysts for the thermochemical conversion of non-reciclable plastic waste

F. Ortega (Department of Chemical Engineering, University of Granada, Spain) L. Jiménez-Rodríguez (Department of Chemical Engineering, University of Granada, Spain) G. Blázquez (Department of Chemical Engineering, University of Granada, Spain) M. Calero (Department of Chemical Engineering, University of Granada, Spain) Mario J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

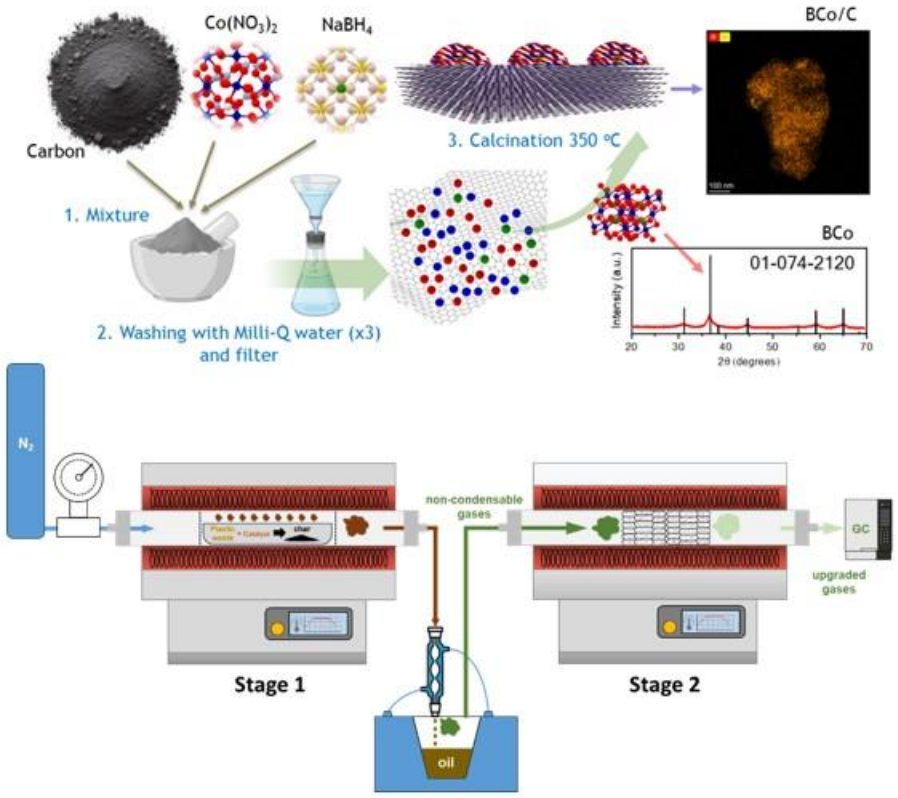
11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

The work presents a catalytic study focused on the valorization of the gas fraction generated during the pyrolysis of non-recyclable plastic waste. It encompasses both the development of catalytic materials and the optimization of a two-step process aimed at improving the gas composition toward a hydrogen-rich stream. The catalysts were synthesized through a simple and scalable solvent-less approach. The most promising material, a ternary Co2O3/B/Carbon system, not only exhibited remarkable catalytic activity but also displayed magnetic properties that facilitate its separation during the insitu pyrolysis stage. The study identifies and discusses the roles of the Co-related metallic components supported on carbon, as well as the contribution of the minor boron species. Overall, this work provides clear evidence of the potential of a two-step catalytic configuration for the valorization of plastic residues that currently accumulate in landfills.



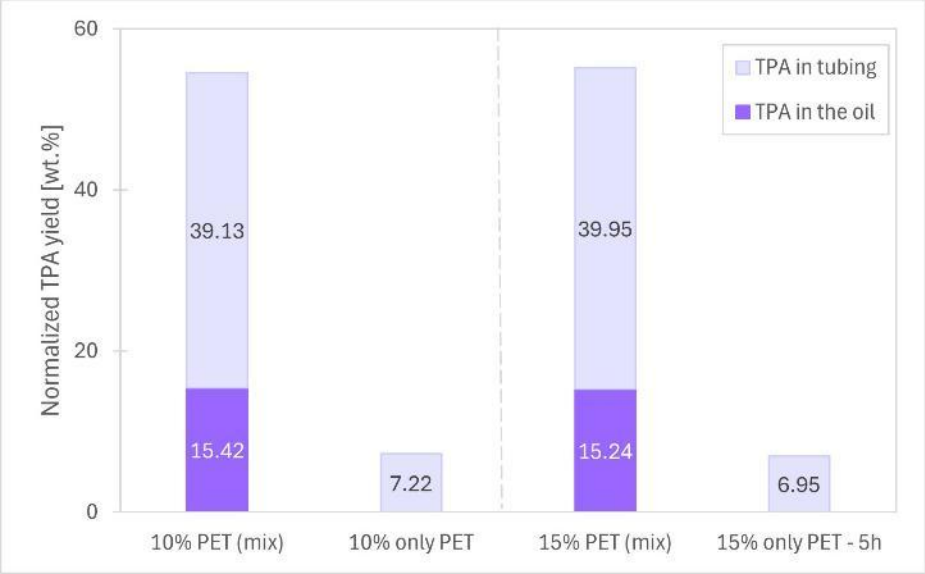
Trade-offs between pyrolysis oil quality and valuable chemicals: the case of the co-pyrolysis of HDPE and PET

Diana Cecilia Ruiz Flores (Maastricht University, Netherlands) Arnab Chaudhuri (Maastricht University, Netherlands) M. Pilar Ruiz (Maastricht University, Netherlands)

11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

Despite its promise, pyrolysis remains challenging to implement for mixed plastic waste recycling. For instance, high-density polyethylene (HDPE) is one of the most abundant polyolefins in plastic waste and an ideal candidate for pyrolysis oil production due to its high volatile matter content (>90 wt.%)[1],[2]; however, when co-pyrolyzed with other plastics like polyethylene terephthalate (PET), the obtained oil yields are lower than its theoretical values [1]. Therefore, the purpose of this study is to better understand the effects of the co-pyrolysis of PET and HDPE on oil yields and their quality. Experiments were conducted in a stainless-steel semi-batch tubular reactor at 440 °C using PET mixtures ranging from 5 to 20 wt.%. Analysis of the composition and molecular weight distribution of the condensable products were performed using GPC, GC-MS, and FTIR. Gas product was analyzed by GC, while the purity of terephthalic acid (TPA) was analyzed by HPLC and FTIR. The results demonstrate a proportional decrease in oil yield with increasing PET content of the feed. This decrease in oil yield was expected, as no oil is produced when PET is pyrolyzed alone. However, the oil yield obtained during co-pyrolysis is lower than the expected value from HDPE depolymerization, indicating that some products derived from HDPE pyrolysis may undergo some kind of aromatization (e.g., benzene, toluene, PAHs). Nonetheless, the aromatization process is not limited to the gas and solid phases. FT-IR analysis reveals that the first four oil samples — collected after 15, 30, 60, and 90 minutes of reaction — also contain aromatic and arene compounds, whose concentration decreases over time. This behavior is consistent with the earlier onset of PET pyrolysis compared to HDPE. In addition to aromatic species, FTIR spectra show the presence of oxygenated compounds in the oil, whose concentration likewise decreases with reaction time. The presence of oxygenated and aromatic compounds undoubtedly lowers the quality of the pyrolysis oil; however, this drawback is partially offset by the enhanced recovery of terephthalic acid (TPA). During these experiments, approximately 55 wt.% of TPA was recovered, mainly in the tubing (≈39 wt.%), with a maximum recovery of 70 wt.% achieved when 5 wt.% PET was present in the feed mixture. Furthermore, HPLC analysis revealed that the TPA collected in the tubing exhibits a purity exceeding 95%, in comparison to the TPA present in the oil phase, which appears to undergo secondary reactions, as indicated by the presence of 3–5 additional peaks in the HPLC chromatograms. When compared with pyrolysis of pure PET, where only 7 wt.% TPA is recovered, these results clearly demonstrate that PET–HDPE co-pyrolysis, although unfavorable for the oil quality, offers a significant opportunity for the recovery of a valuable chemical



. [1] S. D. Anuar Sharuddin, et al., “A review on pyrolysis of plastic wastes,” May 01, 2016, Elsevier Ltd. doi: 10.1016/j.enconman.2016.02.037.

[2] M. Kusenberg et al., “Opportunities and challenges for the application of post-consumer plastic waste pyrolysis oils as steam cracker feedstocks: To decontaminate or not to decontaminate?,” Feb. 01, 2022, Elsevier Ltd. doi: 10.1016/j.wasman.2021.11.009.

Stepwise Thermochemical Conversion Strategies for Waste Plastics: Coupling Auger and Fluidized Bed Reactors for PE and PVC Valorization

Jong-Woo Kim (University of Seoul, South Korea) Chul-Woo Park (University of Seoul, South Korea) Joo-Sik Kim (University of Seoul, South Korea)

11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

This study investigates the multi-stage (stepwise) thermochemical conversion of polyethylene (PE) and polyvinyl chloride (PVC) using distinct reactor configurations. The multi-stage processes were designed as either a two-stage system, consisting of an auger reactor connected to a fluidized bed reactor, or a three-stage system incorporating a tar-reforming reactor connected in series downstream of the fluidized bed reactor. For PE, experiments were conducted using the two-stage process with a feed capacity of 500 g/h, aiming to maximize the direct production of light olefins (C_2–C_4). The results demonstrated that preheating the PE to 300 °C in the first-stage auger reactor prior to the main reaction in the fluidized bed enhanced the light olefin yield by 6–8 wt% compared to direct feeding into the fluidized bed reactor. In the case of PVC, the three-stage process with a feed capacity of 500 g/h was employed to induce dehydrochlorination in the first stage. This approach aimed to convert chlorine in PVC into HCl for extraction prior to entering the fluidized bed reactor, thereby mitigating downstream contamination. The dechlorinated PVC pyrolysis char subsequently underwent steam gasification in the fluidized bed reactor, followed by continuous tar reforming to generate hydrogen-rich, low-tar syngas. Experimental results confirmed that 98 wt% of the total chlorine balance was pre-extracted in the auger reactor. Furthermore, depending on the operating temperature of the tar-reforming reactor, a maximum hydrogen yield of 89 g kg^{-1} PVC was achieved. The primary significance of this research lies in demonstrating that a simple stepwise thermal approach can effectively remove problematic substances from PVC while maintaining stable operating conditions, as well as enhance target product yields (e.g., light olefins in the PE study). Furthermore, this study contributes by proposing process configurations optimized for specific feedstock characteristics and by providing essential inventory data for future process scale-up and expansion assessments.

Heating rate of the rotary-kiln reactor on the pyrolysis of waste plastics

Kai Deng (Dalian Institute of Chemical Physics, China) Xingshan Shi (Dalian Institute of Chemical Physics&Nanjing Tech University, China) Fuzheng Li (Dalian Institute of Chemical Physics&Nanjing Tech University, China) Weiyang Xue (Dalian Institute of Chemical Physics, China) Weiling Piao (Dalian Institute of Chemical Physics, China) Songbo He (Dalian Institute of Chemical Physics&Nanjing Tech University, China)

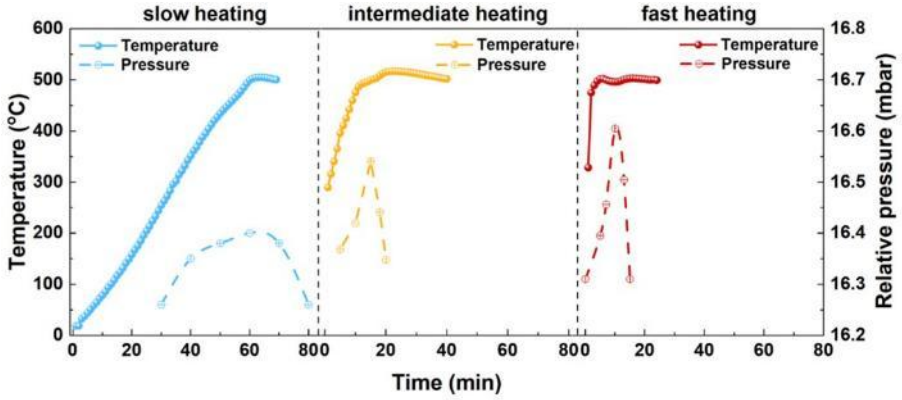
11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

Fast pyrolysis is regarded as a promising pathway for the chemical recycling of waste plastics due to its high heating rate and potential to suppress secondary reactions [1]. However, most supporting evidence is derived from idealized reactors, whereas industrial practice commonly employs rotary-kiln or horizontal reactors with distinct heat and mass transfer [2]. In this study, three representative operations of the rotary-kiln reactors with different heating rates (Figure 1) were investigated, including a slow heating rate of about 6 °C min-1 by programmed heating of the furnace (together with the reactor and plastics), an intermediate heating rate of about 32 °C min-1 by inserting the reactor (together with plastics) into a preheated furnace, and a relatively fast heating of about 100 °C min-1 by loading the plastics to the preheated reactor. Pyrolysis of three types of waste plastics including PP, PE, and PS were studied at temperatures of 450, 500, and 550 °C. The pyrolysis products, including gas, liquid oil, and solid char were analyzed by GC-TCD, GC-FID, SimDis, GPC, XRF, TGA, and elemental analysis. Results of the pyrolysis at 500 °C (Figure 1) indicated that heating rate had a minor influence on the liquid oil yields of 58-60 wt.% for PP, 64-66 wt.% for PE, and 78-83 wt.% for PS. However, the product quality was significantly affected by the heating rate. Compared to slow heating, fast heating resulted in a decreased average molecular weight of liquid oil (e.g., from 2407 to 1566 g mol-1, for PE pyrolysis); a transition from waxy liquid to semi-fluid oil; and an increased selectivity of the product (e.g., styrene, from 46.8% to 58.0% for PS pyrolysis). With the comprehensive analysis of the mass/carbon balance and product property, this contribution is a very good reference for the applied pyrolysis of plastics.



Hydrogen and syngas production from plastic waste pyrolysis and in line sorption enhanced steam reforming

Pablo Comendador (University of the Basque Country, Spain) Stephanie Arias (University of the Basque Country, Spain) Katrin Santin (University of the Basque Country, Spain) Farid Atashi (University of the Basque Country, Spain) Gartzen Lopez (University of the Basque Country, IKERBASQUE, Spain) Maider Amutio (University of the Basque Country, Spain) Maite Artetxe (University of the Basque Country, Spain)

11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

Plastic waste generation is a major concern, as it is continuously increasing around the world, with waste being usually incinerated, disposed of in landfills or released into the environment. Therefore, the promotion of recycling strategies is a key aspect for contributing to sustainability. In particular, thermochemical valorization routes with integrated CO2 capture are very promising due to their potential for producing highly pure H2 with limited CO2 emissions. In this work, the conversion of HDPE, PP, PS and PET to hydrogen through a two-step pyrolysis-reforming process was studied based on thermodynamics. Plastics were first pyrolyzed in a spouted bed reactor using steam as fluidizing agent, and the volatiles generated were directed towards the sorption enhanced steam reforming step. CaO was used as sorbent, and it was found that in the temperature range that allowed full CO2 capture (400-600 °C), maximum H2 production (pure H2) according to stoichiometry was attained (0.43 kgH2 kg-1plastic for the HDPE and PP, 0.38 kgH2 kg-1plastic for the PS and 0.15 kgH2 kg-1plastic for the PET). Above 600 °C, the promotion of the CaCO3 decomposition led to lower H2 production and purity, with the sorption enhancing effect being negligible at 800 °C. The steam to plastic ratio was also evaluated (0.5-4 range), and it was concluded that it had a minimal effect on H2 as long as there was enough steam according to stoichiometry (2.57 kgH2O kg-1plastic for the HDPE and PP, 2.77 kgH2O kg-1plastic for the PS and 0.99 kgH2O kg-1plastic for the PET). It implied that the driving force of the CO2 capture in the reaction network was sufficient for converting all the pyrolysis volatiles to H2. Finally, and using the HDPE case as reference, the conversion of the CaCO3 formed into syngas and CaO by recirculating a fraction of the H2 produced was evaluated. It was identified that the optimum conditions were a CaCO3 regeneration temperature of 750 °C and a ratio between the H2 fed to the regeneration step and the H2 produced of 0.61. Under optimum conditions (pyrolysis temperature of 500 °C, reforming temperature between 400 and 600 °C and steam to plastic ratio higher than 2.57 (stoichiometric value)), 0.43 kgH2 kg-1HDPE were produced. By feeding 0.26 kgH2 kg-1HDPE to the CaCO3 regeneration step (750 °C), 1.36 kgsyngas kg-1HDPE were generated, converting 60 % of the CO2 released from the CaCO3. In conclusion, these results are evidence of the potential of this pyrolysis-reforming process for converting plastic waste into valuable products with low CO2 emissions.

Validating solar relevant PHC:biomass ratios in fluidized bed fast pyrolysis

Gabriel Costa (Instituto de Carboquímica (ICB-CSIC), Spain) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain) José Manuel López (Instituto de Carboquímica (ICB-CSIC), Spain) María Soledad Callén (Instituto de Carboquímica (ICB-CSIC), Spain) Marco Colombi (Politecnico di Milano, Department of Energy, Italy) Marco Binotti (Politecnico di Milano, Department of Energy, Italy) Tomás García (Instituto de Carboquímica (ICB-CSIC), Spain) Ramón Murillo (Instituto de Carboquímica (ICB-CSIC), Spain)

11:00-13:00 Session S2.4: Applied pyrolysis: Polymers and recycling

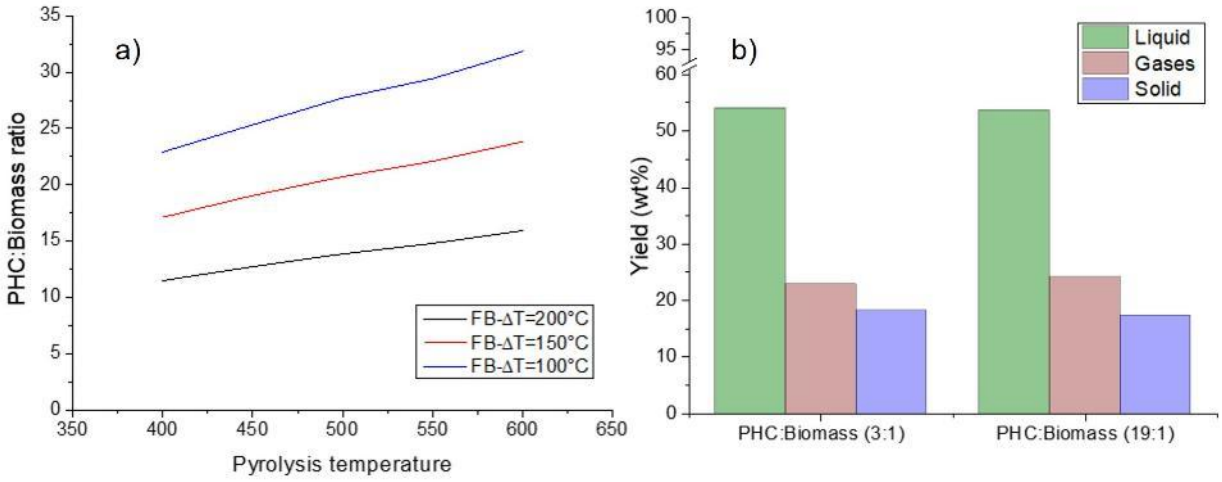
Location: ROOM B – GROUND FLOOR

Chairs: Alba Dieguez-Alonso (TU Dortmund University, Germany) Shogo Kumagai (Tohoku University, Japan)

ABSTRACT

Solar assisted fast pyrolysis can reduce the bio-oil carbon foot print via renewable energy. In PySOLO project, we evaluate particulate heat carriers (PHCs) and fluidized bed operating windows, using electrical heating to reproduce solar boundary conditions. Experiments were performed in a TRL4 bubbling fluidized bed unit (35 runs) under inert N2 using pine chips. Bed temperature and pressure drop were continuously monitored to ensure stable fluidization and steady state. Three PHCs, silica sand, bauxite and olivine, were tested, spanning inert to potentially catalytic behavior. Products were quantified as char, condensable liquids and permanent gases. Liquids were analyzed by GC-MS, while gases were analyzed by GC (H2, CH4, CO, CO2 and C1–C4 hydrocarbons). Operating ranges were: BedT= 400-550 °C, PHCT= 450-650 °C, and 3–9×Vmf (u/umf), with a PHC:biomass ratio of 3:1 and 19:1. Additionally, the heat to be provided by the PHC and thus its mass flow rate (for different ΔT defined as PHCT − BedT) (was quantified by isolating each contribution (reaction heat, gas heating, biomass + moisture heating, and losses) using the Creck fluidized bed model integrated in Aspen Plus. The calculations assumed, biomass at 70 °C with 10% moisture, biomass flow 0.66 kg h-1, fluidizing gas/biomass 3.5 kg kg-1 and bed losses 1% of biomass LHV. Under solar operation, the PHC:biomass ratio sets the thermal buffering capacity required to decouple heat delivery from biomass conversion and maintaining fast pyrolysis heating rates, Figure 1a. Screening results highlight that PHC selection and hydrodynamics must be co-designed. With bauxite, replicate tests at BedT=450 °C, PHCT=550 °C and 5×Vmf yielded 20, 50, 25 wt% (solid, liquid, gases) showed robustness (σ < 3.4). Olivine showed signs of catalytic vapor cracking but presented attrition related operability limitations, thus silica and bauxite were prioritized. The model derived high ratio condition was experimentally validated with silica at 19:1, BedT=450 °C, PHCT=600 °C (ΔT=150°C), 7×Vmf, yields were 17.3, 53.6, 24.1 wt% (solid, liquid, gases) mass balance closure 95 wt% and steady state operation, fully comparable to the reference silica case at 3:1 (BedT=450 °C, PHCT=550 °C, 7×Vmf, yields: 18.2, 54, 22.9 wt% (solids, liquid, gases), Figure 1b. Figure 1. a) Theoretical silica sand:biomass mass ratio calculated with Creck model (Aspen plus integrated) as a function of pyrolysis temperature for different ΔT values (difference between PHCT and BedT); b) Product yields for silica at BedT = 450 °C, 7×Vmf: reference (PHC:biomass 3:1, PHCT = 550 °C) vs solar relevant condition (PHC:biomass 19:1, PHCT = 600 °C; ΔT = 150 °C). The results show that PHC:biomass ratio can be increased to solar relevant levels (19:1) without penalizing yields, provided that PHC selection and fluidization ensure thermal homogeneity and rapid heat transfer.

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Slow pyrolysis under recirculated exhaust gas atmospheres: effect of steam on biochar and co-products

Corinna Maria Grottola (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Paola Giudicianni (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Davide Amato (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Luigi Stanzione (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Raffaele Ragucci (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy)

15:30-16:30 Session S2.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Chamseddine Guizani (VTT, Finland) Hongwei Wu (Curtin University of Technology, Australia)

ABSTRACT

The transition toward a bio-economy, in line with the EU 2030 targets, requires enhanced and more efficient utilization of biomass and alternative renewable resources. Slow pyrolysis is a mature technology suitable for large-scale processing of lignocellulosic feedstocks, producing biochar alongside valuable co-product, namely bio-oil, a precursor of biofuel and chemicals, and a gaseous phase. One strategy for energetically supporting pyrolysis, particularly in the case of decentralised units and mobile installations dedicated to biochar production, is to integrate the pyrolysis unit with a proper burner capable of oxidizing pyrolysis vapors and recirculating the exhaust (containing a mixture of N2, CO2, H2O) to the pyrolysis unit. Different atmospheres can affect product yield and properties. However, steam and CO2 have been widely studied primarly as gasifying or activating agents at high temperatures [1]. Recently, there has been growing interest in the exploration and use of CO2 also under pyrolysis conditions [1], whereas few studies are devoted to the presence of steam and its effect on biochar [2]. Steam plays a role not only in the extraction of volatile compounds, resulting in a well-developed porous structure and active sites on the surface of biochar, but it also strongly influences reaction pathways in the formation of liquid compounds in the early stage of hemicellulose decomposition [3]. Herein, a parametric study is presented to investigate the effect of H_2O concentration in an N_2 carrier gas during the pyrolysis of poplar at different final temperatures. Preliminary results show that the nature of the pyrolysis atmosphere influences the products yields. In particular, at increasing temperatures, the presence of pure steam leads to a reduction in biochar yield compared to pure nitrogen, while promoting the formation of gaseous and liquid products due to intensified devolatilization and secondary cracking. Under inert conditions and lower steam concentration, higher temperatures produced biochar with greater aromaticity, higher carbon content, and lower oxygen levels, characteristics favorable for long-term carbon sequestration. Increasing the steam ratio in the composition of the pyrolysis atmosphere, the reactive action of steam further reduces biochar yield through gasification reactions, enriching the gas composition in CO, CH4, and H_2.

Oxidative torrefaction of biomass in a fluidized bed to produce biochar with high grindability

Mengjuan Zhang (Shenyang University of Chemical Technology, China) Kaixuan Yang (Shenyang University of Chemical Technology, China) Chao Wang (Shenyang University of Chemical Technology, China) Xiaoyu Wu (Shenyang University of Chemical Technology, , China) Gang Song (Shenyang University of Chemical Technology, China) Zhenglin Wang (Shenyang University of Chemical Technology, China) Zhennan Han (Shenyang University of Chemical Technology, China) Xin Jia (Shenyang University of Chemical Technology, China) Guangwen Xu (Shenyang University of Chemical Technology, China)

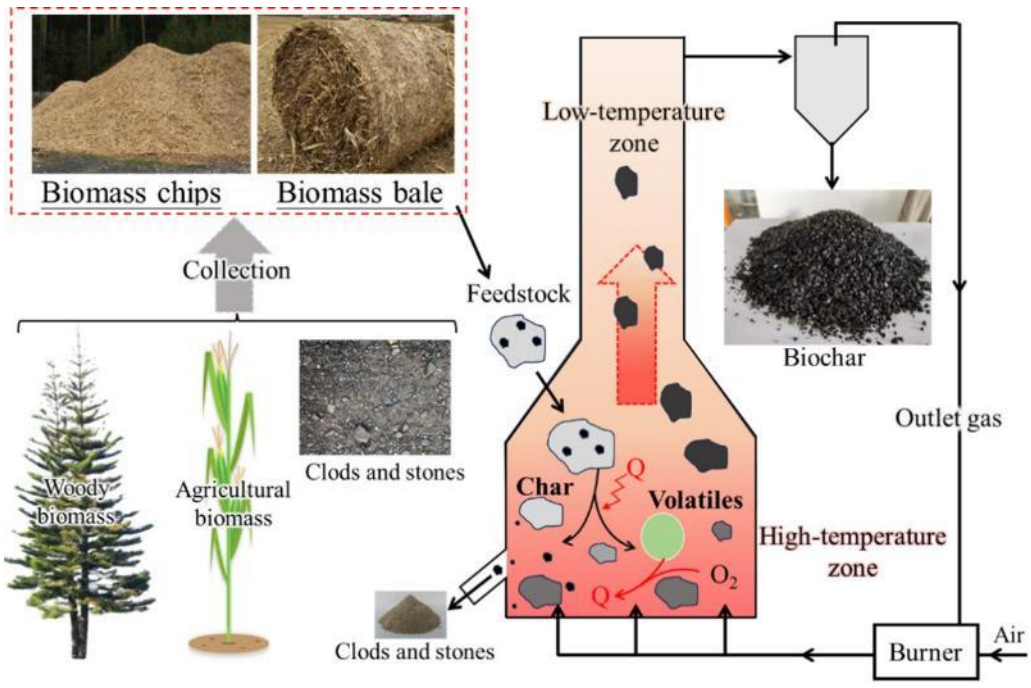
15:30-16:30 Session S2.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Chamseddine Guizani (VTT, Finland) Hongwei Wu (Curtin University of Technology, Australia)

ABSTRACT

As a critical renewable energy source, biomass utilization is hindered by two major challenges: inherently low energy density and poor grindability. During torrefaction process, oxygen is removed through water vaporization and cracking of oxygen-containing functional groups presenting in biomass, thereby raising the energy density of the obtained biochar. The depolymerization or breakdown of cellulose and hemicellulose structures in biomass also enhance the grindability of biochar. In this work, a fluidized bed oxidative-torrefaction process was designed to torrefy pine wood pellets and produce biochar with superior grindability. The results of comparative experiments at a feeding rate of 1 kg/h under varied operating parameters demonstrated that as the operating temperature and O2 concentration in fluidizing reagent increased, the yield of biochar gradually decreased and the grindability of produced biochar obviously improved. The content of oxygen in biochar greatly decreased, proving that the fluidized bed flash-torrefaction increases the energy density of biomass used as a fuel or a raw feedstock for other thermochemical conversions such as gasification. Additionally, the tested oxidative torrefaction exhibited excellent continuous operation stability, and enabled the steady production of biochar, thus providing an effective solution to the upgrading of biomass. Reference



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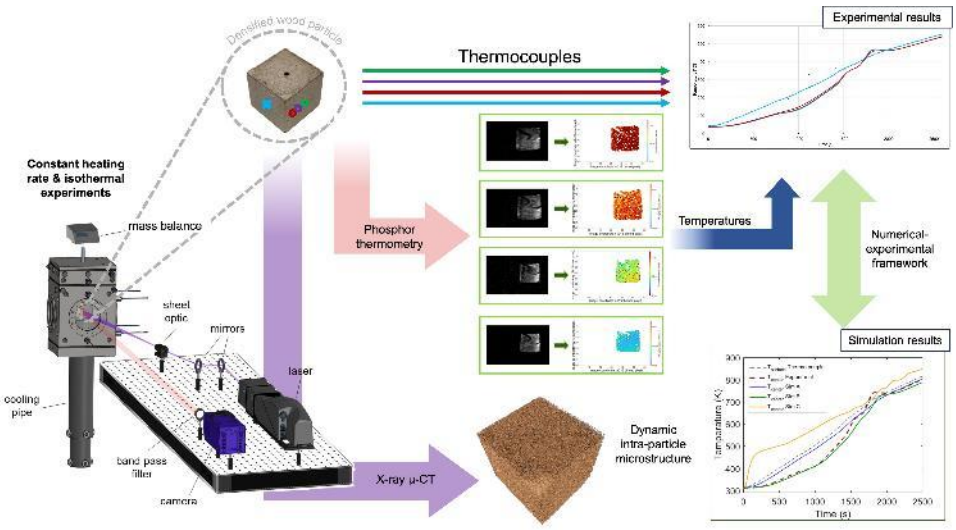
Influence of Wood Anisotropy on Pyrolysis Behavior: Experimental and Numerical Study

Fabienne Ryll (TU Dortmund University, Germany) Andrea Dernbecher (TU Dortmund University, Germany) Reiner Zielke (TU Dortmund University, Germany) Alba Dieguez-Alonso (TU Dortmund University, Germany)

15:30-16:30 Session S2.5: Applied pyrolysis: Biomass valorisation
Location: ROOM A – GROUND FLOOR
Chairs: Chamseddine Guizani (VTT, Finland) Hongwei Wu (Curtin University of Technology, Australia)

ABSTRACT

Solid–fluid reactive systems are fundamental to thermochemical biomass conversion technologies such as pyrolysis and gasification. Further progress in these processes requires a detailed understanding of the coupled transport, reaction, and structural evolution phenomena occurring at the scale of individual particles, which may govern reactor performance [1]. In pyrolysis reactors, particle-scale heat and mass transfer strongly interact with chemical reactions and evolving material properties, directly affecting conversion rates and product yields [1]. However, resolv-ing intra-particle dynamics remains computationally expensive, and most reactor-scale models therefore rely on simplified particle representations. Spatially resolved continuum particle models provide detailed descriptions of intra-particle temperature gradients and transport–reaction coupling but typically assume isotropic properties, uniform boundary conditions, and idealized particle geometries. These assumptions do not generally hold for biomass, due to its hierarchical structure, anisotropic pore network, and non-spherical shape. Pore-resolved studies have demonstrated the importance of intra-particle anisotropic transport during pyrolysis and gasification [2-5], but their computational cost limits their applicability to very small systems. To bridge the gap between physical fidelity and computational efficiency, this work presents a three-dimensional, pore-informed, continuum particle model for biomass pyrolysis.



The model incorporates pore-informed and direction-dependent transport properties, derived from pore-resolved simulations, to account for the influence of pore network on heat and mass transport, as well as on transport-chemistry interactions during pyrolysis. This approach enables spatially resolved predictions of intra-particle temperature and conversion at a computational cost suitable for practical simulations and integration into multiphase reactor models.

Model development and validation are supported by a dedicated experimental campaign measuring internal (several intra-particle positions) and surface particle (with phosphor thermometry) temperatures during pyrolysis. The impact of anisotropic intra-particle pore structure is addresed by comparing natural with densified particles, both using beech wood. Experiments are perfor-med under constant heating rates, representative of slow pyrolysis, and under rapid, isothermal heating conditions relevant to industrial reactors. The combined experimental and simulation results demonstrate the critical role of particle anisotropy and heating mode on intra-particle transport and pyrolysis behavior, providing a physically grounded and computationally efficient pathway for improved particle-scale modeling in biomass pyrolysis.

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Extending the Analytical Power of Applied Pyrolysis for Polymers through Online FT-ICR MS Analysis of Heavy Thermo-desorption and Pyrolysis Products

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15:30-16:30 Session S2.6: Analytical pyrolysis: synthetic polymers; Py instrumentation and methodology

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Degano (Department of Chemistry and Industrial Chemistry, Università di Pisa, Italy) Alessandro Rombolà (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy)

ABSTRACT

(a) Both first authors. Pyrolysis coupled with gas chromatography and mass spectrometry (Py-GC/MS) is a widely used technique for analyzing synthetic polymers and copolymers due to its strong structural identification capabilities. It enables direct analysis, requires very small sample amounts, and provides a chemical fingerprint that allows identification of polymeric materials based on their degradation products. Py-GC/MS is particularly effective for identifying unknown polymers, characterizing copolymer compositions, and studying organic additives even at low concentrations. In addition, pyrolysis is well-suited for investigating aging phenomena, thermal degradation, and the analysis of microplastics in complex matrices. However, the information obtained is most often limited to low-molecular-weight pyrolysis products (< 200 Da), and the low-resolution mass spectrometers commonly employed offer restricted analytical performance. While semi-quantitative information on comonomer distributions can be obtained for copolymers, polymer chain length information remains inaccessible. We have recently developed in our laboratory two novel online methodologies for the analysis of thermo-desorption (TD) and pyrolysis (Py) products of synthetic polymers coupled to Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS). These approaches enable precise identification of the nature and distribution of high-molecular-weight products (up to ~1,500 Da) generated during thermo-desorption and pyrolysis processes, exploiting the ultra-high resolving power and mass accuracy of FT-ICR MS. The first methodology couples a thermal desorption/pyrolysis (TD/Py) device to FT-ICR MS using direct analysis in real time (DART) as the ionization technique. It was applied to two poly(vinylidene fluoride) (PVDF) samples. Below 400 °C, distributions of the smallest oligomers (M_n ≈ 600 Da) were observed, enabling end-group identification and clear differentiation between the two PVDF materials. The detection of specific pyrolysis products for one sample demonstrated that it was a poly(VDF-co-HFP) copolymer containing 5.1% hexafluoropropylene (HFP), in good agreement with the comonomer content determined by ^{19}F NMR spectroscopy. The second methodology enables online analysis of fast polymer pyrolysis products by combining an FT-ICR MS instrument with a modified direct introduction probe (DIP) operated under atmospheric pressure chemical ionization (APCI). A controlled gas flow within the DIP glass capillary allows fine control of the residence time of generated species in the pyrolysis zone. At the same time, a micro-thermocouple in direct contact with the sample provides real-time monitoring of temperature evolution. Comparison with an empty capillary reveals endothermic processes intrinsic to polymer pyrolysis. Application to polystyrene (PS) samples demonstrated a strong dependence of pyrolysis product distributions on polymer chain length. While styrene oligomers containing up to approximately twelve monomer units were detected for all samples, only low-M_n PS led to significant observation of end-group-containing species, either intact (TD) or degraded (Py). Principal component analysis enabled discrimination between end-group-related compounds and products arising from thermal chain degradation. The relative distribution of these two compound families correlated with PS molar mass and shows promise for determining M_n values below 10 kDa.

Fundamental Study on Abnormal Peak Appearance in the Mid-Boiling Point Range in Pyrolysis-GC/MS

Atsushi Watanabe (Frontier Laboratories; Tohoku University, Japan) Pariza Shokeitei (Frontier Laboratories, Japan) Norio Teramae (Frontier Laboratories; Tohoku University, Japan) Chuichi Watanabe (Frontier Laboratories, Japan) Yasuyuki Ishida (Chubu University; Frontier Laboratories, Japan)

15:30-16:30 Session S2.6: Analytical pyrolysis: synthetic polymers; Py instrumentation and methodology

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Degano (Department of Chemistry and Industrial Chemistry, Università di Pisa, Italy) Alessandro Rombolà (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy)

ABSTRACT

In pyrograms of high-density polyethylene (HDPE), hydrocarbon peaks eluting above C14 often show abnormal peak appearance. As shown in Figure 1 a), a distinctive leading edge appears in a series of triplet peaks. Despite the long history of capillary GC, this phenomenon has been unsolved for more than four decades. Similar abnormal peak appearance is also observed for mid-boiling point hydrocarbons in the C20 to C30 range in chromatograms measured by the conventional split injection of liquid samples. In this study, we examined the mechanism of this phenomenon based on HDPE pyrograms and explored practical countermeasures. HDPE samples were pyrolyzed at 600 °C. Measurements were carried out using a GC/MS system with a micro-furnace pyrolyzer (EGA/PY-3030D, Frontier Laboratories Ltd.) which was directly interfaced with the GC injector. The GC oven temperature was programmed from 40 °C (2 min hold) to 350 °C at 20 °C/min (13 min hold). A packed GC insert was used, filled with either Chromosorb W coated with PDMS or α-alumina as the packing material. A deactivated pre-column (SMC; 0.25 mm i.d., 0.25 to 8 m length, same as above) was connected to a metal capillary separation column (5% diphenyl polysiloxane, 30 m length, 0.25 mm i.d., 0.25 µm film, same as above). Peak resolution and reproducibility were evaluated by EIC (m/z 82) of C21 diene (C21") and monoene (C21'). Acceptable peak separation was obtained for the sample amount of 0.3 mg or less, because higher loadings cause non-uniform introduction of pyrolyzates into the separation column. Therefore, all subsequent measurements were carried out for a sample amount of 0.3 mg. The effects of GC insert packing material and the length of SMC on the abnormal peak appearance were then examined. Under the optimized conditions (using an α-alumina-packed insert and a 2 m SMC), the peak shapes beyond C14 improved significantly as shown in Figure 1 b). Furthermore, the reproducibility of the C21 diene peak area improved from 7.57 % obtained under conventional conditions to 0.68 % after optimization. These results demonstrate that the abnormal peak appearance observed in HDPE pyrograms originates from the sample introduction process and can be effectively mitigated by combining an α-alumina-packed insert with SMC, which also enhanced the peak area reproducibility of hydrocarbons in the mid-boiling point range.

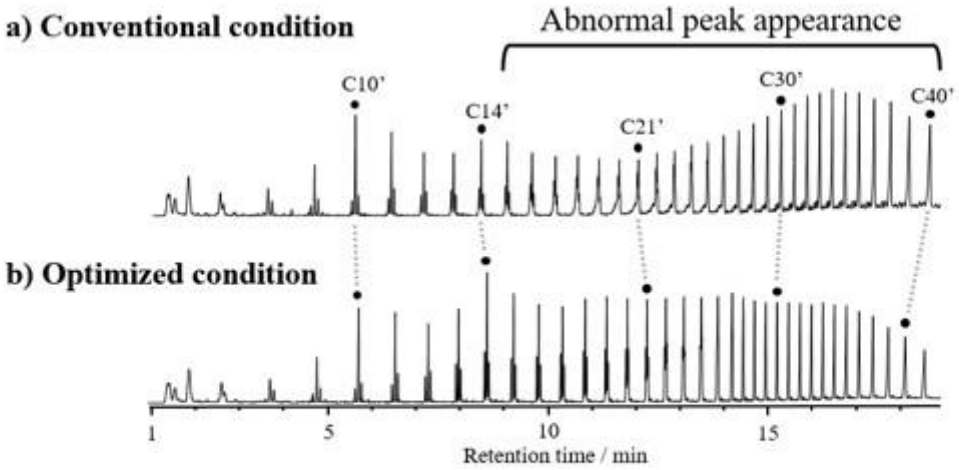


Figure 1. Pyrograms of HDPE. a) Conventional condition without SMC and packing material. b) Optimized condition with SMC and packing material.

Evaluation of recycling potential of wind turbine blade using catalytic pyrolysis and its life cycle assessment

M.S. Giridara Srinivaas (Department of Chemical Engineering, Indian Institute of Technology Madras, Chennai, Tamil Nadu 600036, India, India) Ravikrishnan Vinu (Department of Chemical Engineering, Indian Institute of Technology Madras, Chennai, Tamil Nadu 600036, India, India)

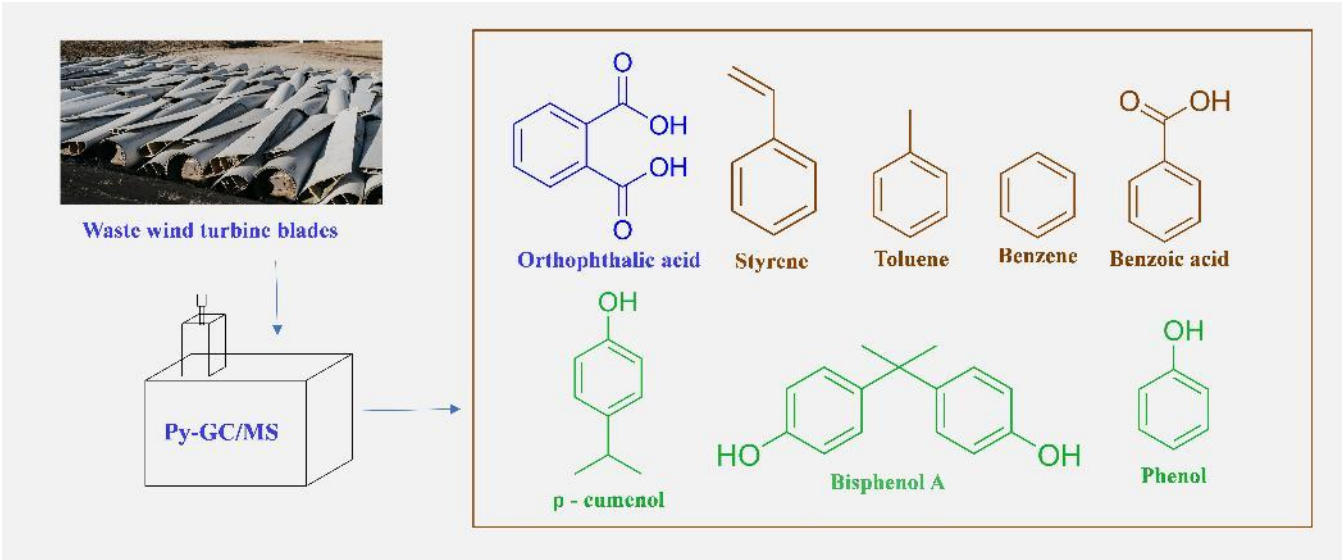
15:30-16:30 Session S2.6: Analytical pyrolysis: synthetic polymers; Py instrumentation and methodology

Location: ROOM A1 – FIRST FLOOR

Chairs: Ilaria Degano (Department of Chemistry and Industrial Chemistry, Università di Pisa, Italy) Alessandro Rombolà (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy)

ABSTRACT

Wind turbine blades (WTB), made of fiber reinforced composites, have a typical lifespan of 20 years, post which they are dumped in landfills. Pyrolysis helps in recycling WTB by converting the polymeric foam and resin portion into pyrolysis oil and gas, while leaving the fibers and char in solid phase. In this study, waste WTB samples from three different installations were analyzed using analytical pyrolysis hyphenated with gas chromatograph/mass spectrometer (Py-GC/MS) to understand the pyrolysis reaction pathways, pyrolysate composition and resource recovery potential. The samples were characterized for their proximate and elemental composition, functional groups and morphology using microscopic and spectroscopic methods. Pyrolysis was carried out at different temperatures, viz., 450 °C, 550 °C, 650 °C, 750 °C. Formation of aromatic acids, phenolics and aromatic hydrocarbons were observed from polyethylene terephthalate foam, epoxy resin and polyester resin portions respectively. The results demonstrated that in the case of resins, temperature is not a significant factor while in the case of polymeric foam, lower temperatures result in high selectivity to specific products such as benzoic acid. Catalytic pyrolysis using HZSM-5 zeolite catalyst produced aromatic hydrocarbons such as benzene, toluene and ethylbenzene. More interesting results on the product quantification and distribution under different temperatures and catalyst loading will be discussed. Life cycle assessment of different recycling methods demonstrated that pyrolysis and chemical recycling provide significant environmental benefits. Energy sources, viz. grid vs wind vs other renewables, were found to have decisive impact on the environmental offsets.



LOW PRESSURE CATALYTIC HYDROPYROLYSIS OF CHLORELLA VULGARIS

Ainhoa Diaz (IMDEA Energy Insitute, Spain) Jennifer Cueto (IMDEA Energy Insitute, Spain) David P. Serrano (IMDEA Energy Insitute, Spain) Inés Moreno (IMDEA Energy Institute, Spain)

15:30-16:10 Session S2.7: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Luis Arteaga-Pérez (Department of Chemical Engineering, Faculty of Engineering, Universidad de Concepción, Concepción, 4030000, Chile., Chile) Liang Wang (SINTEF Energy Research, Trondheim, , Norway)

ABSTRACT

Microalgae are highly promising feedstocks for the production of biofuels and platform chemicals due to their broad availability, rapid growth and high photosynthetic efficiency. Pyrolysis is one of the most widely used methods for converting microalgae into valuable products [1]. However, microalgae-derived bio-oil typically exhibits high oxygen and nitrogen contents and a broad product distribution, including long-chain and short-chain fatty acids, hydrocarbons, esters, light oxygenates, and nitrogenated compounds, which significantly limit their suitability for use as fuel or as a pool of chemicals. As an alternative, catalytic hydropyrolysis integrates pyrolysis and a partial degree of hydroprocessing into a single unit operation, overcoming the main limitations of conventional pyrolysis [2]. In this work, we investigate the catalytic hydropyrolysis of Chlorella Vulgaris (CV) at relatively mild H2 pressures (6 bar), significantly lower than those typically reported in the literature, thus enhancing the technical and economic viability of the process. Specifically, the activity of different bifunctional Pd-based catalysts (5 wt%) supported on ZrO_2, TiO_2, and ZSM-5 is evaluated. As observed in Figure 1A, all catalytic systems reduce bio-oil yields, particularly Pd/TiO_2 and Pd/ZSM-5, which promote the formation of gaseous products and water. Catalyst incorporation leads to a substantial reduction of the oxygen content (<2 wt%); however, the nitrogen amount remains almost invariable (8 wt%), still limiting its application as fuel. Accordingly, the presence of oxygenated compounds such as esters, oxygenated aromatics, and light oxygenates is strongly reduced compared to the thermal experiment (see Figure 1 B), while nitrogenated compounds formed through protein breakdown are the predominant products. Among the catalysts, Pd/ZrO_2 reduces the GC-MS non-detected fraction share (mainly formed by oligomers and heavy species that cannot be detected by this technique and produces the most homogeneous distribution of nitrogenates, primarily monoaromatic pyrrole-derived species. Additionally, it increases the formation of aromatic and aliphatic hydrocarbons compared to Pd/TiO_2 and Pd/ZSM-5.

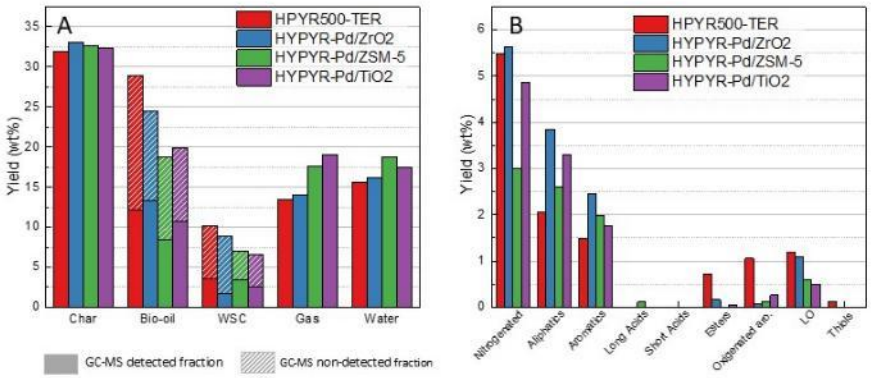


Figure 1. A) Product distribution (mass yields) and B) component family mass yields, determined by GC-MS analyses, obtained in thermal and catalytic hydropyrolysis of CV. Operation conditions: $T_{THERMAL-CATALYTIC}$=500-350 ºC, N_2/H_2=50:50 mL, $[catalyst/CV]_{mass}$=0.2 and 6 bar of H_2 (WSC: Water soluble compounds)

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Acknowledgments

The authors gratefully acknowledge the financial support from MICIU/AEI (10.13039/501100011033) and ERDF/EU under Grant Agreement No. PID2023-147355OB-C21 (HYPY-CAT) and Grant PIPF-2022/ECO-25620 funded by Comunidad de Madrid.

Ex-situ catalytic co-pyrolysis of Bamboo and Polystyrene with Nickel, Molybdenum and cobalt impregnated Red Mud for bio-oil synthesis

Ajay Mugundan Chandran (Indian Institute of Technology Madras, India) Kaustubha Mohanty (Indian Institute of Technology Guwahati, India) Vinu R (Indian Institute of Technology Madras, India)

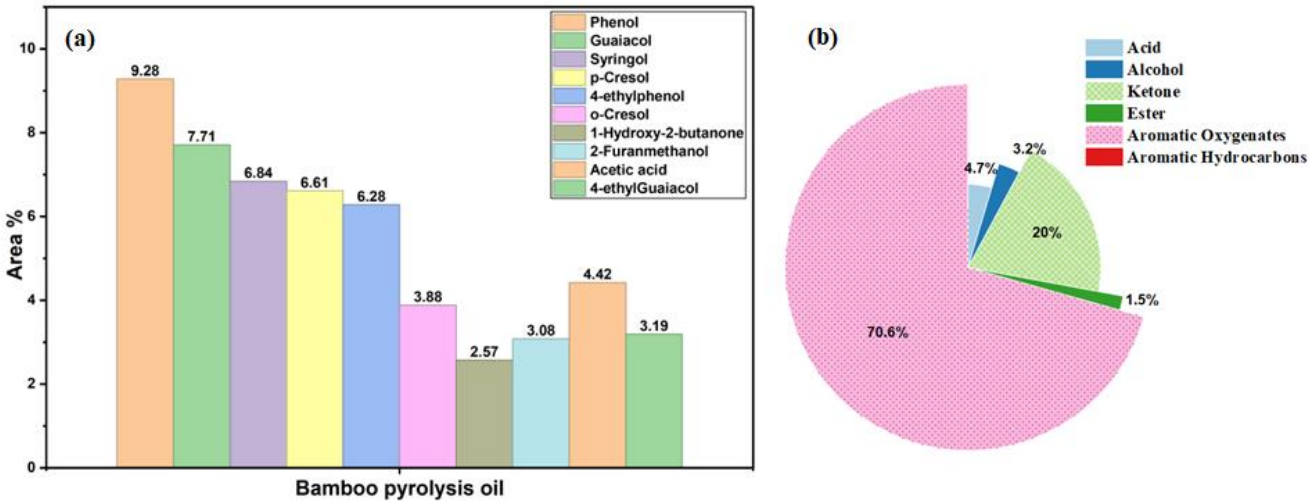
15:30-16:10 Session S2.7: Catalytic pyrolysis: Biomass valorisation

Location: ROOM C1 – FIRST FLOOR

Chairs: Luis Arteaga-Pérez (Department of Chemical Engineering, Faculty of Engineering, Universidad de Concepción, Concepción, 4030000, Chile., Chile) Liang Wang (SINTEF Energy Research, Trondheim, , Norway)

ABSTRACT

Pyrolysis of lignocellulosic biomass like bamboo yields aromatic oxygenates like Phenol, guaiacol and other phenolic derivatives. The presence of intrinsic oxygen in the chemical structure of the oil compounds hinders its usage as biofuel. Therefore, hydrodeoxygenation (HDO) using catalysts or by co-pyrolysis with hydrogen rich plastics like polystyrene (PS) are two of the many effective methods for upgrading bio-derived oils into valuable biofuels with less oxygen content. In this study both of these methods are used and thereby conventional co-pyrolysis of bamboo with polystyrene (PS) was performed using modified red mud catalysts in ex-situ mode. Along with the many metal oxides like Fe2O3, Al2O3, SiO2, TiO2, CaO, Na2O already present in red mud pivotal transition metals like Nickel, Cobalt and Molybdenum that are well-known for deoxygenation, hydrogenation properties were doped with red mud to enhance its catalytic activity. BET surface studies revealed the mesoporous nature of modified red mud catalysts which are desirable for giving higher oil yield. HHVs of biomass and polymer feedstock were 17.7 and 42 MJ/Kg respectively. HHV of the chars were found to be in the range of 31.2 MJ/Kg. Overall, it was observed that calcined red mud and Ni-RM catalysts gave higher oil yield.



Impact of Minerals on the Pyrolysis Behavior and Product Distribution of Polystyrene

Tim Kurtz (Karlsruhe Institute of Technology, Germany) Daniela Merz (Karlsruhe Institute of Technology, Germany) Krassimir Garbev (Karlsruhe Institute of Technology, Germany) Razan Alsharqawi (Karlsruhe Institute of Technology, Germany) Peter Stemmermann (Karlsruhe Institute of Technology, Germany) Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Dieter Stapf (Karlsruhe Institute of Technology, Germany)

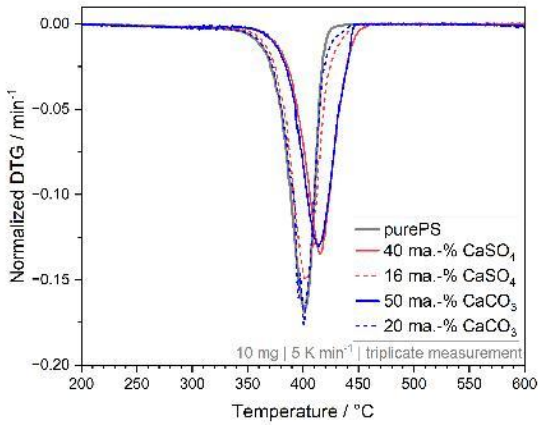
15:30-16:30 Session S2.8: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Haoquan Hu (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China)

ABSTRACT

Mineral fillers are widely used in consumer plastics to enhance processability, improve mechanical properties, and reduce cost [1]. Within a recycling context, however, mineral impurities complicate mechanical recycling, which is primarily suited for feedstocks of higher purities. Chemical recycling via pyrolysis is more tolerant toward contamination and thus suited to process mineral-containing plastics [2]. Understanding the influence of minerals is thus necessary for optimizing pyrolysis-based recycling processes, particularly because knowledge of the pyrolysis behavior of plastics in the presence of minerals is limited. Accordingly, this study investigates the pyrolysis of polystyrene (PS) in the presence of minerals. PS is extensively used in the construction sector as expanded polystyrene (EPS) in external thermal insulation composite systems (ETICS) [3]. During pyrolysis, PS predominantly depolymerizes to the monomer styrene and its oligomers [4]. PS-based ETICS usually contain minerals from mortar and paint layers, such as calcite (CaCO3) and anhydrite (CaSO4). Pyrolytic decomposition of pure PS and PS-composites containing minerals is described using thermogravimetric analysis (TGA). A shift in the PS-decomposition step is used as an indicator for mineral-induced effects. Complementary semi-quantitative analysis of primary pyrolysis products, with focus on styrene, was performed using a microgram-pyrolyzer coupled to gas chromatography-mass spectrometry (Py-GC-MS). The quasi-instantaneous heating in the Py-GC-MS allows for investigations on the effects of minerals as well as temperature. Derivative thermogravimetric (DTG) profiles of PS alongside PS-composites containing mineral fillers are depicted in Figure 1. Normalization to the PS fraction allows for direct comparison. The results show that high concentrations of calcite and anhydrite shift peak PS decomposition to a higher temperature, indicating a stabilization effect, potentially via delaying the unzipping of the polymer chain. This effect is reduced at lower mineral concentrations. Figure 1: DTG of pure PS compared to PS-composites containing different minerals, normalized to the PS fraction. Py-GC-MS results, normalized to the PS fraction, show that anhydrite does not significantly impact the styrene yield, whereas the presence of calcite increases the styrene yield from 47 to 53 area% at 550 °C. In combination with TGA, the results suggest that calcite and anhydrite stabilize different radical intermediates, altering the product distribution. At 650 °C, however, the yield in the presence of calcite (58 area%) is comparable to that of PS (59 area%), indicating that the thermal decomposition outweighs the stabilization effect of calcite. The stabilization of different intermediates and its implications will be discussed in more detail in the conference presentation.



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Simulation of plastic pyrolysis in a fluidized bed reactor under batch-wise and continuous feeding mode

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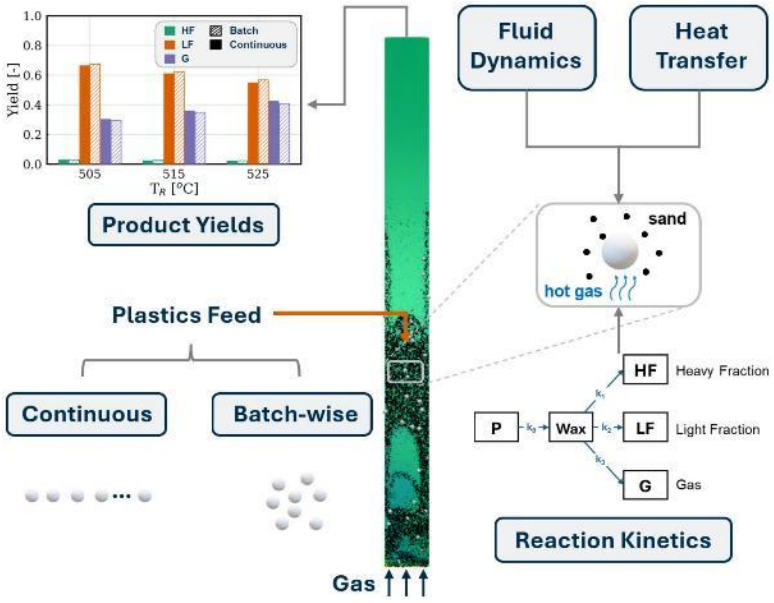
15:30-16:30 Session S2.8: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Haoquan Hu (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China)

ABSTRACT

The increasing production of plastics and inadequate management of plastic waste have led to severe environmental issues. Mechanical recycling is primarily effective for mono-fraction thermoplastics streams, whereas chemical recycling can handle mixed or contaminated feedstocks. Among current chemical recycling processes, pyrolysis offers an attractive balance of environmental impact, economic feasibility, and product quality. Plastic pyrolysis converts polymeric feedstocks into smaller molecules at intermediate to high temperatures in the absence of oxygen. A major challenge to industrial deployment is process scale-up, where the coupled multi-scale physicochemical phenomena remain insufficiently understood. Large-scale experiments alone are time-consuming and costly, making numerical simulations a cost-effective complement. Nevertheless, the effects of operating conditions on competing chemical reactions, heat and mass transfer—and their consequences for product composition—are rarely reported, particularly with respect to different feeding modes. In this study, we conduct Eulerian-Lagrangian CFD simulations of polypropylene (PP) pyrolysis in a laboratory-scale fluidized-bed reactor, which is used in experimental investigations. To reduce computational cost, PP pyrolysis is represented by a five-lump kinetic model, in which complex intermediates and final products are grouped into five pseudo-components based on boiling point: plastics (P), wax (W), heavy fraction (HF), light fraction (LF), and gas (G). The simulations consider the pyrolysis of PP particles with different sizes and systematically examine the effects of reactor temperature (T_R), particle size (d_p), and feeding mode (batch-wise and continuous) on product yields. The investigation starts with a simulation at T_R=505°C under batch-wise feeding, LF is the major product with a yield of 67.4 wt%, followed by G (29.6 wt%) and HF (3 wt%). A characteristic time-scale analysis indicates that pyrolysis reactions are rate-determining under the investigated conditions (t_R = 210 s, t_heating = 10 s). When the T_R is increased by 20°C, the LF yield decreases to 56.7 wt%, while the G yield increases to 40.9 wt% and the HF yield remains nearly unchanged. This trend is consistent with the different activation energies of the competing pathways that generate each product (Ea(W->LF) = 100 kJ/mol, Ea(W->G) = 249 kJ/mol). Subsequent simulations varying d_p from 1.5 to 2.5 mm show that increasing particle size reduces the specific surface area (1/d_p), thereby diminishing external heat transfer rates and increasing the t_heating from 9 to 14 s. However, because the overall process is kinetics-controlled within the examined conditions, these changes in heat transfer have no significant impact on product distribution. This work elucidates role of operating conditions and modes in plastic pyrolysis through particle-level analysis, clarifies their ultimate impact on product distribution, provides guidance for process optimization. Moreover, the modeling method is also appliable to more poorly mixing reactors, where kinetics may no longer be rate-limiting, thereby enabling quantitative analysis of real systems beyond the laboratory-scale.



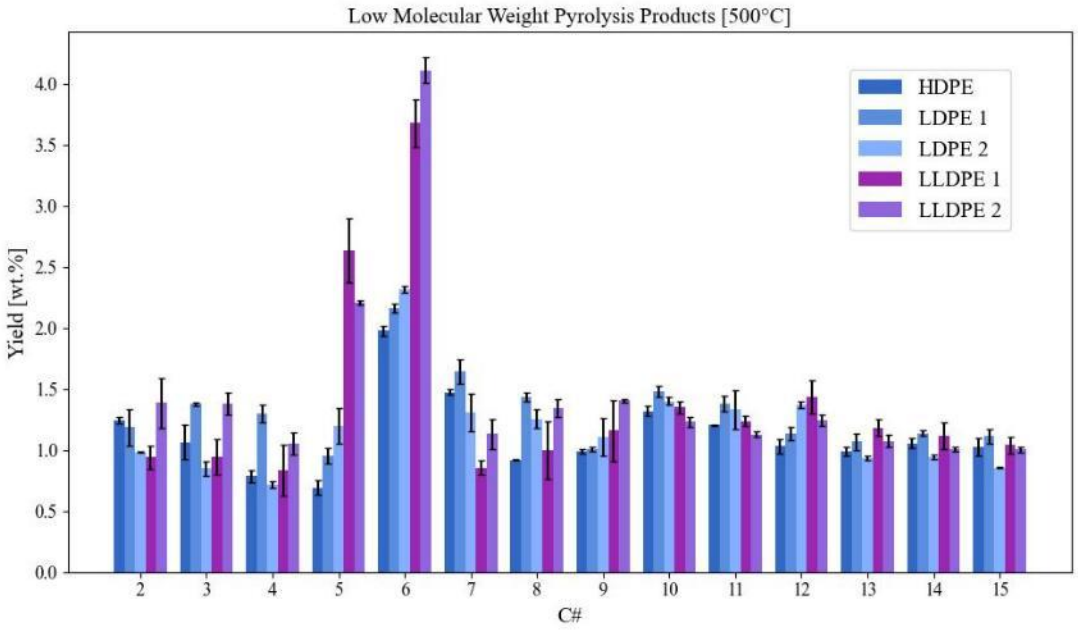
The role of branching in polyethylene pyrolysis

Mackenzie Denton (Ugent, Belgium) Fatma Çalık Ulu (Ugent, Belgium) Robin John Varghese (Ugent, Belgium) Kevin Van Geem (Ugent, Belgium)

15:30-16:30 Session S2.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Haoquan Hu (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China)

ABSTRACT

Plastics are essential materials, yet current end-of-life management practices remain inadequate, resulting in significant losses within the plastics economy and continued dependence on fossil resources. In Europe in 2022, most of the 26.9% of plastic waste recycled was recovered through mechanical recycling; however the effectiveness of mechanical recycling is limited by a reliance on clean, well-sorted streams. Consequently, to achieve a circular plastics economy, complementary recycling methods are needed to process mixed and contaminated plastic waste streams. Pyrolysis is well-suited to address this deficiency. This work investigates how branching in polyethylene (PE) influences pyrolysis behavior and product distributions. Two grades of linear low-density polyethylene (LLDPE) with short-chain branching, two grades of low-density polyethylene (LDPE) with short- and long- chain branching, and one grade of high-density polyethylene (HDPE) with minimal branching, provided by SABIC, were pyrolyzed at 500 and 600 °C. Samples were pyrolyzed using a micropyrolysis unit coupled to an analytical system featuring comprehensive two-dimensional gas chromatography (GC×GC) with parallel detectors, enabling quantification via Flame Ionization Detection (FID) and compound identification through Time-of-Flight Mass Spectrometry (TOF-MS). The most remarkable difference in the distribution of products, by carbon number, was an increase in C5 and C6 products from LLDPE pyrolysis. The yields of low molecular weight products, in particular products in the desirable naphtha range, were impacted more significantly by temperature than by the presence of branching in the feedstock. These insights inform how feedstock composition and process conditions shape pyrolysis product profiles, supporting future optimization of chemical recycling processes.



Abstracts:

Orals Day 3

Wednesday, 10th June 2026

Hydrogen-Rich Syngas Production from Biomass via Low-Temperature Pyrolysis coupled Gasification of Biochar-oil briquette fuels

Hongcai Su (Zhejiang University, China) Wenbin Hua (Zhejiang University, China) Shurong Wang (Zhejiang University, Shenyang University of Chemical Technology, China)

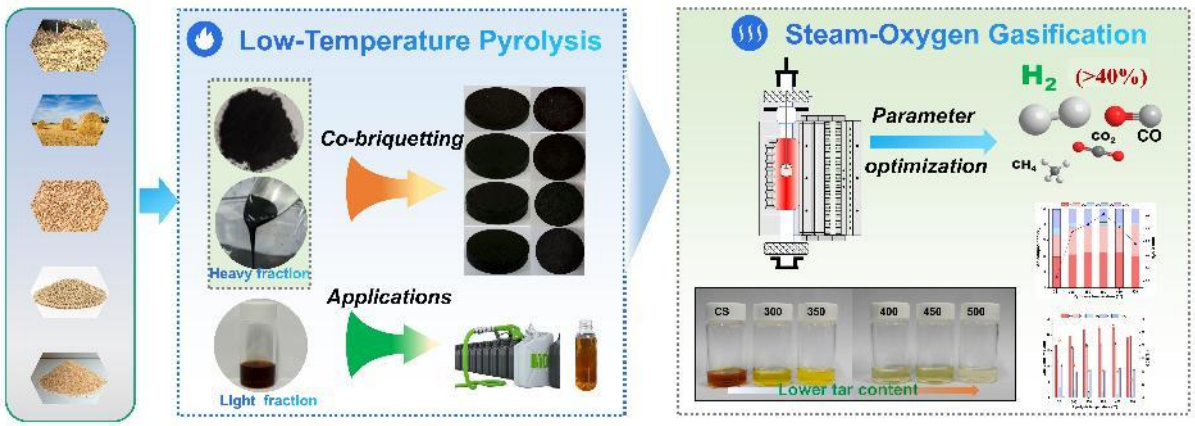
09:30-10:30 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

This study presents an innovative integrated pathway for the efficient, clean production of hydrogen-rich syngas from biomass, addressing key challenges of conventional gasification such as high tar yields and inefficient feedstock utilization. The proposed strategy synergistically combines low-temperature pyrolysis pretreatment, co-briquetting of pyrolysis products, and subsequent steam-oxygen gasification. The process begins with the low-temperature pyrolysis of biomass (corn stalks as a primary feedstock) in a continuous-feed rotary kiln reactor across a temperature range of 300–500℃. The resulting bio-oil is separated by settling, and its heavy fraction—typically difficult to utilize due to its high viscosity and macromolecular content—is repurposed as an effective binder. This heavy bio-oil is mixed with the solid pyrolytic biochar and co-briquetted under pressure to form dense, mechanically robust oil-char briquette fuels. Finally, these briquettes undergo steam-oxygen gasification in a fixed-bed reactor, with systematic optimization of critical parameters including pyrolysis temperature, gasification temperature, equivalence ratio (ER), and steam-to-carbon ratio (S/C). The results demonstrate that low-temperature pyrolysis at 400 ℃ optimally transforms corn stover biochar, significantly lowering its O/C and H/C atomic ratios, developing a porous structure, and enriching catalytically active alkali metals. Using the heavy bio-oil fraction (20 wt% of biochar) as a binder successfully solved the technical challenge of poor briquetting associated with pyrolytic biochar, significantly enhancing the mechanical strength of the briquettes to meet industrial standards while providing a value-added outlet for the heavy oil. Gasification performance was markedly superior using these briquette fuels compared to raw biomass. Under optimized conditions (gasification temperature of 1000 ℃, ER=0.15, S/C=3), the briquette fuel derived from 400 ℃ pyrolysis achieved exceptional results: a high H_2 yield of 32.47 mol/kg, an H2 mole fraction of 46.87% in the syngas, and an H2/CO ratio of 1.42. Crucially, this two-stage pyrolysis-briquetting-gasification process led to a dramatic reduction in tar yield compared to the direct gasification of corn stalks, particularly when the initial pyrolysis temperature exceeded 400 ℃. Tar content was reduced to approximately 90 mg/Nm³, with GC/MS analysis showing a significant decrease in polycyclic aromatic hydrocarbons. Parameter optimization revealed that increasing the gasification temperature from 700 °C to 1000°C enhanced endothermic reactions, raising total gas yield and cold gas efficiency (CGE). An optimal S/C ratio of 3 maximized H2 production by promoting the water-gas shift reaction without excessively cooling the reaction zone. The ER effectively modulated the syngas composition, with lower ER favoring higher H2 concentration. Furthermore, the universality of this integrated route was validated using diverse biomass feedstocks, including wheat straw, rice husk, bean shell, and sawdust. While wheat straw-derived briquettes exhibited the best mechanical strength due to its fibrous structure, bean shell-derived fuel yielded 26.36 mol H2/kg, demonstrating the broad applicability of the technique. A mixture of feedstocks showed synergistic effects, indicating potential for further optimization. In conclusion, this work establishes a technically feasible and effective strategy for the fractional and value-added utilization of all biomass pyrolysis components. By integrating low-temperature pyrolysis, product co-briquetting, and optimized gasification, it enables the clean production of high-quality, hydrogen-rich syngas with low tar content.



Pressure carbonisation of iron doped cellulose Pickering Emulsions towards catalytical applications

Leon Nowack (TU Bergakademie Freiberg, Germany) Francesco D'Acierno (KU Leuven, Belgium) Samuel Eyley (KU Leuven, Belgium) Vanessa Oliveira Castro (TU Bergakademie Freiberg, Germany) Wim Thielemans (KU Leuven, Belgium) Paul Knüpfer (TU Bergakademie Freiberg, Germany) Sven Kureti (TU Bergakademie Freiberg, Germany) Yvonne Joseph (TU Bergakademie Freiberg, Germany) Katja Heise (TU Bergakademie Freiberg, Germany)

09:30-10:30 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

The demand for sustainable materials is greater than ever. The utilisation of cellulose materials, such as cellulose nanocrystals (CNCs), as support materials for catalysis together with catalytically active metals has been documented in literature for some time. CNCs are also frequently used as reducing agents in the synthesis of metal nanoparticles, combining reductive and support functionalities. The present study compares two novel methods for catalyst production. The aim is to produce highly porous carbon materials doped with catalytically active iron species. As starting material cellulose-based Pickering emulsions were used. These emulsions contain high concentrations of iron salt, which, after conversion to iron-containing nanoparticles, will form the active catalytic fraction. In an autogenic pressure carbonisation (APC) process, emulsions were freeze-dried to remove all liquid components (water and oil) after which they were carbonised. In a second approach, we used hydrothermal carbonisation (HTC) where the emulsion remains in its liquid form and is carbonised in an autoclave reactor. The collected hydrochar product is then separated from the liquid phase by vacuum filtration, after which it is carbonised further in a tube furnace. The products were characterised using SEM and SAXS to obtain information about the porosity and surface structure. Additionally, WAXS measurements were performed to identify emerging iron species and to characterize crystallinity. XPS was further carried out to gather information about the chemical composition, especially on the surface of the sample, to determine whether the existing compounds could potentially promote catalytic processes and to obtain information about the carbonisation.

Biomass valorization to furfural: minimizing humin byproduct to enhance furfural yield

Mei Yang (Shenyang University of Chemical Technology, China) Guangwen Xu (Shenyang University of Chemical Technology, China)

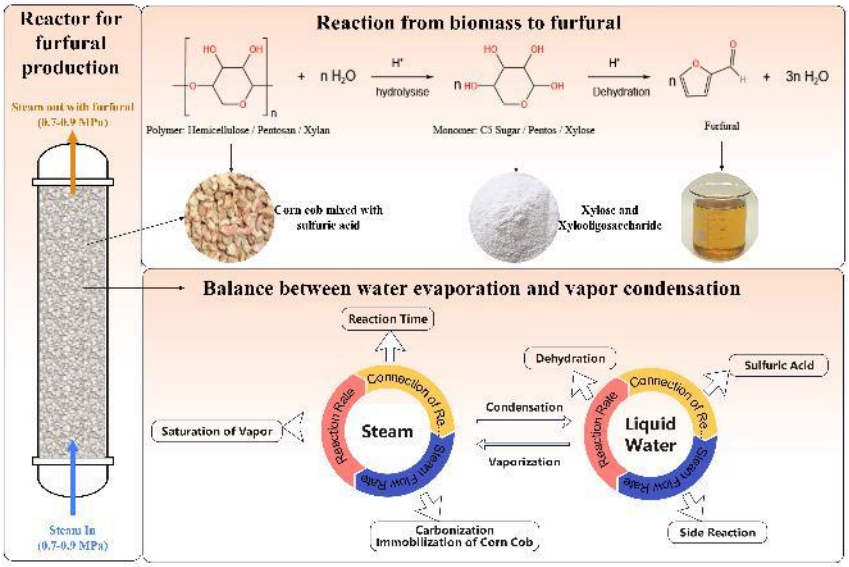
09:30-10:30 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Biomass-derived furfural is a critical platform chemical with broad applications in production of high value-added pharmaceuticals, agriculture and biofuels. Its global production capacity exceeds 1 million tons annually, and over 70% is produced in China. On the other hand, the global furfural market surpasses $1 billion in 2024, while keeping an annual growth rate (CAGR) of 4-5% over the past decade. Despite its great potential, the industrial-scale production of furfural is hindered by the formation of humin via complex side reactions. This study examines the pivotal roles of steam and catalyst in regulating the conversion process of biomass to furfural in terms of raising the product yield to its possibly highest value. A special focus made to clarify how the humin formed in the process affects the final production of furfural. We clarified the mechanism of humin formation and the precise effects of Brønsted acids, Lewis acids, and their synergistic interactions in the sequential reactions of hydrolyzing hemicellulose to xylose and dehydrating xylose to furfural. Beyond catalysis, the influence of reaction media is deeply analyzed, by comparing the solubility and protective capabilities of monophasic mixtures versus those of biphasic extraction systems. Analyzing literature data reveals that coordinating acid sites and appropriate organic solvents can effectively suppresses humin formation and enhance furfural production. The most important cognition is that the formed furfural can react with xylose to form humin. Using Brønsted acid lowers the activation energy of this humin formation reaction to a large extent, thus speeding up the total loss of furfural as well as xylose to decrease the yield of furfural. Based on these insights, a series of experiments were designed to mimick the industrial furfural production process widely adopted in China, where corn cob was used as feedstock and sulfuric acid as the catalyst. These experiments aimed to explore practically feasible approaches to improve the furfural yield. Leveraging the experimental data about the effects of sulfuric acid dosage, reaction temperature and pressure, as well as of the packing state of corn cob, reactor connection mode and steam-flow velocity, we well identified the key factors that determine the furfural yield in the currently existing industrial. (1) A good balance between water evaporation and vapor condensation. It is critical to ensure a possibly sufficient supply of water to the involved biomass valorization reactions, while simultaneously removing the produced furfural from the reactor timely. (2) The precise control of water vapor flow rate, temperature and pressure in the reactor to maximize the furfural yield effectively.



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Performance and synergistic mechanism on co-pyrolysis of PVC/ PVC-containing mixed plastics and coal

Juan Yang (Dalian University of Technology, China) Yang Li (Dalian University of Technology, China) He Yang (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China) Haoquan Hu (Dalian University of Technology, China)

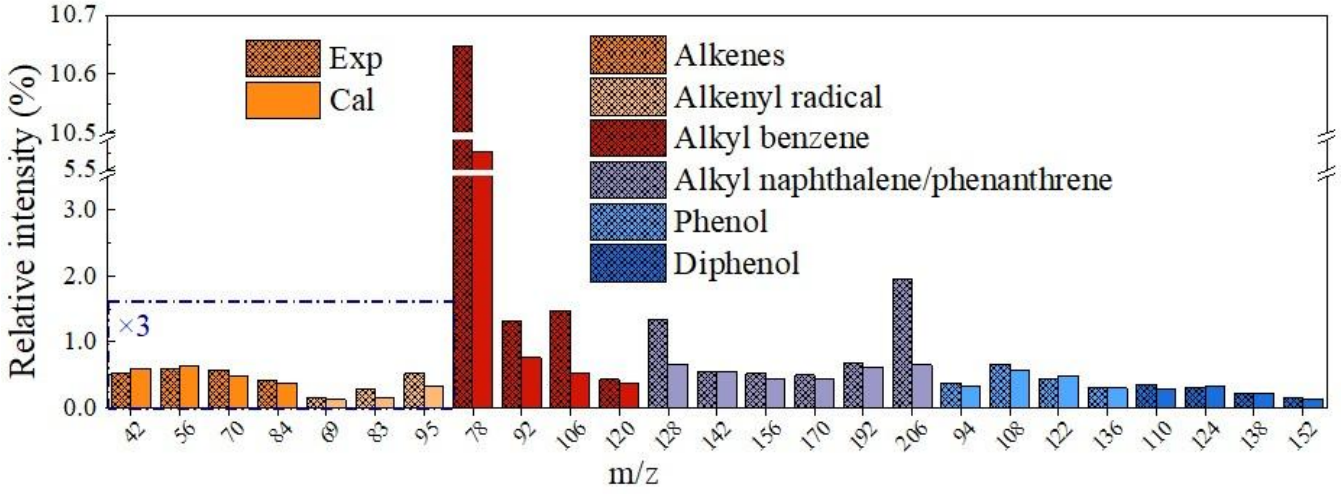
09:30-10:30 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Pyrolysis, as an important way to achieve efficient conversion and utilization of coal and waste plastics, can convert them into liquid fuels or high-value-added chemicals. The co-pyrolysis of coal and waste plastics not only improves the yield and quality of tar, but also achieves the resource utilization, harmless treatment, and clean treatment of waste plastics. However, the existence of PVC (about 56% chlorine) in waste plastics makes the process complicated, which causes environmental pollution and reduces the quality of the oil product. Extensive research on co-pyrolysis of coal and non-halogen waste plastics has been conducted to understand their performances and synergistic mechanisms, and also the single PVC pyrolysis behavior and chlorine migration. However, waste plastics are often recycled in the form of mixtures, which contain non-halogen plastics, such as polyethylene (PE), polystyrene (PS), and PVC, the co-pyrolysis behavior and mechanism of coal with PVC or mixed plastics containing PVC are still to be explored. In this topic, the co-pyrolysis of coal with PVC, or the mixed plastics of PVC/LDPE or PVC/PS were carried out to investigate the pyrolysis behavior, product distribution and composition, the synergistic effect and mechanism of coal and plastics. The results show that in co-pyrolysis of Pingshuo coal (a low rank coal) with PVC, benzene has the highest relative content among the volatile products, which is mainly generated at low temperature stage (below 327 oC). High temperature (327 to 650 oC) is beneficial to enhance the cyclization/ alkylation reaction and promote the production of light tar. In coal/PVC co-pyrolysis system, the addition of LDPE facilitates the production of butene and benzene at low temperatures. Moreover, LDPE promotes the cleavage of Cal-Car and Cal-O bonds connected to the aromatic ring in coal, increasing the production of phenolic products. The addition of PS to coal/PVC can significantly promote the generation of styrene with the highest content and benzene with the second highest content in the volatile products. The addition LDPE or PS to coal/PVC all makes the reduction of chlorinated compounds content and improves the tar quality. Figure 1: Relative content of primary volatiles from Coal/PVC/PS (6:1:1) pyrolysis.



References

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Investigation on sulfur distribution and chemical forms in products from co-pyrolysis of coal and waste tire

Yuxin Wen (Dalian University of Technology, China) Xueer Ning (Dalian University of Technology, China) He Yang (Dalian University of Technology, China) Yang Li (Dalian University of Technology, China) Wenqing Lv (Dalian University of Technology, China) Haoquan Hu (Dalian University of Technology, China) Lijun Jin (Dalian University of Technology, China)

09:30-10:30 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Co-pyrolysis of coal and waste tire presents a promising waste-to-energy strategy, however, sulfur migration poses significant environmental concern. Therefore, this study investigated the sulfur transformation behaviors during co-pyrolysis based on the distribution of total sulfur in gaseous, liquid, and solid products under varying heating rates, temperatures and blend ratios, along with the existence forms and bonding states of sulfur in derived chars to elucidate the sulfur migration mechanism. Results showed that high heating rate facilitated the transfer of sulfur from solid phase to liquid phase. Meanwhile, the release of sulfur-containing gases in both individual pyrolysis and co-pyrolysis increased with the heating rate, however, the generation of H2S was significantly suppressed under high heating rate. Sulfur is mainly concentrated in char during tire pyrolysis, different from coal pyrolysis where sulfur primarily distributed in liquid-phase products. The temperature affected the distribution of sulfur in co-pyrolysis products. When the temperature is above 550 oC, co-pyrolysis promoted the transfer of sulfur from solid and gas phases to liquid phase. Additionally, the yield of sulfur-containing gases during individual pyrolysis and co-pyrolysis increased as the temperature increased. Similarly, co-pyrolysis suppressed the generation of H2S with the temperature being over 550 oC, while the generation of COS and CH3SH was related with the mixing ratio of coal and waste tire. Further analysis of the occurrence forms of sulfur on co-pyrolysis chars at 600 oC revealed that the peak intensities corresponding to ZnS and ZnO in co-pyrolysis chars are significantly reduced, and their experimental relative contents were lower than theoretical relative contents compared to char from tire pyrolysis, which was in correspondence with the inhibitory effect on sulfur distribution in co-pyrolysis char. The study provided an insight into sulfur migration behavior during co-pyrolysis of coal and waste tire, contributing to reducing pollutant emission and enhancing waste valorization, which supports the development of cleaner co-processing technologies for sustainable energy production and effective waste management.

Catalytic Selective Hydrogenolysis of Coal-based Aromatic Ethers

Zan Huang (Dalian University of Technology, China) Xiao Chen (Dalian University of Technology, China) Changhai Liang (Dalian University of Technology, China)

09:30-10:30 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Coal is a precious resource in many countries around the world. The aromatic ring structure plays a crucial role in the composition of coal, being interconnected through bridging, ether, and thioether bonds, along with diverse side chains. The development of directed hydrogenolysis of coal under mild conditions to yield aromatic compounds signifies a pioneering approach for the non-energy utilization of coal, effectively augmenting the added value of coal-derived products. In this work, a synergistic catalyst system composed of PtPdCoNiCu/C high-entropy alloy and H4SiW12O40 has been formulated for the catalytic hydrogenolysis of C-O bonds in coal-derived compounds and low-rank coal. The conversion of benzyl phenyl ether achieves an impressive 99.8%, with yields of toluene (99.8%) and phenol (99.2%) at 50 °C and 0.1 MPa H_2 for 2 h. The apparent activation energy (Ea) for this synergistic catalyst system is merely 31.6 kJ/mol, significantly lower than that of the PtPdCoNiCu/C catalyst alone (86.4 kJ/mol), suggesting that hydrogen spillover facilitates the surface hydrogenolysis of C-O bonds. The products formed are aromatic compounds, devoid of any over-hydrogenated derivatives. Furthermore, an effective method for the hydrogenolysis of C-O bonds by microwave catalysis has been developed. The collaboration of the Pt/CB catalyst with H4SiW12O40, coupled with a high-permittivity polar solvent (1,4-butyrolactone), enhances the microwave-assisted hydrogenolysis of the C-O bonds in the coal-derived platform molecule (benzyl phenyl ether). The microwave heating proves to be more effective than the conventional electric heating. Following optimization of the catalytic conditions, the Pt/CB and H4SiW12O40 catalyst presents highly efficient in 10 min and 300 W with benzyl phenyl ether conversion of 99.9%. This metal-acid catalytic strategy is applied to the hydrogenolysis of other coal-based aromatic ethers and Naomaohu coal, possible providing new opportunities for producing value-added aromatics from coal.

Catalytic pyrolysis of polyethylene: Effects of shaping zeolite particles and of reactor configuration (in-situ and ex-situ)

Souha Denghezli (University of Lille, Lorraine & CNRS, France) Jeremy Dhainaut (University of Lille, CNRS, France) Anthony Dufour (CNRS Nancy, France) Sophie Duquesne (Centrale Lille, CNRS, France) Jean-François Lamonier (University of Lille, CNRS, France)

09:30-10:10 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

The catalytic pyrolysis of polyethylene over acidic zeolites such as ZSM-5 is a promising approach for the selective production of added-value hydrocarbons. However, the majority of experimental studies are still performed using powdered catalysts, which limits their applicability to realistic reactor configurations and hinders process scale-up. Addressing this gap requires not only appropriate reactor design but also the development of shaped engineered catalyst particles with mechanical strength and controled particles sizes. In this study, ZSM-5 zeolite was shaped (with binders) into millimetric granules using an extrusion–granulation approach designed to preserve its acidic and textural properties while ensuring sufficient mechanical strength and a tailored particle size for its use in fixed-bed or stirred reactors. The influence of catalyst shaping and positioning on polyethylene pyrolysis was systematically investigated using 2 complementary reactors (batch and continuous). First, batch sample boat experiments were conducted to compare the catalytic behavior of powdered ZSM-5 and shaped ZSM-5 under identical operating conditions. In addition to direct catalyst–polymer contact (in-situ), a fixed-bed catalytic zone was installed downstream of the sample boat reactor to study ex-situ configuration with the shaped ZSM-5. The zeolites was further evaluated in a continuous staged reactor. In the in-situ configuration, the catalyst was introduced directly into a stirred continuous pyrolysis reactor, ensuring intimate contact with the molten polymer. In contrast, the ex-situ configuration involved positioning the shaped zeolite in a downstream fixed bed reactor, where it selectively interacts with pyrolysis vapors. This work highlights the effect of both zeolite shaping and catalyst positioning in catalytic polyethylene pyrolysis. It assesses the catalytic behavior of zeolites under conditions relevant to scalable reactor designs, and supports the development of engineered catalytic particles for plastic waste pyrolysis.

Sustainable valorization of plastic waste via zeolite-catalyzed pyrolysis and in-line CO2 reforming over Ni-Co-based catalysts

Subhasis Das (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) Alexandr Martaus (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) Dagmar Fridrichova (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) Rozalie Wdowkova (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) Pavel Lestinsky (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia) Amer Inayat (Institute of Environmental Technology, CEET, VSB - TUO, Ostrava, Czechia, Czechia)

09:30-10:10 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

The exponential growth in plastic waste streams, particularly polyolefin-based wastes such as waste polypropylene (WPP), necessitates the development of scalable and sustainable valorization routes beyond incineration and low-value recycling [1]. Herein, an integrated waste-to-chemicals approach, coupling thermo-catalytic pyrolysis of WPP with in-line CO2 reforming of pyrolysis gases for the coproduction of high-value liquid hydrocarbons and synthesis gas, is demonstrated [2]. Pyrolysis of WPP was performed in a two-stage configuration, in which pyrolysis vapors produced during thermal cracking were subsequently upgraded over FAU, BEA, and MFI (ZSM-5) zeolite catalysts featuring similar Si/Al ratios. The goal was to establish clear structure-activity-selectivity relationships in catalytic pyrolysis of WPP over zeolites of different framework. From the results as presented in Fig. 1a, noticeable differences in product distributions were observed as a function of zeolite framework topology. Furthermore, based on the analysis of pyrolysis oils, ZSM-5 was found to catalyze extensive secondary cracking and dehydroaromatization resulting in aromatics-rich pyrolysis oil dominated by BTEX (benzene, toluene, ethylbenzene, and xylenes). In contrast, FAU and BEA promoted the formation of aliphatic hydrocarbons. Clear differences were also observed in the composition of the gaseous products when different zeolites were employed as catalysts. Nevertheless, in all cases, the hydrocarbons observed ranged from C1 to C5. A further goal of this work was to upgrade the pyrolysis gases into syngas. For this purpose, CO2 reforming of the pyrolysis gases was carried out over hydrotalcite-derived mono (Ni) and bimetallic (Ni-Co) catalysts at 650–800 °C. Despite exhibiting high activity at temperatures above 750 °C, monometallic Ni catalysts suffered from pronounced coke formation, which adversely affected the overall syngas yield. In contrast, the coke formation was significantly suppressed by doping Ni -hydrotalcite catalyst with cobalt. In particular, among a series of formulations screened, Ni9.5Co0.5 was identified to have the most favorable combination of activity and stability, providing high CO2 and hydrocarbon conversions, improved coke resistance, and excellent syngas yield (Fig. 1b). The superior performance of the bimetallic catalysts can be ascribed to the synergistic Ni-Co interactions, which enhance CO2 activation, and promote the activation of surface oxygen species, thereby facilitating in-situ carbon gasification [3]. Acknowledgment: This work was financially supported by the ESF in “Waste as an alternative source of energy” project, reg. nr. CZ.02.01.01/00/23_021/ 0008590 within the Programme Johannes Amos Comenius and by REFRESH – Research Excellence For Region Sustainability and High-tech Industries, CZ.10.03.01/00/22_003/0000048 and large research infrastructure ENREGAT supported by MŠMT, project no. LM2023056.

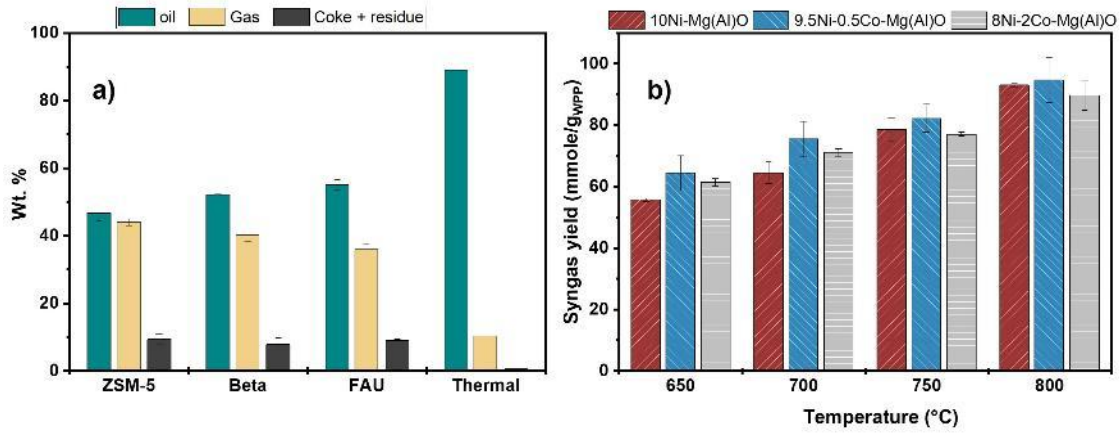


Fig 1: a) Catalytic pyrolysis at 550 °C, and b) syngas yield over different NiCo catalysts during reforming.

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Mechanistic insights and bifunctional effects in $Pd/TiO_2–ZrO_2$-catalyzed conversion of pyrolytic limonene to cymene

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09:30-10:30 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

In Chile, mining operations generate approximately 49,000 tons per year of waste mining truck tires (MTWT), accounting for 28% of the country's total end-of-life tires. This accumulation poses severe logistical and environmental challenges to the productive sector and the ecosystems, respectively. In response, Chile's Extended Producer Responsibility Law (REP Law 20.920) mandates 100% recycling of MTWT by 2030, incentivizing the development of advanced valorization technologies such as pyrolysis. During pyrolysis, the polymeric fraction of waste tires thermally decomposes to yield vapors enriched in limonene (over 20 wt.% of the pyrolytic oil)—a renewable precursor to valuable monoaromatics like cymene. However, the selectivity of cymene formation under non-catalytic conditions is typically <10%, requiring catalytic systems. Here, we investigate the mechanistic role of bifunctional Pd/S (S = TiO_2, ZrO_2, $TiO_2–ZrO_2$) catalyst in the selective transformation of limonene to cymene. Catalysts with varying densities of acid sites were synthesized via wet impregnation (1 %wt. Pd) and featured similar textural (SBET = 50 m2.g-1) and structural properties (Metal Dispersion ≈ 56%). Moreover, their acidity (predominantly Lewis) ranked as follows: TiO_2 < Pd/TiO_2 < $ZrO_2–TiO_2$ < $Pd/ZrO_2–TiO_2$. Catalytic screening and kinetic studies were quantitatively conducted using a Frontier tandem microreactor system (Rx-3050TR) coupled to a GC-MS/FID, where pyrolysis of natural rubber (model tire) occurred at 400–500 °C. The catalytic vapor-phase upgrading was carried out in ex-situ mode between 300 – 500 °C, with catalysts mass of 1.1 – 8.3 mg. Based on the non-catalytic and catalytic experiments the limonene-to-cymene reaction involves (1) isomerization of limonene to terpinenes followed by dehydrogenation to cymene; (2) direct dehydrogenation of limonene to p-cymenene; and (3) parallel side reactions forming alkenes and cycloalkenes. Catalytic performance was governed by acid site distribution rather than total acidity. While normalized limonene conversion remained nearly constant (~15%/$mgcat^{-1}$), the cymene formation rate increased linearly with the proportion of weak acid sites (W/TS), from 10.1 to 14.5 $\mu mol \cdot mg\_cat^{-1} \cdot s^{-1}$. This trend supports a bifunctional mechanism where weak Lewis's acid sites promote isomerization to terpinene intermediates, followed by dehydrogenation to cymene on Pd sites. Cymenene production was significantly lower (1.0–3.7 $\mu mol \cdot mgcat^{-1} \cdot s^{-1}$), confirming selective activation of the exocyclic double bond and preferential cymene formation. These results highlight the synergistic role of acid–metal interfaces in directing product selectivity. A Langmuir–Hinshelwood kinetic model accounting for competitive adsorption of reactants and byproducts reveals that the initial hydrogen abstraction from limonene and dehydrogenation of terpinenes are rate-limiting for pathways (2) and (1), respectively. This work offers a mechanistic and kinetic framework for fundamental understanding the catalytic upgrading of pyrolysis vapors and contributes to the advancement of waste-to-aromatics strategies for circular economy applications in mining.

MOLTEN KOH-ACTIVATED CONVERSION OF PYROLYSIS CHAR DERIVED FROM MIXED PLASTIC INTO HIERARCHICAL POROUS CARBON FOR SUPERCAPACITOR ELECTRODES

Joo-Hyeong Yoon (1. Korea Institute of Industrial Technology, 2. Hanyang University, South Korea) Jong-Su Kim (Korea Institute of Industrial Technology, South Korea) Eilhann E. Kwon (Hanyang University, South Korea) Soo-Hwa Jeong (Korea Institute of Industrial Technology, South Korea)

09:30-10:30 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Upcycling mixed plastic waste into functional carbon materials has attracted increasing attention as a strategy to address both environmental concerns and the growing demand for sustainable materials. In contrast to battery-oriented hard carbon, supercapacitor electrodes require a high specific surface area and well-developed hierarchical porosity to enable efficient ion transport and charge storage. In this study, pyrolysis char derived from mixed plastics, including polyethylene terephthalate (PET), polycarbonate (PC), polyurethane (PU), polystyrene (PS), and acrylonitrile butadiene styrene (ABS), was used as a precursor for porous carbon materials. The feedstocks were thermally decomposed under an inert atmosphere to produce carbonaceous char, followed by chemical activation using potassium hydroxide (KOH) at 850 °C with varying KOH-to-char ratios. Different mixing ratios (PET/PC/PU/PS/ABS = 35/25/15/20/5% and PET/PC/PU = 60/25/15%) were examined to evaluate their influence on pore development. Surface and structural properties were analyzed using nitrogen adsorption–desorption (Brunauer–Emmett–Teller, BET) analysis and complementary structural analyses to assess pore characteristics and carbon structure. The results confirmed the formation of porous carbon with hierarchical micro- and mesostructures. The presence of PS significantly enhanced pore development, indicating its key role in generating accessible porosity. PU-containing systems additionally contributed to nitrogen incorporation, modifying surface chemistry. Electrochemical performance was evaluated in half-cell configurations using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) to assess electrochemical characteristics relevant to supercapacitor applications.

Comprehensive Upgrading of Plastic-Derived Pyrolysis Oil to Improve the Quality of Steam Cracking Feedstock

Miloš Auersvald (UCT Prague and LCT, Ghent University, Czechia) Petr Straka (UCT Prague, Czechia) Vít Vyskočil (UCT Prague, Czechia) Anas Jamil Abdulrahman (LCT, Ghent University, Belgium) Azd Zayoud (LCT, Ghent University and Pryme Cleantech, Belgium) Kevin M. Van Geem (LCT, Ghent University, Belgium)

09:30-10:30 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Waste plastics can be easily depolymerized via pyrolysis to oil, which can be further valorized to produce base chemicals. A wide distillation range of plastic pyrolysis oils results in a high melting point, and the amount of heteroatoms exceeds limits for steam cracking feedstocks. Those aspects complicate the direct valorization of plastic oil in steam cracking, and oil upgrading is thus desired. In this research, we studied a complex hydroprocessing strategy to upgrade oil from the pyrolysis of mixed post-consumer waste polyolefins in a flow-fixed-bed catalytic unit at a wide range of conditions. The waxy oil produced by industrial-scale continuous pyrolysis exhibited a wide distillation range of over 600°C and contained significant amounts of heteroatoms, especially nitrogen, and metals. In the first step, the sample was hydrotreated over a sulfided Ni-Mo/γ-Al2O3 catalyst to reduce the nitrogen content to below 25 mg/kg, thereby preventing deactivation of the hydrocracking catalyst. The hydrotreated sample was hydrocracked over a sulfided Ni-W catalyst at various conditions in the following step. Two approaches were compared: (i) hydrocracking of the whole sample and (ii) the sample free of the naphtha fraction. Hydrogen consumption and off-gas composition were monitored online during hydroprocessing using a refinery gas analyzer. The comprehensive analysis of liquid products was carried out using GC×GC-FID/MS. During the conference, the following aspects will be discussed: 1) The effect of hydrotreating temperature on the olefin's saturation and heteroatom's removal. 2) The stability of the hydrotreating catalyst during the processing of 30 kg of plastic pyrolysis oil. 3) The effect of the hydrocracking conditions on a liquid product's final boiling point reduction and its composition changes regarding the use as a feedstock for steam cracking. 4) The benefit of sample distillation before hydrocracking, including hydrogen savings. 5) Overall comparison of the studied hydroprocessing approaches, including the mass balance from plastic waste to steam cracking feedstock.

Fermentability of water-soluble products from HTC-Py-AD processes: comparison of fast and intermediate pyrolysis

Andrea Facchin (University of Bologna, Italy) Federica Zimbardi (Univeristy of Bologna, Italy) Daniele Fabbri (University of Bologna, Italy) Cristian Torri (University of Bologna, Italy)

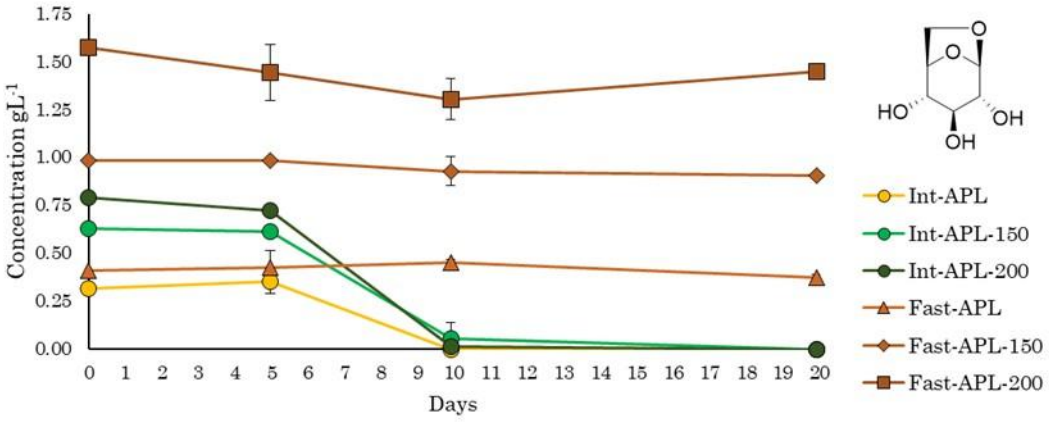
11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Hybrid thermochemical-biological is a relatively novel way to overcome the complexity of bio-oils derived from biomass's pyrolysis. In this approach, microorganisms in both single or mixed cultures are used to funnel the aqueous phase liquid (APL) of bio-oil and incondensable products obtained from the thermochemical step into few valuable products such as methane or volatile fatty acids (VFA) [1]. However, despite the efforts, the direct fermentation of APL has been proved to be feasible only in presence of a easily fermentable co-feed, which may be provided by sugary addition to the fermentation broth, making the process economically unsustainable [2]. To overcome this issue, combination of hydrothermal carbonization (HTC) and pyrolysis has been proposed as a way to deliver a sugar enriched thermochemical output [3,4], however the fermentation of the obtained solution was not yet tested. In this study, HTC performed at two temperatures (150 and 200°C) and both intermediate and fast pyrolysis were coupled. The solutions obtained, namely HTC liquids and APL from pyrolysis, were individually fermented utilizing mixture cultures and anaerobic conditions (nitrogen environment and 55°C). Daily analyses were performed to trace the production of VFA and biogas (chemical oxygen demand content, GC-MS, GPC). As a result, APL derived from fast pyrolysis from both HTC pre-treated and not, were not converted even after 100 days of experiment, meanwhile intermediate pyrolysis APLs solutions display degradation after only 5 days (Figure 1). Moreover, APL derived from HTC pre-treatment displayed a similar degradation as for direct pyrolysis, highlighting an increased share of chemical energy converted when HTC is applied. Figure 1. Levoglucosan trend during fermentation of APL from intermediate and fast pyrolysis. https://doi.org/10.1039/C8GC03957G.



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Exploiting Fast Pyrolysis Conditions for one-step synthesis of Carbon Dots from Biomass

Carmela Russo (CNR, Italy) Francesca Cerciello (CNR, Italy) Maria Maddalena Oliano (CNR, Italy) Osvalda Senneca (CNR, Italy) Barbara Apicella (CNR, Italy)

11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Fast pyrolysis of lignocellulosic biomass represents a powerful thermochemical route for the conversion of renewable carbon resources into value-added materials. In this contribution, we report the synthesis of carbon dots (CDs) through the fast pyrolysis of biomass performed in a modified wire-mesh reactor, referred to as a heated strip reactor (HSR). The HSR differs from conventional wire-mesh reactors in that the metallic grid traditionally used as a sample holder is replaced by a pyrolytic graphite foil, which acts both as a mechanical support and as a resistive heating element. This configuration allows the reactor to reach temperatures as high as 2073 K while maintaining extremely high heating rates, on the order of 10^4 K s^{-1}, which are ideal conditions for probing intrinsic fast-pyrolysis pathways. Small amounts of lignocellulosic biomass were deposited on the graphite strip and subjected to rapid heating under controlled atmospheres. Under these conditions, thermal decomposition occurred within milliseconds, generating volatile species that were immediately quenched upon leaving the hot zone. The rapid quenching, enabled by the strong temperature gradient between the heated strip and the surrounding environment, effectively suppressed secondary reactions of the vapors, such as cracking, repolymerization, and gas-phase aromatization. The volatile products condensed on a Pyrex glass bridge positioned above the HSR collected and were subjected to solvent extraction and fractionation using organic solvents of different polarity (acetone and N-methylpyrrolidone, NMP), allowing the separation of fractions with distinct chemical compositions. These fractions were characterized by spectroscopic techniques, Size Exclusion Chromatography (SEC) and gas chromatography mass spectrometry (GC-MS, only in the case of acetone fraction) in order to check their fluorescence, size and chemical composition, respectively. The first extraction in acetone allowed isolating species, which exhibit intense blue photoluminescence under UV–visible excitation and size in the range 1.5-2.5 nanometers. The fraction insoluble in acetone was dissolved in NMP, obtaining species fluorescing in green region and having size in 1.7- 2.8 nm range. The formation of CDs is attributed to the rapid thermal breakdown of biopolymers followed by the nucleation of small aromatic clusters, whose growth is arrested by the extremely short residence time at high temperature and by immediate quenching. The surface chemistry, rich in oxygen-containing functional groups inherited from the biomass precursor, is believed to play a key role in CD photoluminescent behavior. This study demonstrates that fast pyrolysis reactors, when operated under well-controlled high heating rate and short vapor residence time conditions, can be exploited not only for fuel and chemical production, but also as one-step approach to synthesize functional bio-derived carbon nanomaterials. The possibility of selectively isolating different classes of CDs through solvent fractionation further highlights the versatility of the approach. The CDs obtained show significant potential for applications in photonics, optoelectronics, chemical sensing, and other advanced materials fields. Overall, the work emphasizes the added value that fast pyrolysis can provide in the context of sustainable materials synthesis, opening new perspectives for the integration of pyrolysis science with nanomaterials engineering.

Experimental and Modelling Studies on Biomass Pyrolysis in Molten Salts

Arne Hommes (University of Groningen, Netherlands) Jessi Osorio Velasco (University of Groningen, Netherlands) Parniya Badr (University of Groningen, Netherlands) Robertus Venderbosch (Biomass Technology Group BV, Netherlands) Hero Jan Heeres (University of Groningen, Netherlands)

11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Pyrolysis is a key technology for transforming lignocellulosic biomass into liquids that can be further processed into high-value fuels and chemicals. Conventional pyrolysis requires relatively high operating temperatures. However, a slow heat transfer can negatively affect depolymerization efficiency and product selectivity. Molten salt-assisted thermal treatment has therefore attracted increasing interest in biomass conversion, as molten salts can enhance heat transfer through their high thermal conductivity and heat capacity. In earlier work from our group, pyrolysis of sawdust in the presence of a molten salt mixture at a salt-to-biomass weight ratio of 10:1 resulted in a total liquid yield of 46% at 450 °C, with highly selective formation of acetic acid and furfural as the organic liquid. Such selective production of target compounds is advantageous, as it reduces the need for extensive downstream separation compared to the complex bio-oil mixtures typically obtained from conventional biomass pyrolysis. In the present study, the molten salt-assisted sawdust pyrolysis was systemically optimized using a eutectic ZnCl2-KCl-NaCl mixture (44.3:41.9:13.8 mol%), which exhibits a low minimum melting temperature. Experiments were conducted in a staged free-fall pyrolysis reactor that enabled controlled feeding of the salt-biomass feed mixture into the reactor. The setup further allowed efficient screening of reaction conditions, while enabling the collection of sufficient sample quantities for detailed analysis. A Design of Experiments (DoE) approach was applied to evaluate the influence of pyrolysis temperature (340-410°C) and biomass fraction in the feed (5-94 wt%) on product yields and liquid-phase composition. The highest liquid yield (71.2 wt%) was obtained at 375°C using a feed containing 5 wt% biomass and 95 wt% molten salt, which is significantly higher than that obtained in salt-free pyrolysis at otherwise the same reaction conditions (31.9 wt%). This shows the optimization potential of using molten salts in the pyrolysis of biomass, due to the improved heat transfer and slight catalytic role of the molten-salt medium. At high salt loadings, the liquid phase consisted predominantly of water, with a yield of only 4.5 wt% of organic liquid phase products. Under these conditions, the organic fraction was composed almost exclusively of acetic acid and furfural. Increasing the biomass loading in the feed to 94 wt% reduced the total liquid yield; however, the highest organic liquid yield (18.8 wt%) was obtained. In this case, the organic liquid phase had a more complex composition with a broader distribution of organic compounds. These results clearly demonstrate a tradeoff between maximizing total liquid production and selectivity towards specific organic products. A statistical model was developed that was able to describe the product yields as a function of temperature and biomass-to-salt ratio with high accuracy (R2 exceeding 0.98, with most model terms exhibiting p-values below 0.05). The model enables the prediction of optimal operating conditions, depending on whether a high total liquid yield or high selectivity towards specific organic products is targeted.

Integrating Hydrothermal Treatment and Microalgal Cultivation for Brewery Spent Grains Valorization

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11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

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Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Beer production generates large quantities of by-products, among which brewery spent grains (BSGs), the insoluble solid fraction of grains, are the most abundant, accounting for 85% of total brewing waste [1]. Nearly 36.4 million tons per year of BSGs are produced globally and are typically landfilled, releasing ~513 kg CO_2 per ton, or diverted to low-value livestock feed. However, their high lignin (~30% dry weight, dw) and moisture content (>70%) severely limit their shelf life. Despite this, BSGs are rich in structural carbohydrates (e.g., 19% dw cellulose), proteins, and essential mineral elements, making them an attractive feedstock for circular biorefinery approaches. Hydrothermal carbonization (HTC) and liquefaction (HTL) have emerged as promising thermochemical pathways for the valorization of wet lignocellulosic biomasses such as BSGs, as they can be applied to wastes with up to 80–95% moisture, eliminating energy-intensive pre-drying steps [2]. The reactions take place near the critical point of water (TC = 374 °C, PC = 22 MPa), where it exhibits a reduced dielectric constant and behaves similarly to a non-polar solvent. Under subcritical conditions, the elevated ionic product of water ($K_w > 10^{-14}$) favors ionic reaction mechanisms, whereas radical and non-ionic pathways dominate under supercritical conditions. These processes convert biomasses into a solid fraction (hydrochar), an organic fraction (biocrude), gases, and an aqueous phase (AP), that is considered a secondary by-product. All these fractions hold potential as fuel precursors or as sources of value-added chemicals. Chlorella sp. is a widely investigated microalga for sustainable bio-based applications, including wastewater treatment and the production of biofuels and bioproducts, thanks to its ease of cultivation and high lipid content. In this context, Tarhan et al. demonstrated the successful cultivation of Chlorella minutissima in diluted AP obtained from HTC of olive and orange pomace, achieving high growth rates and efficient nutrients removal [3]. The resulting biomass, enriched in carbohydrates, proteins, and lipids, was suitable for the production of value-added biofuels and chemicals. Following this approach, the present project investigates the optimization of operating conditions for HTC and HTL applied to BSGs, evaluating the yields of hydrochar, subsequently tested as functional carbon material, biocrude, as potential source of added-value chemicals, and gases. Chemical and energetic valorization were carried out on all process streams to evaluate their potential end uses. Particular attention was also devoted to the energetic and nutritional valorization of HTC/HTL by-product, i.e. AP, which is characterized by high organic (~30,000 mg/L) and ammonia content (~500 mg/L). Chlorella sp. was cultivated under mixotrophic conditions in CO_2-supplemented tubular systems to simultaneously recover nutrients from diluted AP, enabling further valorization of this process stream and reducing thermochemical treatment costs. References [1] M. Jakowski et al., Energies 13 (2020) 2058 [2] B. Ciuffi et al., Sci Rep. 11 (2021) 15504 [3] S. Z. Tarhan et al., J. Water Process Eng. 40 (2021) 10178

Assessment of heterogeneous secondary reactions and the role of char loading in fluidized bed pyrolysis of biomass

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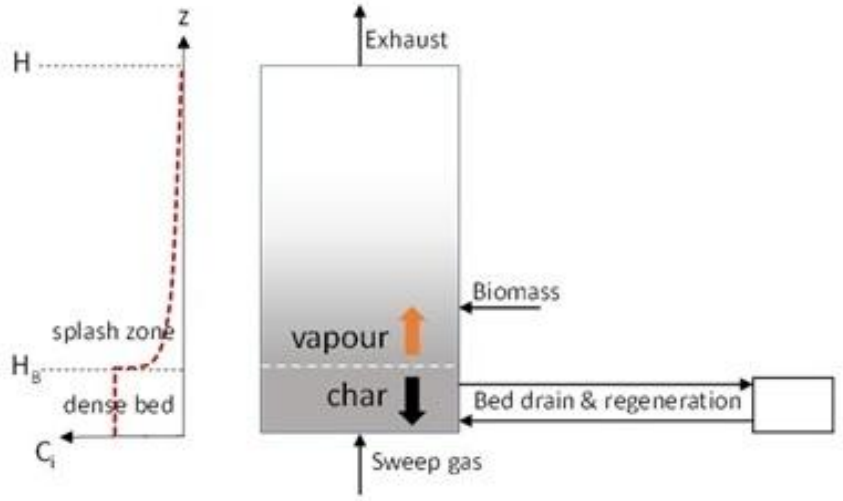
11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Biomass fast pyrolysis can support decarbonization by replacing fossil fuels, enabling carbon neutral energy and supplying hard to decarbonize sectors with renewable fuels and platform chemicals. During fast pyrolysis, biomass quickly decomposes to biochar, bio-oil and gases through a complex network of series-parallel thermally activated chemical reactions. However, bio-oil is characterized by high viscosity, acidic pH and limited stability. These issues stimulate research activities aimed at improving the design of pyrolytic converters and process conditions to maximize yield/selectivity toward valuable compounds. Fluidized bed reactors represent a favourable environment for biomass fast pyrolysis, due to their robustness, efficient multiphase contact and superior thermal performance. However, particle heating and time-temperature history, biomass and volatile/gas residence times, gas-solids contacting and mixing need to be controlled to drive conversion along the prescribed chemical pathway. A specific concern regards the course of secondary reactions between depolymerization products and char, whose progress may alter the quantity/quality of the bio-oil [1,2]. The relevance of the heterogeneous vapor-char interaction to bio-oil production emphasizes the importance of proper control of char loading establishing during steady operation of a fluidized bed pyrolytic converter, a state variable of the system that must be carefully controlled by proper reactor design and operation [3]. In the present study fluidized bed pyrolysis of biomass is assessed with a focus on operational modes that maximize the yield to depolymerization products: pyrolytic sugars, from decomposition of holocellulose; BTX and substituted monoaromatics, from decomposition of lignin. Accordingly, the reactor design and operating conditions are selected so as to minimize secondary interaction between primary pyrolytic vapours and biochar. Hence, a shallow fluidized bed with overbed feeding of relatively fine biomass particles is assumed (Figure 1).



A one-dimensional model including the key features of the fluidized bed pyrolytic converter is developed. The remarkable feature of the model is careful consideration of processes that control the establishment of a steady char loading in the bed, namely, entrainment, elutriation, attrition, and bed drain/regeneration. Primary pyrolytic decomposition of biomass and secondary reactions have been modeled using a semi-detailed reaction scheme. Different kinetic mechanisms are considered for the secondary reactions of the main macropolymers (cellulose, hemicellulose and lignin), including sugars dehydration and fragmentation, demethoxylation and demethylation of guaiacyl-containing structures from lignin depolymerization, uptake and decomposition of aromatic structures on char surface. Model results elucidate the role of heterogeneous secondary reactions, the main composition of bio-oil and the proper management of char loading during fluidized bed pyrolysis, providing criteria for optimal reactor design and operation.

References:

[1] H. Zhu et., 2021. The Effects of Char and Potassium on the Fast Pyrolysis Behaviors of Biomass in an Infrared-Heating Condition. Energy, 214, 119065. [2] C. Plouffe et al., 2022. The Role of Biochar in the Degradation of Sugars during Fast Pyrolysis of Biomass. J. Anal. Appl. Pyrolysis, 161, 105416. [3] M. Troiano et al., 2022. Fluidized Bed Pyrolysis of Biomass: A Model-Based Assessment of the Relevance of Heterogeneous Secondary Reactions and Char Loading. Energy Fuels, 36, 9660. Figure 1. Fluidized bed pyrolytic converter.

Long-Duration Low-Temperature Pyrolysis of Wood: From Polymer Degradation to Char Formation

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11:00-13:00 Session S3.1: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Vinu R (Indian Institute of Technology Madras, India)

ABSTRACT

Low-temperature pyrolysis of lignocellulosic materials remains insufficiently characterised, despite its critical relevance for long-duration heating scenarios such as concealed smouldering, storage degradation, and sub-critical fire exposures. In contrast to conventional short-duration laboratory experiments, prolonged exposure to moderate temperatures can trigger slow but cumulative physicochemical transformations that significantly affect thermal stability, ignition propensity, and char formation pathways. However, experimental data addressing such extended time scales remain scarce. In this study, beech (Fagus sylvatica L.) and spruce (Picea abies Karst.) wood specimens (150 × 150 × 20 mm³) were subjected to long-term thermal treatment at 150 °C for up to one year in an electrically heated furnace under oxidative atmosphere. Internal temperatures were continuously monitored using embedded thermocouples to ensure stable and homogeneous thermal conditions within the samples. Mass loss was determined at six-week intervals by extracting and weighing all specimens. Three samples were removed for detailed analysis of thermal, chemical, and optical changes at the same intervals. Beech consistently exhibited higher degradation rates than spruce throughout the exposure period, reflecting species-specific differences in chemical composition and thermal sensitivity. Colour measurements revealed an early convergence of both wood species, already after six weeks of storage, particularly with respect to lightness. With increasing exposure time, a gradual darkening was observed. The colour differences between beech and spruce diminished with prolonged heating. Simultaneous thermal analysis demonstrated a continuous depolymerisation of the wood matrix, manifested by a systematic reduction of the pyrolysis onset temperature with increasing storage duration. This behaviour is attributed to oxidative processes, progressive depolymerisation reactions, and the formation of thermolabile structures during long-term heat exposure. FTIR spectroscopy confirmed these trends, showing early hemicellulose deacetylation and cellulose depolymerisation, followed by an increasing dominance of lignin-derived structures in the residual matrix at longer treatment times. Ultimate and proximate analyses revealed a gradual increase in carbon content accompanied by a loss of oxygen and hydrogen, while ash content increased with mass loss. Simultaneously, volatile matter decreased and fixed carbon content increased, indicating a slow transition towards a char-like material. Overall, this study demonstrates that extended low-temperature exposure at 150 °C induces substantial and time-dependent changes in wood chemistry and thermal behaviour, underscoring the importance of duration effects in low-temperature pyrolysis. The results are not only relevant to pyrolysis science and fire safety, but also to a broader range of disciplines concerned with the long-term thermal ageing of wood. In particular, they broaden the understanding of self-heating and spontaneous ignition of biomass, smouldering combustion and deep-seated fire scenarios, and the durability and fire resistance of timber structures exposed to sustained moderate temperatures. Furthermore, the observed progressive heat induced disintegration links the findings to biochar formation and biomass conversion, highlighting the influence of storage and pre-treatment on devolatilisation behaviour and reaction kinetics. Finally, the work has implications for material testing and standardisation, as it demonstrates that short-duration laboratory protocols may not adequately capture time-dependent degradation processes relevant under real long-term thermal exposure conditions.

Hydropyrolysis: towards fluorescence-free Raman analysis of internal diesel injector deposits

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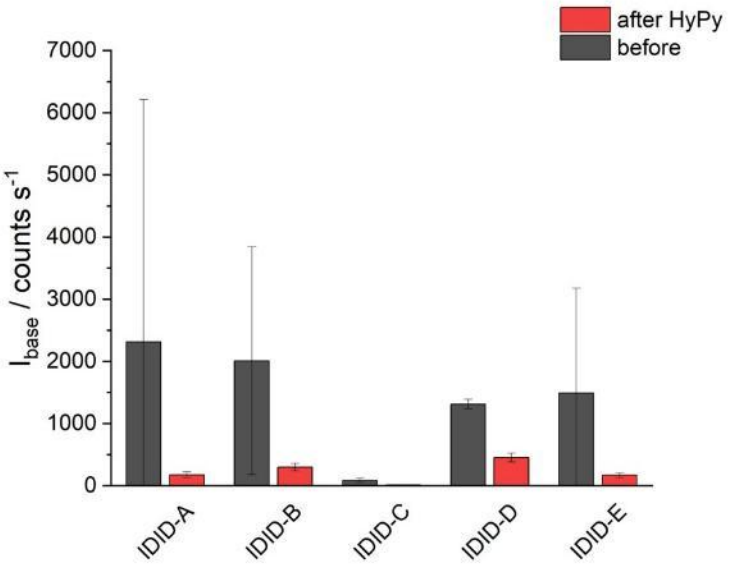
11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Micro-Raman spectroscopy (μRS) is an established analytical tool enabling facile determination of the structural ordering within carbonaceous materials, including the particulate-matter found in vehicle deposits and environmental matrices. However, if fluorescent species are present within the material under examination, analysis by μRS can be at best complicated and at worst impossible. Common methods to circumvent this issue, such as changing the excitation laser wavelength and/or photobleaching, are not always possible. In this study, we demonstrate pyrolysis under high hydrogen pressures (hydropyrolysis, HyPy) as an effective thermal treatment for the removal of fluorescent species at relatively low temperatures (350 oC), without significantly altering the structure of the parent carbonaceous material. This was illustrated through μRS investigation of a series of six carbon reference samples, whereby, after HyPy, the interference from fluorescence was significantly reduced, whilst the positions, widths and intensity ratios of the diagnostic D and G bands remained largely unchanged. Application of hydropyrolysis to a series of internal diesel injector deposits (IDIDs) enabled a μRS investigation of the physicochemical structure of the deposited carbons for the first time. Moreover, mass spectrometry analysis of the volatile species removed during HyPy of IDIDs where engine failures had occurred suggested that linear polyunsaturated n-C16 and n-C18 alkenes were likely responsible for the fluorescence. As HyPy can be readily applied to a variety of carbonaceous materials, for example, petroleum source rocks contaminated with drilling muds, the approach we describe here represents a general strategy for fluorescence suppression enabling structural investigation of carbons by μRS.



Carbon-Catalyzed Methane Pyrolysis in Fluidized-Bed Reactors: Analytical Investigation of Polyaromatic Hydrocarbon Formation and Two-Phase Reactor Modeling

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11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

The transition to a climate-neutral society will significantly depend on the production of low-cost, low-emission hydrogen (H2), given its role as a sustainable chemical feedstock and energy carrier. Global H2 production is projected to increase from 99.8 Mt in 2024 to 150 Mt by 2030. In this context, methane pyrolysis represents a promising technology for producing low-emission H2 by decomposing any source of renewable or fossil methane into H2 and value-added solid carbon by-product, thereby improving overall process economics. To enable methane pyrolysis at lower temperatures, catalysts are employed to enhance radical formation, which is essential for initiating the methane cracking chemistry and promoting solid carbon growth via acetylene deposition. Methane pyrolysis in carbon-catalyzed systems herein mitigates coking-induced deactivation, a major limitation of metal-based catalysts, where active sites are susceptible to blockage by carbon deposits. Furthermore, fluidization of the carbon catalyst prevents pressure build-up and reactor blockage caused by coke accumulation, commonly encountered in conventional fixed-bed reactors at temperatures exceeding 950 °C. However, the impact of carbon deposition on the carbon structure evolution, potential defluidization, and gas product distribution, particularly the formation of polyaromatic hydrocarbons (PAHs) responsible for equipment fouling and operational downtime, remains unclear.

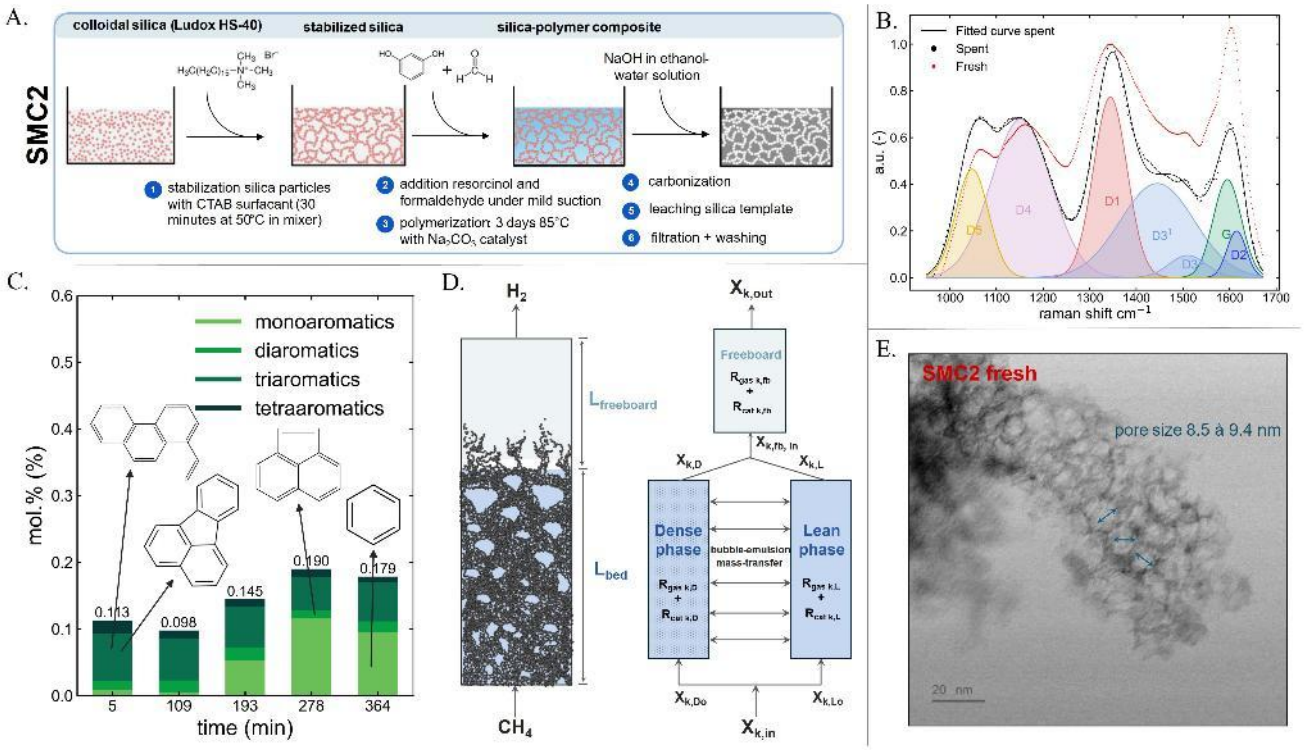


Figure 1. A) Schematic representation of the synthesis of SMC2 through the soft-templating technique based on a Ludox HS-40 template, B) Experimental and fitted Raman spectrum of untreated fresh and spent SMC2 with deconvolution in (i) D1 ~ 1350 cm^{-1} for graphene layer edges, (ii) D2 ~ 1615 cm^{-1} for graphene surface layers, (iii) D3[1] ~ 1450 cm^{-1} for polyene-like structures and amorphous carbon, (iv) D3[2] ~ 1500 cm^{-1} for heterogeneities, (v) D4 ~ 1150 cm^{-1} for polyene-like structures, (vi) D5 ~ 1060 cm^{-1} for aromatic rings, and (vii) G ~ 1590 cm^{-1} for graphitic lattice, C) Polyaromatic hydrocarbon distribution (mol.%) with indication of the most abundant mono-, di-, tri-, and tetraaromatics in function of the reaction time for methane pyrolysis at 1000°C, 1.1 bar, WHSV 42 hr^{-1} for the carbon black pearls 2000 catalyst under fluidization conditions, D) Conceptual representation of the general two-phase fluidized-bed reactor model with indication of bubble-emulsion phase mass transfer and freeboard section, and E) Bright-Field scanning electron microscopic image of the untreated SMC2 catalyst.

In this work, carbon black Pearls 2000 and SMC2 ordered mesoporous carbon, synthesized through a soft-templating technique on a colloidal silica template, have been thoroughly characterized (N2-physisorption, Raman spectroscopy, CHN/O elemental analysis, XPS, and BF-STEM) to determine the carbon structure prior to and after performing methane pyrolysis in a laboratory scale fluidized-bed reactor. SMC2 exhibited the highest initial H2 yield due to its high specific surface area (1243 m^2/g_cat) and initial oxygen content (7.7 wt.%), but gradually deactivated through pore filling and blockages. Carbon black Pearls 2000 demonstrated greater stability, achieving the highest cumulative carbon yield (3.9 g_carbon/g_cat) after 6 hours of reaction at 1000°C. Carbon deposition led to the formation of graphitic domains around the primary carbon black particles, reducing structural heterogeneities and defects in the overall carbon framework. Additionally, with increasing reaction time, the PAH distribution, as identified using both Van den Dool–Kratz and Lee retention indices, shifts from mostly triaromatics, with vinylphenanthrene as the most abundant PAH (0.019 mol.%), to mostly monoaromatics after 6 h of reaction, notably benzene (0.04 mol.%). The identification of naphthalene, acenaphthalene, phenanthrene, pyrene, and their corresponding vinyl-substituted derivatives indicates that the hydrogen-abstraction carbon-addition mechanism (HACA) via consecutive acetylene addition is the dominant pathway for PAH growth during methane pyrolysis. Finally, a two-phase fluidized-bed reactor model was developed, comprising a low density, dominantly gas phase and a high density, dominantly solid phase, coupled to a freeboard section. Transitions between bubbling, turbulent, and fast fluidization were explicitly accounted for using probability density functions on the critical transition velocities. The model integrates homogeneous gas-phase and heterogeneous surface kinetics through the Cantera framework and was validated against the fluidized-bed experiments. Under the assumption of reactor isothermicity, the model will be used to quantify axial heat requirements, providing key insights for the design and scale-up of electrified industrial fluidized-bed reactor systems.

Catalytic Methane Pyrolysis in Molten Media: From Bubble Dynamics to Tailored Solid Carbon Synthesis and Process Scale-up

Zhiyuan Shi (Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, China) Qingkai Yu (Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, China)

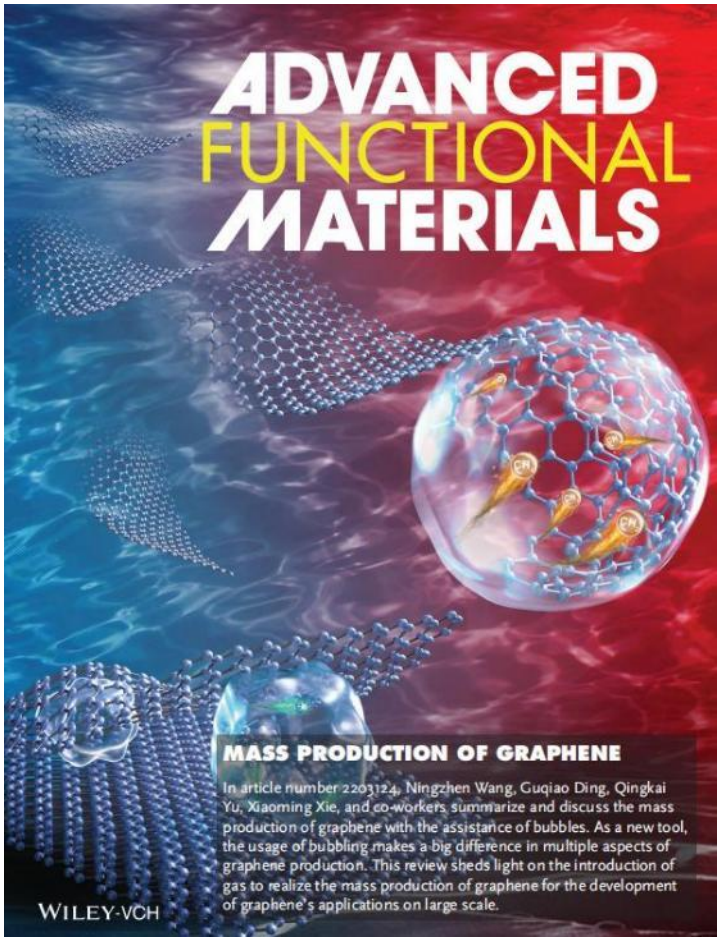
11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Methane pyrolysis via molten media catalysis offers a promising route to low-carbon hydrogen production, concurrently generating valuable solid carbon rather than CO2. The process offers a dynamically refreshed reaction interface where forming carbon is continuously separated and buoyed away by rising gas bubbles, effectively enabling catalyst anti-coking and high reaction throughput. This study reports integrated progress in bubble behavior simulation, solid carbon synthesis, and scale-up of this promising technology. A coupled VOF-DPM model was developed to quantitatively elucidate the bubble dynamics inside the melt, linking hydrodynamics to reactor performance. Building on this foundation, bubbling chemical vapor deposition was systematically employed to control solid carbon morphology. By regulating bubble size and residence time, the selective synthesis of zero-dimensional carbon black, two-dimensional graphene, or three-dimensional graphitic microspheres was achieved, establishing a direct link between fluid dynamics and tailored material architecture. Finally, the technology has been advanced toward pilot-scale implementation, demonstrating continuous hydrogen production and solid carbon co-generation in a scalable reactor configuration. This work provides a cohesive framework from fundamental multiphase modeling to controlled material synthesis and process engineering, underscoring the potential of catalytic molten media systems for combined decarbonization and valuable solid carbon with tailored structure production.



Multi-scale investigation of methane pyrolysis for the simultaneous production of COx-free hydrogen and valuable carbonaceous materials for the steelmaking sector

Marco Orsenigo (Politecnico di Milano, Italy) Veronica Piazza (Politecnico di Milano, Italy) Lidia Castoldi (Politecnico di Milano, Italy) Gianpiero Groppi (Politecnico di Milano, Italy) Matteo Maestri (Politecnico di Milano, Italy) Chiara Negri (Politecnico di Milano, Italy) Gianluca Dall'Osto (Politecnico di Milano, Italy) Carlo Mapelli (Politecnico di Milano, Italy) Alessandra Beretta (Politecnico di Milano, Italy)

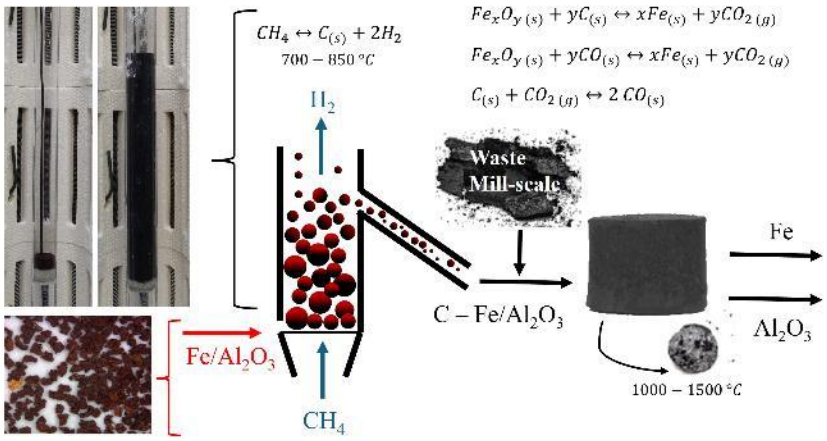
11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Catalytic Methane Pyrolysis (CMP, CH4=2H2+C(s), ΔH°=75 kJ/mol) is receiving increasing attention to produce COx-free hydrogen along with solid carbon (3:1=C:H2 wt.). The latter represents a valuable by-product whose valorization is essential to make the process economically competitive. However, its deposition poses significant challenges to process design and scale-up. In this work, CMP performances of iron-alumina catalyst are experimentally investigated on multiple scales to elucidate mechanisms governing C-growth and deactivation. Furthermore, changes in morphology and reactivity of the resulting iron-carbon materials (i.e. spent catalyst) are assessed as function of operating conditions. Attention is focused on carbon-purity and graphitization-degree (G) with the aim of evaluating the valorization potential in steelmaking as reducing agent for waste iron recovery, to couple hydrogen production with circular iron and carbon management strategies. Fe-Al2O3 catalysts were prepared by fusion-decomposition method and tested in thermogravimetric balance (TG, 0.004gcat), packed-bed (PBR, 0.75gcat), and fluidized-bed (FBR, 3.50gcat) reactors. The effects of Fe-loading (5-100wt.% Fe), temperature (700-850°C), space velocity (GHSV, 1-100 NL/h/gcat), and inlet CH4 (2.5-95vol.%) on catalytic performances were assessed. Furthermore, fresh, reduced and spent catalysts were characterized, including microscopic (e.g. BET, XRD, RAMAN, SEM) and macroscopic (e.g. particle size and density) properties. Finally, the obtained spent-catalyst was pelletized with waste mill scales (60wt.%FeO + 30wt.%Fe3O4) and used as reducing agent for the carbothermal conversion of the mixed FexOy into metallic-iron (FexOy+yC(s)=xFe0+yCO(g), 750-1500°C, 100vol.%Ar). Firstly, a screening campaign in TG identified the Fe-Al2O3 catalyst (52wt.%Fe) as the best formulation in terms of activity and C-accumulation capacity. This catalyst was further tested in PBR to explore the effect of operating conditions on CH4 conversion and the corresponding C-load (gC/gcat). In all tests, a rapid decrease in conversion was observed due to carbon deposition, becoming more pronounced at increasing CH4 feed and temperature. Notably, operating at temperature and GHSV below 780°C and 5 NL/h/gcat, respectively, maximized catalyst lifetime and C-load up to 5 gC/gcat, a key requirement for scale-up. A dynamic reactor model was developed in order to predict C and H2 productivity in a wide operating range. However, PBR operations were inherently limited due to C-induced overpressure and clogging. These limitations were overcome in FBR, where bubbling fluidization regime minimized overpressure, enabled longer experiments, favored carbon growth, its discharge and post-characterization. Notably, time on stream and C-load were identified as the primary parameters governing the evolution of spent solid properties. Carbon was deposited either as encapsulating-C or bent and twisted multi-walled carbon nanotubes. The latter were the responsible of the reduction in bulk density (700-45 kg/m3) and enlargement of particle size (150-400 µm) observed with the C-load growth in FBR. Over time, carbon became more ordered as evidenced by XRD (G > 50%) and Raman spectroscopy (IG/ID > 2), while C-purity increased with increasing C/Fe-Al2O3 ratio. When applied to self-reducing agglomerates, spent catalysts (C-load >1.0 gC/gcat) exhibited performances comparable to those of metallurgical-grade coke. Promising reduction degree above 80% were achieved at 1375°C, while iron recovery increased with carbon purity, highlighting the potential synergy between pyrolysis and steelmaking.



Leaching and enrichment behaviors of hazardous heavy metal elements in the process of coal gasification

Xingjun Wang (ECUST, China)

11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Coal gasification is a key route for coal clean utilization. As the mainstream technology in modern coal chemical industry, entrained-flow coal gasification features a carbon conversion rate exceeding 99% and broad feedstock adaptability, and is advancing toward independent technology upgrading, feedstock-product diversification, and green low-carbon development [1]. However, the annual output of coal gasification slag in China exceeds 70 million tons, with stockpiling and landfilling as the primary disposal method. The hazardous elements contained pose potential environmental risks, and the utilization rate of gasification slag is below 20% [2]. During gasification, the slag is divided into CS (quenched and collected in the quench chamber, ~60%–80% of total slag, low carbon content) and fine slag (carried out of the gasifier by syngas, ~20%–40% of total slag, high carbon content) [3]. During entrained-flow gasification, to clarify the migration, enrichment and regulation mechanisms of Hg, Cd, Pb, Cr and As in coal gasification slag, this study systematically investigated the leaching and enrichment characteristics of these five elements. Combining FactSage calculations with experimental analysis, it explored their enrichment and speciation in CS and FS, leaching behaviors under different heating rates, and the effect of Fe2O3 on Cr migration. Results showed that weakly volatile Cd was mainly enriched in slag, with a higher proportion in FS, existing as Cd, CdO and CdS. Highly volatile Hg only accounted for 15.6% of the total in slag (10.5% in FS), dominated by HgO with low Hg and HgS contents. Partially volatile Pb was more concentrated in FS, with PbS as the dominant species. As exhibited a similar enrichment pattern to Cd, with 81.9% remaining in slag. Heating rate significantly affected element distribution: rapid heating induced coal particle porosification and larger specific surface area, accelerating Cd and As volatilization while enhancing their adsorption, resulting in higher contents in slag than slow heating. Pb content showed no obvious change due to mineral combination under slow heating versus volatilization-adsorption balance under rapid heating. Under the reductive atmosphere, Fe mainly existed as FeO. Fe2O3 addition affected Fe speciation transformation: 1 wt.% addition increased Fe(Ⅱ) contents, while excessive addition reduced them. Cr primarily existed as highly stable CrO in slag. This study provides theoretical support for heavy metal pollution control of coal gasification slag.

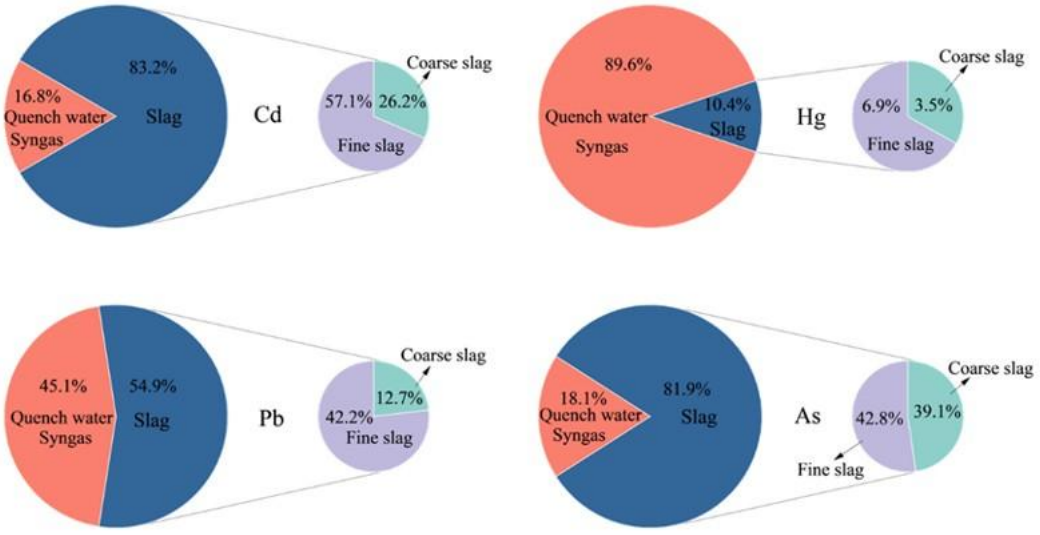


Fig.1 Cd, Hg, Pb, and As element distribution during coal gasification

References [1] Yifan Zhang, et al. Distribution, occurrence, and leachability of typical heavy metals in coal gasification slag. Science of The Total Environment, 2024, 926, 172011. [2] Tao Wu et al. Characterisation of residual carbon from entrained-bed coal water slurry gasifiers. Fuel, 2007, 86(7–8): 972-982. [3] Wenke Jia. et al, Chongdian Si. Co-combustion of carbon-rich fraction from coal gasification fine slag and biochar: Gas emission, ash sintering, heavy metals evolutions and environmental risk evaluation, Chemical Engineering Journal, 2023, 471, 144312

Carbon Formation on Surfaces during Methane Pyrolysis: Effects of Temperature, Methane Flow Rate, and Operation Time

Emmanuel Busillo (Sapienza Università di Roma, Italy) Maria Paola Bracciale (Sapienza Università di Roma, Italy) Paolo De Filippis (Sapienza Università di Roma, Italy) Benedetta de Caprariis (Sapienza Università di Roma, Italy)

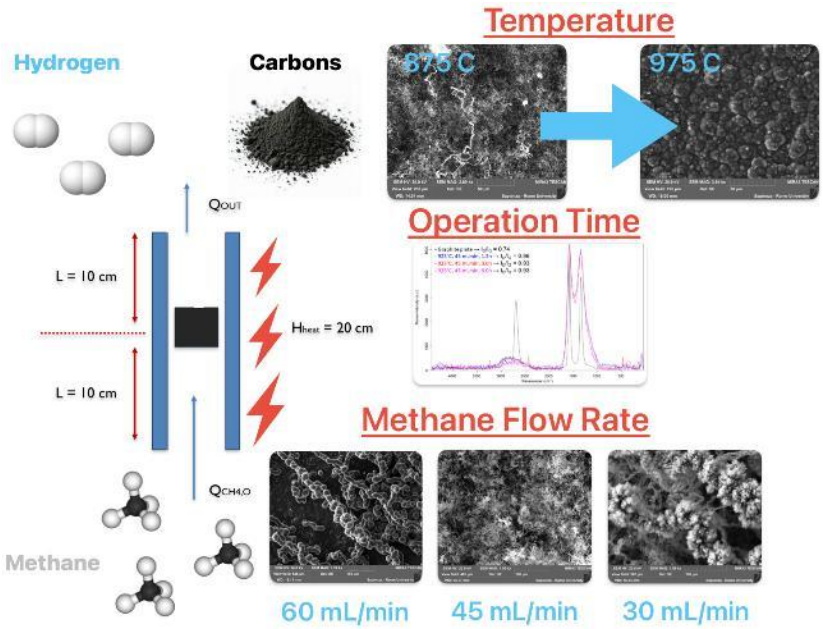
11:00-13:00 Session S3.2: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marcin Sajdak (Silesian University of Technology, Department of Air Protection, 44-100 Gliwice, Poland, Poland) Guozhu Liu (Tianjin university, China)

ABSTRACT

Methane pyrolysis is attracting growing interest as a sustainable route to CO2-free hydrogen production and advanced carbon materials. However, the fundamental mechanisms governing carbon nucleation and growth on reactor walls and solid substrates remain only partially understood, particularly under conditions relevant to industrial operation. This work presents a combined experimental and characterization study of carbon deposited on quartz walls and graphite plate surfaces during methane pyrolysis, with the objective of elucidating how operating conditions and gas-phase chemistry govern the resulting carbon morphology and structure. Methane pyrolysis experiments were conducted in a tubular flow reactor (length 40 cm, inner diameter 1.5 cm) containing a graphite plate (13×25 mm) positioned at the reactor centerline. The system was operated over a temperature range of 875–975 °C, residence times adjusted via methane inlet flow rates of 30–60 mL/min, and exposure durations of 0.75–3 hours. This parametric design enabled systematic investigation of temperature, flow rate, and operation time effects on carbon deposition. The morphology and structure of surface-grown carbon were characterized ex situ by scanning electron microscopy (SEM), Raman spectroscopy, and Brunauer–Emmett–Teller (BET) surface area analysis. These complementary techniques enabled discrimination between amorphous particles, pyrolytic carbon, and filamentous structures, while providing quantitative insight into morphology, structural disorder, and specific surface area. Results demonstrate that carbon deposition during methane pyrolysis is strongly governed by temperature. At lower temperatures (875 °C), filamentous carbon structures formed and grew with increasing residence time, with structure complexity and branching features modulated by gas mean residence time in the reactor. Increasing temperature suppressed filament formation in favor of more compact, two-dimensional carbon growth. This morphological transition was quantitatively confirmed by BET measurements, which showed a dramatic decrease in specific surface area from 75 m²/g at 875 °C to 5 m²/g at 975 °C, consistent with the loss of high-surface-area filamentous features. Raman spectroscopy revealed that carbon deposits on the graphite plate exhibited lower structural order than the substrate itself, with intensity ratios ID/IG ranging between 0.93 and 0.96, indicating substantial disorder and defect density in the deposited material. Overall, this study provides quantitative data and mechanistic insight into carbon formation on surfaces during methane pyrolysis, bridging the gap between homogeneous gas-phase decomposition chemistry and heterogeneous carbon formation. These findings are directly relevant for optimizing methane pyrolysis reactor design and operation for low-carbon hydrogen production, as well as for understanding and controlling carbon deposition, fouling, and selective carbon growth in high-temperature industrial processes.



Reliability of milligram-scale high-throughput screening for evaluating polyolefin chemical recycling in the melt with heterogeneous catalysis

Brent Smeyers (KU Leuven, Belgium) Kseniia Vikanova (KU Leuven, Belgium) Jonathan Van Waeyenberg (KU Leuven, Belgium) Michiel Aerts (KU Leuven, Belgium) Toon Van Vaerenbergh (KU Leuven, Belgium) Oguzhan Akin (UGent, Belgium) Qing He (UGent, Belgium) Andreas Eschenbacher (UGent, Belgium) Robin John Varghese (UGent, Belgium) Jules Henrotte (KU Leuven, Belgium) Anton Ginzburg (KU Leuven, Belgium) Kevin Van Geem (UGent, Belgium) Bert Sels (KU Leuven, Belgium)

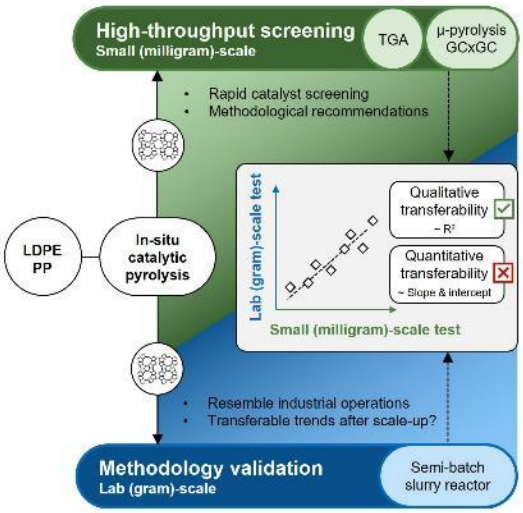
11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

Effective management of plastic waste is an increasingly urgent global challenge, and catalytic pyrolysis of polyolefins offers a promising route to convert waste plastics into high value base chemicals. Despite extensive research, catalyst discovery efforts remain fragmented, with most studies relying on milligram scale tools such as thermogravimetric analysis (TGA) and micropyrolysis GC×GC FID/MS. These approaches often use inconsistent methodologies, limiting comparability across studies and raising uncertainty about the transferability of small scale results to larger scale systems. This work introduces a rational, standardized catalyst screening methodology and provides the first systematic validation of its predictive power across scales. A fast and robust workflow was developed to evaluate catalyst activity, stability, and selectivity for the direct in situ catalytic pyrolysis of LDPE and PP melts. Catalyst activity was quantified using three TGA derived temperature metrics (ΔTonset, ΔTmidpoint, ΔTmax), with ΔTmidpoint identified as the most reliable indicator due to its sensitivity to catalytic effects and its ability to normalize feedstock variability. Catalyst stability was assessed via coke content, reflecting the extent of deactivation through active site blockage. A unique 2D TGA method was established to simultaneously determine catalytic activity (ΔTmidpoint) and stability (coke content) in a single experiment. Plotting these metrics in a 2D scatterplot enabled rapid categorization of catalyst performance (high, moderate, low). Applied to more than 60 heterogeneous catalysts, this approach provided an unprecedented comparative overview of catalyst behavior in polyolefin pyrolysis. For LDPE, ZSM 5 (25) and ASA [40] HPV emerged as the top performing zeolite and non zeolite catalysts, respectively. For PP, USY (40) and ASA [70] HPV were found optimal from the scatterplot. These catalysts reduced polymer degradation temperatures by more than 125 °C relative to thermal pyrolysis. To evaluate transferability to larger-scale reactors, selected catalysts were tested in a gram scale semi batch slurry reactor. Activity (Tonset) and stability (coke content) were quantified and compared to small scale results using regression analysis. A distinction was made between qualitative transferability (preservation of performance ranking; assessed via R^2 and F tests) and quantitative transferability (accurate prediction of absolute values; assessed via slope and intercept confidence intervals). Qualitative trends for activity, stability, and selectivity were successfully transferred for both LDPE and PP. Quantitative transferability, however, was limited. For LDPE, coke contents were systematically higher at lab scale, likely due to longer residence times. For PP, although coke levels were also higher, the difference was not statistically significant. Selectivity trends, captured via the average carbon number (ACN), were qualitatively transferable for both polymers, while quantitative agreement was confirmed only for PP. This study delivers the first statistically validated framework demonstrating that TGA and micropyrolysis GC×GC FID/MS reliably predict qualitative catalyst behavior in polyolefin pyrolysis. While quantitative predictions remain setup dependent, the methodology enables rapid, comparable, and community wide catalyst assessment, providing a foundation for more coherent catalyst development strategies in plastic waste valorization.



High-throughput on-line mass spectrometry screening of catalytic fast pyrolysis of cellulose over ZSM-5 zeolites

Nathan Traullé (LCP-A2MC, Université de Lorraine, France) Thomas Lemaître (LCS, UMR 6506, ENSICAEN, France) Théo Voellinger (LCP-A2MC, Université de Lorraine, France) Vincent Carré (LCP-A2MC, Université de Lorraine, France) Jasmine Hertzog (LCP-A2MC, Université de Lorraine, France) Sébastien Schramm (LCP-A2MC, Université de Lorraine, France) Yann Le Brech (LRGP, Université de Lorraine, France) Anthony Dufour (LRGP, Université de Lorraine, France) Ludovic Pinard (LCS, UMR 6506, ENSICAEN, France) Frédéric Aubriet (LCP-A2MC, Université de Lorraine, France)

11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

Fast pyrolysis (FP) of lignocellulosic biomass notably produces bio-oils rich in oxygenated platform molecules. Catalytic fast pyrolysis (CFP), particularly when zeolite catalysts are used, alters the reaction pathways of conventional FP and promotes the formation of hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Conventionally, pyrolysis studies rely on bio-oil production in a pyrolysis reactor for each condition, followed by offline chromatographic analysis, often coupled with mass spectrometry. Alternatively, direct infusion high-resolution mass spectrometry (HRMS) can be employed. While powerful, these approaches are time-consuming and may introduce compositional biases due to chemical evolution of bio-oils or reactions with recovery solvents. Moreover, they provide limited insight into the dynamic evolution of pyrolysis reactions. To accelerate CFP optimization, we developed a high-throughput methodology enabling direct HRMS analysis of pyrolysis products. This approach allows rapid characterization of the molecular species formed during pyrolysis as a function of key parameters such as catalyst type, biomass, and temperature. The methodology was validated using cellulose CFP over Socony Mobil Five (ZSM-5) zeolites, extensively reported in the literature for their upgrading performance in catalytic pyrolysis. Commercial ZSM-5 catalysts with Si/Al ratios ranging from 0 to 75 and Brønsted acid site densities between 0 and 980 µmol/g were investigated. Avicel® PH-101 cellulose was selected as a model biomass. FP experiments required less than 1 mg of sample and were performed in a glass capillary mounted on a modified direct injection probe (DIP). The probe incorporates a controlled nitrogen flow through the capillary, minimizing residence time of the pyrolysis vapors in the heated zone and efficiently transferring products to an atmospheric pressure chemical ion (APCI) source. Temperatures up to 530 °C were reached. For CFP experiments, a fixed-bed catalyst layer was introduced downstream of the biomass. Product ions were analyzed using a Fourier transform ion cyclotron resonance mass spectrometer (FT-ICR MS), and the resulting data was processed with Punc'Data software for molecular formula assignment and graphical representation. Under non-catalytic conditions, anhydro-oligosaccharides such as levoglucosan and cellobiosan, two markers of cellulose pyrolysis, were prominently detected, together with dehydrated and secondary products. In contrast, catalytic conditions strongly suppressed these species and favored the formation of less oxygenated molecules, such as furfural, as well as fully deoxygenated hydrocarbons, including BTEX. Catalyst screening revealed an increase in the relative abundance of hydrocarbons with decreasing Si/Al ratio and increasing Brønsted acid site density. In addition, the degree aromaticity of the products increased with catalyst acidity, in agreement with previously reported trends.[1,2] These results demonstrate that combining micro-scale CFP with direct HRMS analysis provides a rapid, low-sample and low-catalyst demand, and realistic assessment of CFP performance. This methodology opens new perspectives for high-throughput and in-depth investigation of CFP mechanisms across a wide range of catalysts, operating conditions, and feedstock. [1] Mihalcik et al., Journal of Analytical and Applied Pyrolysis, 2011, 92, 1 [2] Engtrakul et al., Catalysis Today, 2016, 269

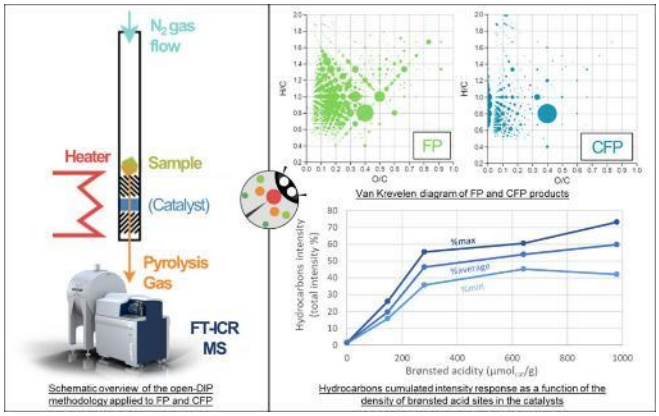


Figure: Schematic overview and results of analysis obtained with the modified DIP methodology, using Punc'data software for comparison of FP and CFP products.

Catalytic Pyrolysis of E-Waste Plastics Using Red Mud

Mohnish Madhukar Borker (INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY INDIA, India) Srinivas Seethamraju (INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY INDIA, India)

11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

The rapid growth of electrical and electronic waste (e-waste) plastics, along with the need for a circular economy and sustainability, poses a significant opportunity for e-waste recycling. Pyrolysis is one such technique that focuses on waste valorization through catalytic pyrolysis of e-waste. In this study, catalytic pyrolysis of e-waste plastics was performed using red mud , an effluent from the alumina industry, as a low-cost and sustainable catalyst. Thermal and catalytic pyrolysis experiments were conducted to analyze the influence of red mud on product yield, composition, and fuel quality. Fresh, regenerated red mud and spent FCC catalyst were compared to assess catalytic activity and stability. A comprehensive characterization of the feedstock, catalyst, and pyrolysis products was carried out using proximate analysis, TGA DSC, XRD, FTIR, GC-MS, and CHNS analysis. The utilization of redmud for catalytic pyrolysis significantly enhanced the cracking reactions, improving the fuel oil quality as compared to thermal pyrolysis. The plastic from e-waste, composed of Acrylonitrile Butadiene Styrene (ABS) and High Impact Polystyrene (HIPS), underwent catalytic pyrolysis at 550 °C with 15 wt% of redmud as a catalyst in a bench-scale reactor. It generated approx. 75 wt% aromatic hydrocarbon-based oil. It was observed that the pyrolysis oil properties closely match those of gasoline. The utilization of regenerated redmud resulted in similar oil yields. The pyrolysis oil can be suitably blended with conventional fuels for engine applications. Overall, the study demonstrates the potential of redmud as an effective catalyst for e-waste plastic pyrolysis, offering an environmentally sustainable route of utilizing two major waste streams – one for fuel production and another for catalyst synthesis

Thermogravimetric Insights into Polyethylene Degradation: Effect of Clay-Based Catalyst Acidity and Textural Properties

Maryann Ifeoma Uzochukwu (IMT Atlantique, France) Deny Grekov (IMT Atlantique, France) Sary Awad (IMT Atlantique, France)

11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling
Location: ROOM C1 – FIRST FLOOR
Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

With the urgent need to valorise over 80% of global plastic waste polluting the environment, many strategies have been developed to address this challenge, with one of the most promising routes with long-term solutions being catalytic pyrolysis of plastic waste into useful hydrocarbons and chemicals. Thermal cracking of polyethylene requires high activation energy and produces more waxy products. The use of catalysts in the pyrolysis of plastics reduces this activation energy, yielding lower molecular weight hydrocarbons and providing selectivity for target products. However, the rapid deactivation of these catalysts, caused by carbon coke deposits common to the most expensive synthetic zeolite-based catalysts, and the loss of activity during regeneration processes, have motivated research into cheaper alternatives, such as clay-based catalysts. Developing a low-cost catalyst with efficient activity for the degradation of plastic into value-added hydrocarbons is key. Clay catalysts are low-cost and naturally occurring materials that can be modified to increase activity through acid activation. In this study, seven (7) commercially available acid-activated clays were investigated for the effects of their acidity and textural properties on the degradation of PE plastic into value-added hydrocarbons and chemicals using thermogravimetry analysis. Acid-montmorillonite clay with unknown acidity details from two sources was used. The catalysts were characterised for their acidity using temperature-programmed desorption of ammonia on active acid sites (NH_3-TPD), their Si/Al ratio by SEM-EDX, and cationic exchange capacity was also determined. The textural properties of the surfaces and pore volumes of the catalysts were determined using nitrogen gas adsorption/desorption. The catalytic degradation of the PE over a clay-based catalyst was carried out using a thermal analyser with a catalyst-to-plastic ratio of 1:1 and 1:10. of The result showed that the clay-based catalysts' total acidity ranges from 0.26 to 0.53 mmol NH_3/g catalyst, exhibiting four distinct acidity levels: weak acidity (WA), medium acidity (MA), strong acidity (SA) and very strong acidity (VSA), which were categorised based on their desorption temperature ranges: 150–250°C, 250–350°C, 350–500°C and above 500°C, respectively. Analysis of the results for the temperature shift, which is the difference between peak degradation temperatures of the catalysed and uncatalysed PE mass loss, shows that K10 exhibited the highest temperature shift of 87℃ and 56℃ at a catalyst-to-plastic ratio of 1:1 and 1:10, respectively and performed better than zeolite based catalyst at catalyst to plastic ratio of 1:1.The greater the temperature shift, the better the catalyst effectiveness to reduce the energy requirement for degradation. Clay catalyst acidities, surface area, and mesoporosity correlate with the most effective catalyst for PE degradation. The clay catalyst's medium and very strong acidities contribute significantly to the shift in temperature during catalytic degradation, with correlation coefficient R^2 values of 0.90 and 0.84 for catalyst-to-plastic ratios of 1:1 and 1:10, respectively, resulting in low coke yield.

Optimization of catalytic hydrocarbon aromatization to BTX in a lab-scale fluidized bed reactor

Javier Ordonez Loza (Groningen University, Colombia) Jelmer Dijk (Groningen University, Netherlands) Hero Jan Heeres (Groningen University, Netherlands) Arne Hommes (Groningen University, Netherlands)

11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

Benzene, toluene, and xylenes (collectively known as BTX) are essential feedstocks in the manufacture of a wide range of chemical products. Currently, practically all BTX is produced from fossil-carbon sources in the petrochemical industry. However, recent advances have been made on BTX production from waste plastics, offering a promising method for the valorization of hard-to-recycle plastic waste. In such process, waste plastics are first pyrolyzed to crack the plastic chains into a complex mix of hydrocarbon vapor stream (generally represented mainly by C5-C12 paraffins) and precipitate out inorganic impurities as solids. The produced vapor is subsequently upgraded to BTX in a second reactor through catalytic aromatization, typically with a zeolite catalyst. Light olefin and paraffin gases are formed as byproducts. This study addresses the catalytic aromatization of plastic-derived hydrocarbons in a lab-scale fluidized bed reactor using a HZSM-5 catalyst and model hydrocarbons as the feed (i.e., hexane, dodecane, or 1-hexene). The hydrocarbon feed was diluted with N2 before entering the reactor. BTX reaction products were recovered by a series of condensation steps followed by biodiesel scrubbing. the remaining gaseous product was collected for compositional analysis and to determine the mass balance. The effect of reactor operating conditions (temperature, feed concentration, contact time) on the BTX and gaseous product yields was systematically evaluated with hexane as the feed. at temperatures between 500 - 600 °C and molar N2 to feedstock ratios of 1.2 to 3.6. An increase in temperature significantly improved the total BTX yield, from 10 wt% at 500 °C to 21 wt% at 600 °C. Furthermore, operating temperature had a considerable effect on the BTX product distribution. Toluene was the most abundantly formed aromatic product, with 48% selectivity at 600 °C. Benzene yield increased at higher temperatures, from ~1.0 wt% to ~5.3 wt%. Xylene selectivity was mostly independent of temperature, remaining within ~20–28%. Feed dilution experiments at 550 °C strongly affected the BTX formation. Increasing molar nitrogen to hydrocarbon ratio 1.2 to 3.6 resulted in a lower total BTX yield, with especially less toluene (~9.2 vs. ~6.8 wt%) and xylenes (~6.9 vs. ~3.8 wt%) formed. The benzene yield remained relatively equal (~2.5–2.8 wt%), indicating a higher thermal stability. Overall, increased feed dilution suppressed secondary aromatization and alkylation by reducing effective residence time. Experiments with 1-hexene or dodecane as alternative hydrocarbon feeds highlighted the role of feed structure on BTX formation. The olefinic feed strongly enhanced BTX formation, increasing toluene yield to ~16.0 wt%, compared to ~7.8 wt% with hexane as the feed under otherwise the same reaction conditions. Xylene and benzene yields reached ~10.7 wt% and ~5.3 wt%, respectively. In contrast, dodecane produced lower BTX yields and higher fractions of light non-aromatic hydrocarbons. The presented experimental study provides insight into the optimized conditions for BTX formation from plastic-derived feeds, aiding reactor design and scale-up towards a maximized BTX yield or selective production of targeted BTX compounds.

Pyrolytic modification of wood enhances its cascaded use

Clemens Knill (Swero GmbH & CO.KG, Germany) David A. Agar (Swedish University of Agricultural Sciences, Sweden)

11:00-13:00 Session S3.3: Catalytic pyrolysis: Polymers and recycling

Location: ROOM C1 – FIRST FLOOR

Chairs: Salar Tavakkol (Karlsruhe Institute of Technology, Germany) Cristian Torri (Università di Bologna, Italy)

ABSTRACT

The European Union promotes the cascaded use of wood in new products to support a carbon sink functionality and the non-energy valorisation of biomass. Thermally modified wood (TMW) building products, such as cladding and decking, are increasingly utilised in modern architecture. Being produced using mild pyrolysis, TMW is chemical-free, which facilitates its reuse in bioeconomy applications. The cascaded use of TMW in urban landscapes contributes to more sustainable building practices and alleviates pressure on forest ecosystems where virgin wood is harvested. Despite rapid growth in TMW volumes over the last decade, this resource remains largely unmapped and unmanaged in our cities. In this study, the TMW sector in Europe is illuminated and mapped. Light is shed on the details of the pyrolytic modification process, selection of raw material species, by-products generated, standing volumes of TMW in key markets and the potential of end-of-life TMW materials. Through networking with key partners, recent developments in the field including policy considerations are also described. The findings paint a picture of a rapidly maturing TMW industry with great market appeal for both environmental and technical performance reasons. The presented results include specific evidence from preliminary and on-going research work. The conclusions reached are that TMW materials (both end-of-life and production by-products) are of high-value in the bioeconomy and their uniqueness greatly enhances the potential for the cascaded use of wood.

Pyrolysis of end-of-life paddle balls: assessing the kinetics and the recovery of value-added products

Juan Daniel Martinez Angel (Instituto de Carboquímica (ICB-CSIC), Spain) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain) Alberto Veses (Instituto de Carboquímica (ICB-CSIC), Spain) Sara Ledesma (Instituto de Carboquímica (ICB-CSIC), Spain) José Manuel López (Instituto de Carboquímica (ICB-CSIC), Spain) María Soledad Callén (Instituto de Carboquímica (ICB-CSIC), Spain) Tomás García (Instituto de Carboquímica (ICB-CSIC), Spain) Ramón Murillo (Instituto de Carboquímica (ICB-CSIC), Spain)

11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Millions of paddle and tennis balls are used worldwide each year. These balls are nearly identical in composition and have a very short lifespan, resulting in a significant amount of waste. Additionally, they are primarily made of rubber coated with textile felt, making them more difficult to manage as waste. Similar to end-of-life tires, the main conventional disposal methods for these balls are energy recovery and material recovery. However, incorporating this type of waste into more circular economy strategies is essential, and chemical recycling methods, such as pyrolysis, are necessary to achieve this goal. Pyrolysis retains the carbon embedded in end-of-life products, making it available for new processes and reducing the consumption of fossil resources. Based on this, the present study evaluates the thermochemical recycling of end-of-life padel balls (ELPBs) via pyrolysis. To this end, thermogravimetric analysis (TGA) was performed, and the Distributed Activation Energy Model (DAEM) was employed to analyze the kinetics of the rubber and textile felt. Additionally, a laboratory-scale fixed bed reactor at the third technology readiness level (TRL-3) was employed to assess the impact of temperature (350–600°C) on the yields and primary characteristics of the resulting products. There are no detailed studies on the kinetics of this particular waste; and therefore there are no mathematical expressions describing conversion (X) and reaction rate (dX/dt) with respect to temperature (T). Kinetics is essential to incorporate into both particle and reactor models, i.e. when designing and scaling up the process. In addition, the activation energy (Ea) distribution of the rubber was found to fluctuate between 170 and 300 kJ/mol, suggesting the presence of complex, multistep reactions, including parallel, competitive, and consecutive reactions. All of the experimental kinetic curves were satisfactorily reproduced, and the deviations between the experimental and predicted data revealed the soundness and robustness of the DAEM application to these complex samples. On the other hand, the proof-of-concept trials demonstrate the technical feasibility of pyrolyzing these wastes, paving the way not only to determine the effectiveness of this chemical recycling process, but also to take it to a higher level of maturity. In this sense, the pyro-oil yield stabilizes at 45.0 wt% at 400 °C, and contains up to 5 wt% of limonene, which is associated with rubber depolymerization. Monocyclic aromatic hydrocarbons (BTEX) were also detected, increasing as the pyrolysis temperature increased. The solid fraction was found to stabilize at 400 °C, reaching a yield above 50 wt%. It is composed mainly of Ca (18 wt%), followed by Al (5.0 wt%), S (2.2 wt%), Ba (2.5 wt%), Zn (2.25 wt%), and Mg (1.25 wt%). Meanwhile, the gas fraction is predominantly rich in H_2 (20 vol%), CH_4 (14 vol%), and C_4 (14 vol%). These data are expected to provide the fundamental knowledge necessary to assess the technical feasibility of pyrolysis for thermochemical recycling of ELPBs.

Exploring the thermochemical recycling of polystyrene waste using thermo-oxidative degradation

Cindy Natalia Arenas (Universidad Pontificia Bolivariana, Colombia) María Victoria Navarro (Instituto de Carboquímica (ICB-CSIC), Spain) Juan Daniel Martinez Angel (Instituto de Carboquímica (ICB-CSIC), Spain) Olga Sanahuja (Instituto de Carboquímica (ICB-CSIC), Spain) Mariluz Betancur (Universidad Pontificia Bolivariana, Colombia) María Soledad Callén (Instituto de Carboquímica (ICB-CSIC), Spain) José Manuel López (Instituto de Carboquímica (ICB-CSIC), Spain) Tomás García (Instituto de Carboquímica (ICB-CSIC), Spain) Ramón Murillo (Instituto de Carboquímica (ICB-CSIC), Spain)

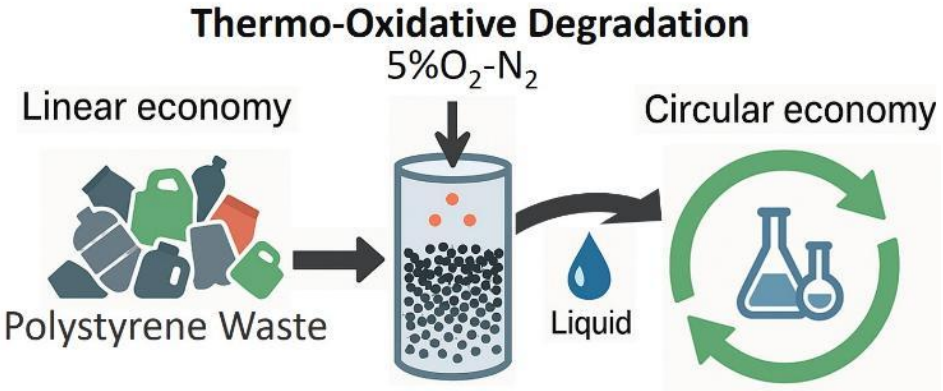
11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

The current linear economic model, which relies heavily on fossil-based resources, has caused a continuous increase in plastic waste generation worldwide. This growing amount of plastic waste creates serious environmental challenges and highlights the need for efficient recycling strategies to produce secondary raw materials and support the transition to a circular economy. In this context, chemical recycling technologies have received increasing attention because they allow the recovery of valuable chemical compounds from plastic waste streams that are not suitable for conventional mechanical recycling. Among chemical recycling options, pyrolysis is considered one of the most promising technologies. It involves the thermal degradation of polymers under inert conditions, typically at temperatures between 400 and 600 °C. Depending on the operating conditions and the type of plastic, pyrolysis can produce a liquid composed of oils and/or waxes, which can be further upgraded into fuels or chemical feedstocks, as well as gaseous and solid products. However, the large-scale application of conventional endothermic pyrolysis (CEP) is still limited by poor heat transfer efficiency. In most reactors, heat is supplied externally through the reactor walls or heating media. As reactor size increases, this surface-based heat transfer becomes inefficient, while the energy demand remains distributed throughout the entire reactor volume. This mismatch represents a major limitation for process scalability and energy efficiency. Thermo-Oxidative degradation (TOD) has been proposed as an alternative route to overcome some of these limitations. In this approach, small and controlled amounts of air or oxygen are introduced into the reactor. This promotes exothermic oxidation reactions that generate heat in situ, partially compensating for the endothermic cracking reactions of the polymer. As a result, thermal homogeneity is improved and the need for external energy input is reduced. Although this strategy has been successfully applied to biomass feedstocks, its application to plastic waste remains relatively unexplored. In this work, the TOD of polystyrene waste (PSW) was investigated using thermogravimetric analysis under varying oxygen concentrations to evaluate its thermal behavior. Complementary experiments were conducted in a laboratory-scale fixed-bed reactor. The objective was to assess energy consumption, product distribution, and product quality, and to evaluate the potential of oxygen-assisted process intensification while preserving selectivity toward high-value liquid products. Thermogravimetric results showed a reduction in the main decomposition temperature of PSW from 475 to 450 °C with the introduction of low oxygen concentrations. Reactor experiments demonstrated a 16% reduction in external energy demand, attributed to a 50 °C decrease in operating temperature under TOD conditions compared to CEP. At an oxygen concentration of 5% O_2/N_2, higher overall conversion yields were achieved, with only a minor reduction (below 4%) in the liquid fraction and a marginal increase in gas production. Liquid characterization revealed a significantly higher styrene content under TOD conditions (57.6 wt%) compared to CEP (39.2 wt%). These results demonstrate that TOD is a promising strategy for process intensification in plastic chemical recycling, offering improved energy efficiency, enhanced product quality and greater sustainability, thereby contributing to the development of scalable and circular solutions for plastic waste management.



Comprehensive characterization of pyrolysis oil using GCxGC-TOFMS, FD-TOFMS, and blank tube FI-TOFMS

Robert Green (JEOL, UK)

11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Pyrolysis oil, obtained through the pyrolysis of waste polymeric materials, is utilized as a feedstock for both alternative petroleum based-fuels and recycled polymers. This process is regarded as a crucial technological pathway toward achieving a circular economy. GCxGC-Time-of-Flight mass spectrometry (TOFMS) is widely used for characterizing pyrolysis oils; however, it requires a long measurement time. In contrast, the direct MS methods, including FD (Field Desorption)-TOFMS and blank tube FI (Field Ionization)-TOFMS, have shorter measurement times. Analysis time can also be shortened by combining the Kendrick Mass Defect (KMD) analysis. In this study, we investigated the complementary analysis of pyrolysis oils using the above three methods. Pyrolysis oils are produced by adjusting the blending ratio of polyethylene (PE) and polypropylene (PP). For GCxGC-TOFMS, JMS-T2000GC (JEOL Ltd.) was combined with INSIGHT-Thermal modulator (SepSolve Analytical). For the FD-TOFMS and blank tube FI-TOFMS, the samples were introduced directly without the use of GC separation. The molecular ions of a complex mixture of hydrocarbons were observed in mass spectra. By using KMD analysis, the distribution of the number of carbons and DBEs can be visualized in the KMD plots. As a result, it was possible to confirm the difference in pyro-oil due to the PE/PP blend ratio using all three methods. GCxGC-TOFMS enables the elucidation of structural information due to its high separation capability. The FD-TOFMS and the blank tube FI-TOFMS facilitate the confirmation of the hydrocarbon profile in a short time. By combining these methods, a complementary analysis can be efficiently performed.

Triple Synergy in Waste Plastic Upcycling: Enhanced BTEX Production via Plasma-Assisted Catalysis over Ga-Modified β-Zeolites

Jie Gu (University of Leeds, UK) Paul Williams (University of Leeds, UK)

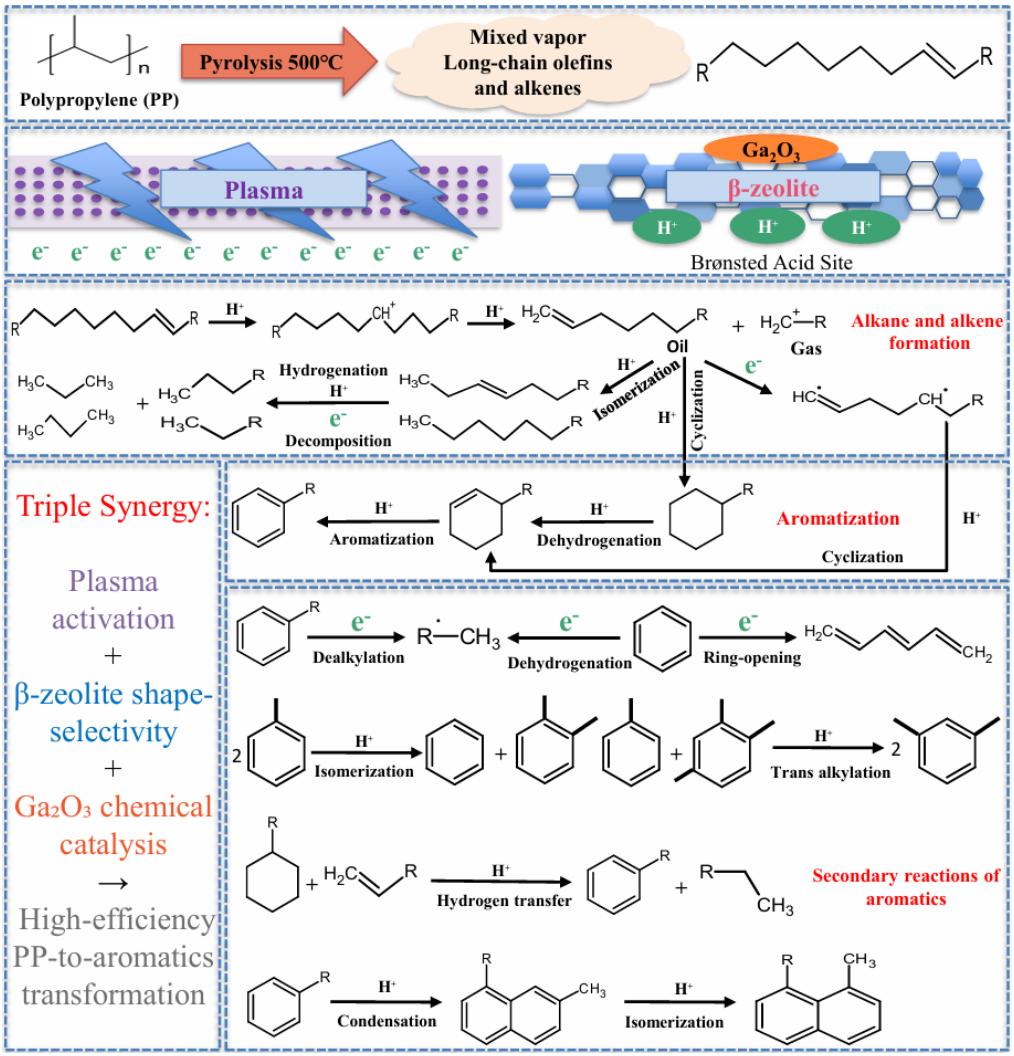
11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

The accumulation of waste polypropylene (PP) presents a critical environmental challenge but also offers a significant opportunity to produce high-value petrochemical feedstocks. This study investigates a novel two-stage upcycling process integrating pyrolysis with non-thermal plasma (NTP) catalysis to maximize the yield of single-ring aromatic hydrocarbons (BTEX). We systematically evaluated the catalytic performance of microporous Y-zeolite versus shape-selective β-zeolite, followed by an optimization of β-zeolite supported metal promoters (Ni, Ga, Mo, Zn). Experimental results demonstrate that β-zeolite outperforms Y-zeolite due to its unique pore topology, which favors the diffusion of aromatic intermediates while suppressing coke formation. The introduction of NTP (40 W) at 500 °C significantly enhanced reaction efficiency. Among the metal-modified catalysts, the Ga/β-zeolite exhibited superior performance, achieving a record BTEX yield of 45.6%. This enhancement is attributed to a "triple synergy": (1) high-energy plasma species activate stable alkane intermediates; (2) Ga species (likely GaO) specifically promote the rate-determining dehydrogenation-cyclization steps; and (3) the β-zeolite pore structure provides shape-selective confinement for aromatization. Additionally, Ga and Zn promoters were found to maintain substantial gas yields alongside high aromatic conversion, indicating a balanced product distribution. This work provides a mechanistic understanding of plasma-catalyst interactions and proposes a highly efficient route for circular plastic economy.



Effect of Water Content in Activated Carbon on the Low-Temperature Microwave-Assisted Pyrolysis of HDPE

Michal Vastyl (VSB-TUO, CEET, Institute of Environmental Technology, Czechia) Amer Inayat (VSB-TUO, CEET, Institute of Environmental Technology, Czechia) Pavel Lestinsky (VSB-TUO, CEET, Institute of Environmental Technology, Czechia) Josephine M. Hill (University of Calgary, Department of Chemical and Petroleum Engineering, Canada) Lenka Matejova (VSB-TUO, CEET, Institute of Environmental Technology, Czechia)

11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Microwave-assisted chemical recycling represents an attractive approach for the low-temperature conversion of polyolefin waste; however, the influence of catalyst properties under microwave irradiation remains insufficiently understood. This study investigates the low-temperature microwave-assisted decomposition of high-density polyethylene (HDPE) using activated carbon (AC) as both a microwave absorber and catalyst, with particular emphasis on the role of water inherently present in the carbon structure. Two types of activated carbon were examined: untreated activated carbon containing naturally adsorbed moisture (AC-W, ~16 wt.%) and thermally dried activated carbon (AC-D, ~1.5 wt.%). Experiments were performed at 260 °C under a mildly oxidising atmosphere (3 vol.% O2 in N2), enabling HDPE conversion at significantly lower temperatures than those required in conventional pyrolysis processes. Product yields and compositions were analysed as a function of residence time using gravimetric methods, gas chromatography (GC), and GC–MS. Although similar overall HDPE conversion levels were achieved with both absorbers, substantial differences in product distribution were observed. The use of AC-W resulted in increased wax formation, with wax yields reaching approximately 25 wt.% and consisting predominantly of long-chain n-alkanes. In contrast, AC-D strongly favoured gas-phase products, particularly hydrogen and light hydrocarbons, indicating more extensive polymer chain scission and secondary dehydrogenation reactions. Hydrogen yields were markedly higher for AC-D, while AC-W exhibited elevated formation of CO and CO2. The findings demonstrate that moisture in activated carbon plays a decisive mechanistic role rather than acting as an inert component during microwave-assisted HDPE degradation. Control of the water content in activated carbon offers an effective strategy for tuning product selectivity between hydrogen-rich gases and hydrocarbon waxes, providing new opportunities for the targeted and energy-efficient chemical recycling of plastic waste. Funding: The work was supported by the OP JAK project "INOVO!!!", No. CZ.02.01.01/00/23_021/0008588 supported by the Ministry of Education, Youth and Sports and co-financed by the European Union. Experimental results were accomplished by using Large Research Infrastructure ENREGAT supported by the Ministry of Education, Youth and Sports of the Czech Republic under projects no. LM2018098 and LM2023056.

Evaluation of operating conditions on the pyrolysis and in-line catalytic cracking of HDPE over a ZSM5 zeolite catalyst

Katrin Santin (University of Basque Country, Spain) Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Leire Olazar (University of Basque Country, Spain) Farid Atashi (University of Basque Country, Spain) Maider Amutio (University of Basque Country, Spain) Maite Artetxe (University of Basque Country, Spain)

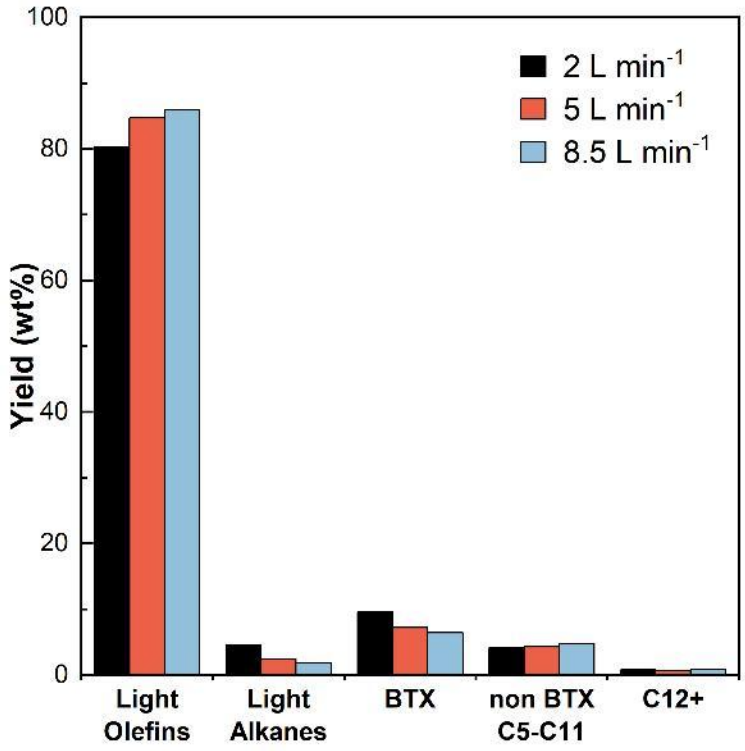
11:00-13:00 Session S3.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Gartzen Lopez (University of the Basque Country and IKERBASQUE Basque Foundation for Science, Spain) Kentaro Umeki (Luleå University of Technology, Sweden)

ABSTRACT

Plastics have become an essential product of the current lifestyle, because of their excellent properties and versatility. Consequently, annual plastic waste world generation has increased and will continue to increase in the future. For this reason, the management or recovery of this waste is indispensable. Chemical recycling, and especially pyrolysis, is a promising option to recover high value-added products from plastics. The use of catalyst is necessary to obtain a narrow product distribution and increase the selectivity of valuable products. ZSM5 zeolite has demonstrated a great selectivity to olefins and aromatics [1,2,3]. In this work, the pyrolysis and in-line catalytic cracking of a HDPE over a ZSM5 zeolite catalyst has been studied, which was agglomerated with alumina and bentonite. The plastics pyrolysis step has been carried out in a conical spouted bed reactor, and the volatile stream has been fed in line to a fixed bed catalytic reactor. Specifically, the effect of catalytic bed temperature (400-550 °C) and catalyst space-time (2-15 gcatalyst min gplastic) on the distribution of product yields at zero-time stream have been studied. In addition, the influence of the residence time has been assessed, by varying nitrogen flow rate in the 2-8.5 L/min range. The determination of product distribution has been carried out by gas chromatography. Light olefins (predominantly propylene and butene) have been obtained as the primary products. By increasing temperature and space-time time, the cracking reactions of heavier fractions, as well as secondary olefin condensation reactions, are favoured. Therefore, the yield of light olefins and BTX increase with a maximum of 86 % and 6.4 %, respectively at 550 °C and 15 gcatalyst min gplastic. In contrast, nitrogen flow rate has an opposite effect on light olefins and BTX yields. In other words, decreasing the nitrogen flow rate reduces the yield of light olefins because secondary reactions are favoured. As a result, the yield of BTX and light alkanes increases up to a maximum of 9.6 % at 2 L/min (Figure 1).



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Effect of acid and basic pretreatment on the performance of hydrothermal liquefaction of sewage sludge and olive oil pomace as real waste biofeedstocks

Claudia Prestigiacomo (University of Palermo, Italy) Elisa Ciccarello Cicchino (University of Palermo, Italy) Federica Proietto (University of Palermo, Italy) Onofrio Scialdone (University of Palermo, Italy) Alessandro Galia (University of Palermo, Italy)

15:30-16:30 Session S3.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

INTRODUCTION: According to the Global Waste Management Outlook of 2024 [1], 2.1 billion tons of municipal solid waste were produced in 2023, and only 13% of the controlled fraction was disposed of using the waste-to-energy approach.Hydrothermal liquefaction (HTL) is a promising thermochemical method that transforms wet bioresources into biocrude (BC) without expensive pre-drying [2]. To our knowledge, the existing literature contains just one study that examined the impact of hydrolytic pretreatment on the quality of BC produced through HTL of microalgae [3]. Furthermore, the literature indicates that acidic and alkaline additions enhance biofeedstock degradation during pretreatments, as well as improve the production and quality of BC in HTL processes. This work provides a first comparative examination of acid and alkaline pretreatment utilizing two kinds of real waste biofeedstocks, sewage sludge (SS) and olive oil pomace (OOP) residues, for BC production by HTL. The objective was to do an empirical systematic investigation to elucidate the impact of specific pretreatments on the distribution of the organic and inorganic fractions of the feed. RESULTS Following the HTL of pretreated SS, we were able to get larger yields of BC that were richer in aliphatic chains, along with higher values of H/C ratios and overall energy recovery. It is worth noting that pretreating SS with KOH resulted in the minimization of chemical species containing oxygen and nitrogen from the feedstock. Additionally, the H/C ratio of the BC obtained after HTL increased from 1.79 to 1.93 at 300°C and from 1.67 to 1.85 at 350°C. After HTL at 350 °C, SS that had been pretreated with HCOOH showed a significant increase in both the yield of BC and the amount of energy recovered. This can be due to the favorable impact that acid pretreatment has on increasing the organic content of the matrix. A densification of chemical energy in the generated BC is made possible, according to the data that was collected, by pretreatment with HCOOH and by ensuring that the kinetic severity of HTL is appropriate. CONCLUSIONS Hydrolytic pretreated SS as HTL feedstock increased BC yield from 18% to 23 and 34%; increased H/C ratios led to higher HHV values; and reduced relative intensity of the olefinic and aromatic C=C stretching bands, suggesting that the pretreatment may increase the aliphatic character of BC generated from hydrolysis. OOP pretreated feedstocks had lower BC yields than native ones and no significant HHV improvement. These findings show that pretreatments improve BC yield more for heterogeneous and mixed biofeedstocks like SS than for homogeneous matrices as OOP. ACKNOWLEDGEMENTS PRIN Refuel (PRJ-0900) Progetti di Rilevante Interesse Nazionale 2022 funded by Ministero dell'Università e della Ricerca is acknowledged for supporting and funding this work

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Thermochemical synthesis of tin-containing hard carbons from waste hemp hurd for sodium-ion battery anodes

Daniel Antoran (UNIVERSITY OF ZARAGOZA (SPAIN), Spain) Darío Alvira (Universidad de Zaragoza, Spain) Joan J. Manyà (Universidad de Zaragoza, Spain)

15:30-16:30 Session S3.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

Hard carbons derived from biomass are widely investigated as negative electrode materials for sodium-ion batteries (SIBs), particularly when produced through thermochemical routes that enable control over morphology, microstructure and surface chemistry. In this study, hard carbons (HCs) were synthesized from waste hemp hurd (WHH) using a scalable two-step thermochemical process consisting of hydrothermal carbonization (HTC) followed by high-temperature carbonization under inert atmosphere. The influence of acid-assisted HTC and the incorporation of metallic tin particles on the structural features and electrochemical performance of the resulting materials was systematically investigated. Acid-assisted HTC was employed to promote controlled polymerization and aromatization, while Sn-containing hybrid carbons were prepared following two different strategies: (i) addition of SnCl2 during the HTC pre-treatment step, and (ii) hydrothermal post-treatment of the already carbonized HC with SnCl2, followed by thermal treatment. This approach enabled a direct comparison of the effect of the Sn incorporation stage on the morphology, dispersion of the metallic phase and electrochemical performance of the hybrid materials. SEM-EDX images/analysis showed that Sn particles were effectively embedded within the carbon matrix in both hybrid materials, although a more homogeneous spatial distribution was achieved when Sn was introduced prior to the HTC step. This observation suggests that early-stage Sn incorporation favors a more intimate interaction between the metallic species and the evolving carbon framework during subsequent carbonization. Electrochemical characterization in sodium half-cells revealed that the incorporation of Sn led to a marked enhancement in performance compared to Sn-free HCs. Among the Sn-containing materials, the sample synthesized following strategy (i), exhibited the highest specific capacities, delivering up to 620 mA h g−1 at 0.1 A g−1 and retaining comparatively high capacities at increased current densities. The corresponding post-treated Sn-containing material also showed improved electrochemical behavior, although to a lesser extent, suggesting that Sn addition after carbon formation is less effective in achieving an optimal hybrid structure. By contrast, Sn-free samples displayed lower specific capacities and inferior rate capability, particularly in the absence of acid-assisted pre-treatment, highlighting the combined effect of HTC conditions and metal incorporation on Na-ion storage performance.

Characterization of Volatile Carbonyl Compounds in Biorefinery Streams using SPME-GC: Implications for Occupational Health and Safety

Philip Bulsink (Natural Resources Canada, Canada) Silvia Sant'Anna (Natural Resources Canada, Canada) Benjamin Bronson (Natural Resources Canada, Canada) Benjamin Spencer (Natural Resources Canada, Canada) Guillaume Gagnon-Caya (Natural Resources Canada, Canada) Jawad Jeaidi (Natural Resources Canada, Canada)

15:30-16:30 Session S3.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

Biorefineries employing fast pyrolysis convert lignocellulosic feedstocks into bio-oil, biochar, and non-condensable gases, enabling renewable energy and chemical production. However, these processes generate complex mixtures of volatile organic compounds, including carbonyl species such as formaldehyde, which pose occupational health and safety concerns. Understanding the distribution and transformation of these compounds across feedstock and product streams is critical for risk mitigation, occupational health and safety controls, and environmental compliance. This research investigates the chemical evolution of volatile carbonyls and other hazardous species during a fluidized bed fast pyrolysis run at Natural Resources Canada's CanmetENERGY-Ottawa facility. Each feedstock and resulting product—solid biochar, liquid bio-oil fractions, and gaseous outputs—will be sampled and analyzed using Solid Phase Microextraction (SPME) coupled with gas chromatography and flame ionization/mass spectrometric detection (GC-FID/MS). Universally applicable to each product stream, SPME enables selective, reproducible headspace sampling, providing a robust approach for tracking trace volatiles without matrix interference. Both on-fibre derivatization or direct analysis strategies will be explored, with a focus on enhancing analytical sensitivity and specificity. This work contributes to a deeper understanding of thermal conversion chemistry while addressing critical occupational health considerations in emerging bioenergy technologies.

Role of solvent-separated group components and their sub-fractions on coal caking properties

Linhuan Wei (Anhui University of Technology, China) Jingchong Yan (Anhui University of Technology, China) Hengfu Shui (Anhui University of Technology, China)

15:30-16:30 Session S3.6: Applied pyrolysis: Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Young-Min Kim (Daegu University, South Korea) William Meredith (University of Nottingham, UK)

ABSTRACT

This study clarifies relations between structures and caking properties of coals by correlating the structural features with caking behavior of the solvent-separated group components and their sub-fractions of coals. Sequential extraction and counter-extraction of four raw coals (RCs) of differing ranks with a mixed carbon disulfide/N-methyl-2-pyrrolidone (CS2-NMP) solvent were conducted to isolate various components. The characterizations of distinct components were conducted to clarify their structural features, and caking properties of each component were determined. A strong positive correlation is observed between the mass fraction of the medium component (MC) and maximum plastic layer thickness (Y) as well as caking index (G) of RCs. Heavy component (HC) possesses high graphitized carbon (CGR) content, low hydrogen-donating capacity, and negligible caking properties (G < 10). In contrast, the MC primarily comprises amorphous carbon (CAM) with low CGR, forming cross-linked networks of polycyclic aromatic hydrocarbons (PAHs) and alkyl groups. The G value of MCs correlates negatively with carbon unsaturation and positively with hydrogen-donating capacity. Crucially, this work distinguishes two sub-fractions of MC: The loose medium component (LMC) features smaller PAHs structures, longer side alkyl chains (SACs), and high caking properties (G > 90). Conversely, the dense medium component (DMC) poses larger PAHs structures, shorter but more SACs, higher hydrogen-donating capacity, and exceptionally strong caking properties (G > 100). This work shells light on the structural determinants (PAH size, alkyl chain length, hydrogen radical availability, carbon ordering) of caking properties and these results can be used to promote the targeted utilization of specific coal components to optimize coking efficiency.

Pressure-Dependent Pyrolysis of Cyclopropanated Fuel exo-TCN: Experiments and Kinetic Modeling

Haihan Fu (Tianjin University, China) Xiangwen Zhang (Tianjin University, China) Li Wang (Tianjin University, China) Guozhu Liu (Tianjin University, China)

15:30-16:30 Session S3.6: Applied pyrolysis: Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Young-Min Kim (Daegu University, South Korea) William Meredith (University of Nottingham, UK)

ABSTRACT

The global demand for high-performance, energy-dense, and cleaner-burning fuels has driven the development of advanced hydrocarbon-based alternatives for propulsion and power generation applications. Conventional hydrocarbon fuels, while widely used due to their mature infrastructure and high energy content, face increasing scrutiny due to environmental concerns, inefficient combustion under extreme conditions, and the growing need for fuel systems compatible with next-generation aerospace and defense platforms. One promising strategy for improving fuel performance is structural modification at the molecular level, particularly through ring strain engineering. In this context, cyclopropanation—the introduction of three-membered cyclopropyl rings into hydrocarbon structures—has emerged as a viable route to enhance the energetic characteristics of fuels. Cyclopropane rings are known for their unique chemical and physical properties arising from their significant ring strain (approximately 115 kJ/mol), which leads to higher enthalpies of combustion, increased energy densities, and improved reactivity. Incorporating such rings into fuel molecules not only increases the gravimetric and volumetric heat of combustion but also modifies their thermal decomposition and ignition behaviors, making them attractive candidates for use in high-speed propulsion systems such as scramjets and advanced gas turbines. Despite the potential advantages, the design and development of practical cyclopropanated fuels require a deep understanding of their synthesis, stability, and combustion mechanisms under relevant conditions. In recent years, pyrolysis studies of highly strained fuels like cubane, bicyclo-octanes, and dicyclopropyl compounds have demonstrated that ring strain can dramatically alter reaction kinetics, promoting early ring-opening and subsequent fragmentation. However, most of these studies remain limited to fundamental molecules, and detailed kinetic models for practical multi-cyclopropanated fuels are scarce. In particular, experimental data on large cyclopropanated structures under combustion-relevant conditions are lacking, which hinders model validation and predictive development. This work investigates the pyrolysis characteristics of a novel cyclopropanated fuel, exo,exo-tetracyclo[3.3.1.02,4.06,8]nonane (exo-TCN), synthesized from norbornadiene via the Simmons–Smith cyclopropanation method. exo-TCN is a highly strained three-membered ring fuel with high density, high net heat of combustion, and good low-temperature performance, making it a promising candidate for high-energy-density liquid fuels. The pyrolysis experiments were performed in a micro flow tube reactor under varying temperatures and pressures. Reaction intermediates and final products were analyzed using gas chromatography coupled with mass spectrometry, providing detailed speciation data. These results were complemented by high-level quantum chemical calculations and rate constant predictions using RRKM/master equation analysis to elucidate the underlying reaction pathways and kinetic parameters. A detailed kinetic model was constructed to describe the pyrolysis behavior of exo-TCN. The model includes a reaction mechanism that accounts for the cleavage of cyclopropyl rings, ring-opening isomerizations, hydrogen abstractions, and β-scissions, as well as the formation and consumption of key intermediates such as allenes and propargyl. Model validation was performed by comparing simulation results with experimental data over a wide range of conditions, demonstrating good agreement and predictive capabilities. The validated model provides new insights into the thermal decomposition mechanisms of cyclopropanated fuels and establishes a framework for the future design and optimization of similar molecules.

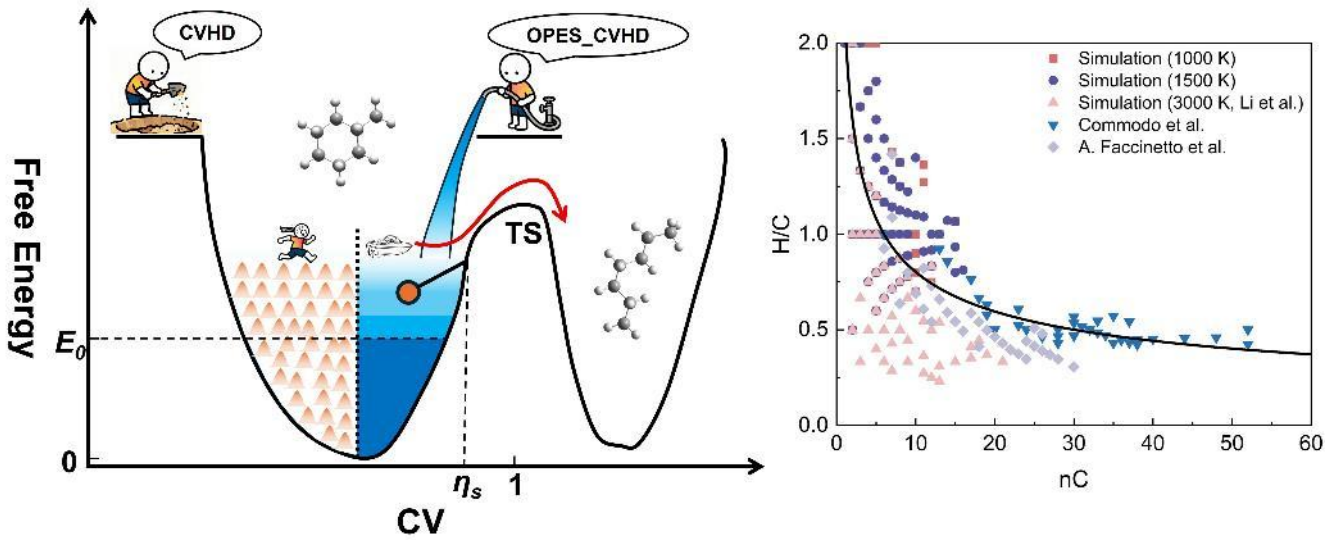
Molecular-Level Investigation of Hydrocarbon Cracking and Early Coke Formation Enabled by an Enhanced Sampling Framework

Junhao Guo (Tianjin university, China) Yutong Wang (Shenyang University of Chemical Technology, China) Guozhu Liu (Tianjin university, China)

15:30-16:30 Session S3.6: Applied pyrolysis: Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Young-Min Kim (Daegu University, South Korea) William Meredith (University of Nottingham, UK)

ABSTRACT

Understanding hydrocarbon cracking and coke formation at the molecular level is critical for advancing industrial thermal cracking processes. Conventional molecular dynamics simulations are typically limited to unrealistically high temperatures in order to overcome large and widely distributed reaction barriers, which can distort reaction pathways and product distributions. In this work, we present an enhanced sampling framework, termed OPES_CVHD, which integrates on-the-fly probability-enhanced sampling (OPES) with collective variable-driven hyperdynamics (CVHD), enabling efficient and kinetically reliable simulations of complex cracking and coking chemistry at moderate temperatures. In OPES_CVHD, the bias potential is constructed from the marginal probability distribution of collective variables and adaptively updated through a self-consistent barrier parameter. A damping strategy is introduced to regulate bias growth near transition states, preventing excessive bias deposition and preserving accurate reaction kinetics. This framework requires minimal prior knowledge of reaction pathways and is particularly suited for systems involving multiple competing reactions with widely separated energy barriers. The performance of OPES_CVHD is demonstrated through simulations of styryl radical β-scission and, more importantly, the pyrolysis of methylcyclohexane (MCH), a representative cycloalkane fuel. Simulations conducted at 1000–1500 K reproduce MCH conversion, product distributions, and reaction kinetics consistent with conventional enhanced sampling simulations and experimental observations. Compared with standard CVHD, OPES_CVHD achieves significantly improved sampling efficiency, enabling deeper cracking within the same computational cost. Crucially, OPES_CVHD enables direct observation of the early-stage formation of aromatic and polycyclic aromatic hydrocarbons at temperatures far below those required in conventional molecular dynamics simulations. The simulations resolve detailed formation pathways of monocyclic and bicyclic aromatic species, revealing highly reversible reaction networks involving β-scission, radical addition, hydrogen abstraction, isomerization, and cyclization. The predicted H/C ratios and carbon-number distributions of coke precursors are in good agreement with experimental measurements, demonstrating the physical reliability of the approach. Overall, OPES_CVHD provides a powerful and flexible molecular simulation framework for investigating hydrocarbon cracking and early coke precursor formation under industrially relevant conditions, offering new mechanistic insights into thermal cracking and coking processes.



Tailored biochar based composited for electromagnetic enhanced composite preparation

Mattia Bartoli (Fondazione Istituto Italiano di Tecnologia, Italy) Mauro Giorcelli (Politecnico di Torino, Italy)

15:30-16:30 Session S3.7: Biochar

Location: ROOM C1 – FIRST FLOOR

Chairs: Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy)

ABSTRACT

The increasing demand for lightweight, sustainable, and multifunctional materials for electromagnetic interference (EMI) shielding and microwave absorption has stimulated growing interest in biochar-based composites as environmentally benign alternatives to conventional carbonaceous fillers. Tailored biochar, derived from the controlled pyrolysis of biomass, offers a unique combination of hierarchical porosity, tunable electrical conductivity, surface chemistry, and structural disorder, making it a highly promising platform for enhancing electromagnetic properties in polymer, ceramic, and hybrid composites. This work presents a comprehensive overview of the design, tailoring, and application of biochar as an advanced functional filler for the development of composites with enhanced electromagnetic performance. The electromagnetic response of biochar-based composites is strongly governed by the intrinsic physicochemical characteristics of the biochar, which can be precisely engineered through feedstock selection, pyrolysis temperature, heating rate, residence time, and post-treatment strategies. High-temperature pyrolysis promotes graphitization and electrical conductivity, favoring conduction loss mechanisms, while lower temperatures preserve oxygenated functional groups that contribute to dipolar polarization and interfacial loss. Additionally, the development of multiscale porosity and defect-rich microstructures enhances multiple scattering and impedance matching, thereby improving microwave absorption efficiency over broad frequency ranges. Surface functionalization and heteroatom doping further expand the electromagnetic tunability of biochar by modulating charge distribution, dielectric relaxation behavior, and interfacial polarization phenomena. When integrated into polymeric or ceramic matrices, tailored biochar establishes percolated conductive networks and extensive interfacial regions, which synergistically enhance dielectric loss, suppress electromagnetic wave reflection, and improve absorption-dominated shielding effectiveness. Hybridization with magnetic phases, such as ferrites or transition metal nanoparticles, enables the development of biochar-based composites exhibiting combined dielectric–magnetic loss mechanisms, thus achieving superior EMI shielding and radar absorption performance at reduced filler loadings. Beyond electromagnetic functionality, biochar-based composites offer significant advantages in terms of low density, thermal stability, cost-effectiveness, and environmental sustainability. The utilization of renewable or waste biomass as a carbon source aligns with circular economy principles and contributes to carbon sequestration strategies, positioning tailored biochar as a strategic material for next-generation green electromagnetic composites. Potential applications span aerospace structures, stealth and radar-absorbing materials, flexible electronics, energy devices, and construction materials requiring EMI mitigation. Here, we presented our more recent advancements in the tailoring of biochar for the preparation of electromagnetic enhanced properteis.

Insight into the pyrolytic characteristic and heavy metal immobilization during the co-pyrolysis of phytoremediation biomass with duckweed

Wei Cheng (Huazhong University of Science and Technology, China) Hao Jiang (Huazhong University of Science and Technology, China) Jingai Shao (Huazhong University of Science and Technology, China) Haiping Yang (Huazhong University of Science and Technology, China) Hanping Chen (Huazhong University of Science and Technology, China)

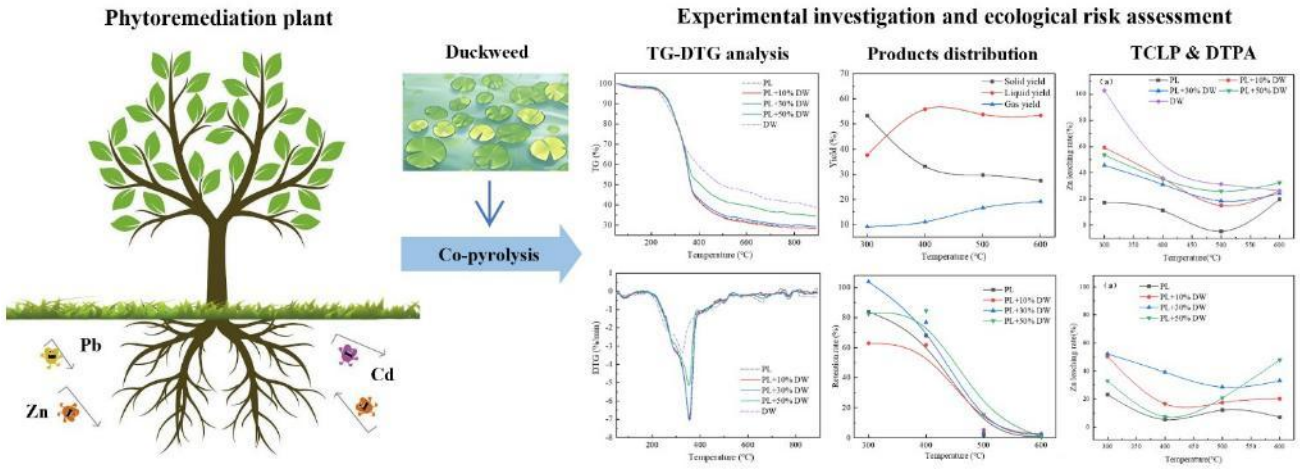
15:30-16:30 Session S3.7: Biochar

Location: ROOM C1 – FIRST FLOOR

Chairs: Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy)

ABSTRACT

Phytoremediation, as a low-cost, green and highly efficient way for soil remediation, has been increasingly applied in China. However, the phytoremediation plant will lead to secondary pollution without appropriate treating. In this work, the co-pyrolysis of poplar (for soil remediation) and duckweed (for wastewater remediation) was investigated for the first time. The co-pyrolysis experiments were carried out successively in thermogravimetric analyzer and horizonal fixed-bed system, and the characteristics of three-phase products as well as the environmental risk assessment of Zn, Cd, and Pb were analyzed. The results indicated that with the blending ratio of duckweed rising (10% → 50%), the biochar yield generally showed an upward trend, while that of bio-oil decreased to some extent. The overall yield of gaseous product increased with the temperature rising (300 ℃ → 600 ℃), and the addition of duckweed promoted the production of H2, thereby achieving a higher heating value. It also shows that co-pyrolysis can improve the surface chemical structure and inorganic crystal phase composition of biochar, forming richer functional groups containing oxygen, nitrogen, and phosphorus, and generating stable phosphate/pyrophosphate structures, thereby providing more heavy metal complexation and fixation sites. Furthermore, toxicity characteristic leaching procedure (TCLP) and diethylenetriaminepentaacetic acid (DTPA) leaching tests were conducted to determine the mobility and ecological risk of heavy metals in biochar. It was found that the co-pyrolysis process was conductive to reduce the toxic leaching rate and enhance the stability, with the effectiveness following the order: Pb > Cd > Zn. Meanwhile, the bioavailability of Cd and Pb also decreased to a certain extent.



Synthesis, characterization and catalytic activity in dry reforming reaction of Ni/C catalysts prepared from different biomasses

Eya Ghomri (IS2M, CNRS- University of Haute-Alsace, IS2M, 68100 Mulhouse, France, France) Yann Le Brech (LRGP, CNRS- University of Lorraine, LRGP, 54000 Nancy, France, France) Marine Guilmont (IS2M, CNRS- University of Haute-Alsace, IS2M, 68100 Mulhouse, France, France) Mohamed Hechmi Aissaoui (LRGP, CNRS- University of Lorraine, LRGP, 54000 Nancy, France, France) Younes Bouizi (CRM2, CNRS- University of Lorraine, LRGP, 54000 Nancy, France, France) Anthony Dufour (LRGP, CNRS- University of Lorraine, LRGP, 54000 Nancy, France, France) Roger Gadiou (IS2M, CNRS- University of Haute-Alsace, IS2M, 68100 Mulhouse, France, France)

15:30-16:30 Session S3.7: Biochar

Location: ROOM C1 – FIRST FLOOR

Chairs: Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy)

ABSTRACT

Hydrogen is widely recognized as a promising alternative carbon-free energy carrier due to its versatility in production from different energy sources. Dry reforming and thermocatalytic decomposition of methane using different types of catalysts have been studied to replace conventional hydrogen production technology by steam reforming [1]. Biochars, generated from biomass pyrolysis, offer compelling advantages, including low cost, high carbon content, and good textural properties. They exhibit significant catalytic activity for cracking of hydrocarbons such as methane [2], and they are also interesting support materials for the synthesis of metal/carbon catalysts [3]. Beside studies on biochars production from conventional lignocellulosic biomasses, the last decade showed a great interest on the valorisation of agricultural residues which are widely available in many countries. Nevertheless, the differences in biopolymers and mineral mater composition of biomasses can lead to variable properties of the biochars. The aim of this study was to compare a conventional lignocellulosic biomass with catalysts obtained from douglas and corn cobs. The biochars were produced by fast pyrolysis at 800°C in a tubular reactor. Their physicochemical properties were determined by different characterization technics (Elemental Analysis, TGA, XRF, Raman, XRD, NMR 13C, SEM, N2 and CO2 adsorption). In order to improve their reactivity and textural properties, douglas and corn cobs biochars were activated physically by steam, CO2 and air. Some activated biochars were impregnated with nickel nitrate salts to obtain Ni/C catalysts. The catalytic performances of these materials were studied for dry reforming of methane (DRM) and thermocatalytic decomposition of methane (TDM) at temperatures between 750°C and 850°C during 30 min in a fixed-bed reactor. The reaction was followed by exhaust gas analysis by a micro gas chromatograph, and the spent catalysts were characterized after reaction. A reaction rate analysis based on gas phase analysis and carbon mass balance was done for DRM and TDM experiments, allowing to quantify the different chemical processes: direct methane cracking, boudouard reaction, reverse water gas shift. Gasification reaction is strongly dependant of the catalyst precursor and preparation method while thermal cracking is less influenced. The addition of nickel nanoparticles induces an important increase of gasification rate for wood-based catalyst while this effect is lower for corn cob material. The thermal cracking is less modified. The study of the deactivation of the catalyst allowed to explore the different competitive processes: carbon deposits in pores and on nickel particles, gasification of the deposits and of the support. 1 Dufour, A et al. Catalytic Conversion of Methane over a Biomass Char for Hydrogen Production: Deactivation and Regeneration by Steam Gasification. Appl. Catal. Gen. 2015, 490, 170–180. 2 Mahmoudi,M et al. Evaluation of Activated Carbons Based on Olive Stones as Catalysts during Hydrogen Production by Thermocatalytic Decomposition of Methane. Int. J. Hydrog. Energy 2017, 42, 8712–8720. 3 Mahmoudi, M.et al. Hydrogen Production by Methane Decomposition over Ni Doped Activated Carbons: Effect of the Activation Method. Comptes Rendus Chim. 2022, 25, 225–236.

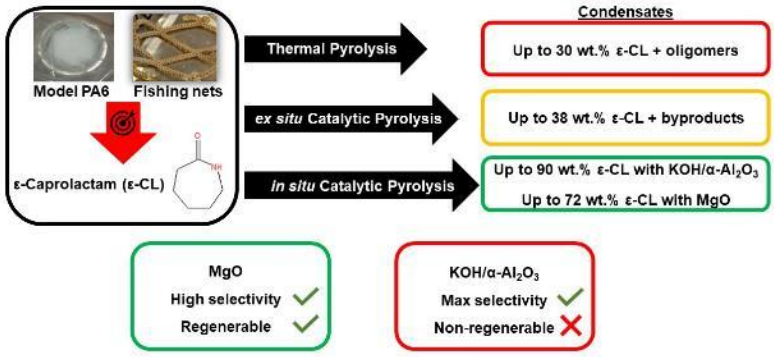
Chemical recycling of nylon-6 via catalytic pyrolysis for the selective recovery of ε-caprolactam

Moschos Moschos (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece) Evangelia Vouvoudi (Department of Chemistry, Aristotle University of Thessaloniki, Greece, Greece) Dimitris Achilias (Department of Chemistry, Aristotle University of Thessaloniki, Greece, Greece) Angelos Lappas (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

15:30-16:30 Session S3.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Global nylon-6 (polyamide-6, PA-6) production is projected to reach 10.4 million t/y by 2027, necessitating effective recycling of waste streams like fishing nets and other synthetic fiber residues. Research on PA-6 chemical recycling has focused primarily on solvolysis, whereas pyrolysis offers greater feedstock flexibility, faster reaction times, and ambient-pressure operation, while avoiding the use of costly solvents and unrecoverable catalysts [1]. The literature indicates that pyrolysis can efficiently depolymerize PA-6 to its monomer, ε-caprolactam. However, studies on PA-6 pyrolysis and catalytic pyrolysis remain limited and largely confined to analytical-scale investigations, and only a few laboratory- and bench-scale studies report robust quantitative product analysis and closed mass balances. Here, we report a PA-6 chemical recycling route based on catalytic pyrolysis using acidic and basic catalysts to selectively recover ε-caprolactam, demonstrated in a batch laboratory fixed bed reactor with thorough condensate analysis and quantitative ε-caprolactam measurements. E-caprolactam, standard PA-6, and waste fishing nets were pyrolyzed in a fixed-bed reactor at 300-600 °C using in situ and ex situ Y, ZSM-5, MgO, and KOH/Al2O3 catalysts. Gas, solid, and condensate products were collected and analyzed. E-caprolactam in the condensate was quantified by GC–FID calibrated with internal and external standards. Thermal pyrolysis demonstrated ε-caprolactam's thermal stability at 300-400 °C, resulting in 99-100 wt.% recovery in the condensate, while at 500 °C limited degradation reduced recovery to 94 wt.%. Thermal pyrolysis of standard PA-6 at 500 °C yielded 96 wt.% condensate but quantitative GC-FID showed only 33 wt.% ε-caprolactam content, with the remainder comprising of oligomers, confirmed by GPC. Similar results were obtained with waste fishing nets. Ex situ catalytic pyrolysis with ZSM-5 and MgO reduced oligomers but marginally increased ε-caprolactam recovery from 31 wt.% to 32 wt.% and 36 wt.%, respectively. Y exhibited the highest activity for the conversion of oligomers but also for the decomposition of ε-caprolactam, resulting in reduced overall recovery. On the other hand, in situ catalytic pyrolysis enabled depolymerization at lower temperatures and increased ε-caprolactam selectivity, reaching up to 90 wt.% ε-caprolactam content in the condensate using KOH/Al2O3. However, KOH/Al2O3 deactivated rapidly due to carbon deposition, and regeneration by oxidation was not feasible because high temperatures decomposed KOH. MgO was the next most active catalyst, yielding condensates with 72 wt.% ε-caprolactam content, while also allowing high-temperature regeneration due to its superior thermal stability. Overall, ε-caprolactam was recovered from PA-6 via pyrolysis. However, the condensate comprised primarily of oligomers, resulting in lower recoveries than previously suggested. Ex situ catalytic pyrolysis yielded condensates with reduced oligomers, but ε-caprolactam recovery marginally benefited due to byproduct formation. In situ catalytic pyrolysis with a benchmark KOH/Al2O3 yielded condensates with 90 wt.% ε-caprolactam, consistent with previous reports, but deactivated rapidly and could not be regenerated. MgO yielded condensates with high ε-caprolactam content as well, and could be regenerated after use. Figure. Comparison of PA-6 pyrolysis strategies for the selective recovery of ε-caprolactam.



[1] S. Czernik, C.C. Elam, R.J. Evans, R.R. Meglen, L. Moens, K. Tatsumoto, Journal of Analytical and Applied Pyrolysis, 46 (1998) 51–64.

Impact of stabilizers on the pyrolysis mechanism in chemical recycling of polyvinyl chloride waste

Grazyna Straczewski (KIT, Germany) Robin Hesse (KIT, Germany) Krassimir Garbev (KIT, Germany) Salar Tavakkol (KIT, Germany) Dieter Stapf (KIT, Germany)

15:30-16:30 Session S3.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Polyvinyl chloride (PVC) is a common thermoplastic widely used thanks to its properties and relatively low cost. However, its production results in large quantities of chlorinated waste and associated disposal issues. A more sustainable solution is chemical recycling. Compared to other standard thermoplastics, PVC decomposes at a significantly lower temperature. To prevent autocatalytic dehydrochlorination of PVC and improve its stability and end-use properties, additives such as heat stabilisers and plasticisers are incorporated into pure PVC. Catalytically active additives, such as metal salts, can accelerate or inhibit the dehydrochlorination reaction. Therefore, the pure PVC decomposition mechanism may not fully explain the pyrolysis behaviour of PVC waste due to the presence of various additives. This work aimed to investigate the influence of additives in real PVC waste on the pyrolysis mechanism. Representative samples of PVC waste containing additives, such as hard and soft PVC, along with the purest possible PVC sample, were analysed using X-ray diffraction, attenuated total reflectance Fourier-transform infrared spectroscopy and inductively coupled plasma optical emission spectrometry. The samples were then pyrolysed in a µg pyrolyser for reference purposes. The resulting volatile pyrolysis products were identified using gas chromatography-mass spectrometry. A comparison was made between the observed pyrolysis products and the identified components corresponding to the additives and their decomposition products. The possible influences on the pyrolysis mechanism were then discussed. In general, PVC degrades via a two-step process: at 290 °C, dehydrochlorination occurs, resulting in the formation of a conjugated polyene. This is then followed by the formation of aromatic hydrocarbons at 424 °C[1]. Many additives, such as the carboxylic acid groups found in plasticisers and the alcohol groups found in heat stabilisers, can replace the unstable chlorine atoms in PVC. It is therefore assumed that cyclisation of the dehydrochlorinated PVC backbone is suppressed during primary pyrolysis. This could lead to reactions resulting in cross-linking of the macromolecule. Consequently, the formation of benzene and naphthalene is also suppressed. During the second stage of the mechanism, cleavage of the cross-linked macromolecule predominantly forms substituted derivatives. Due to stronger cross-linking, it is also assumed that cleavage of the polyene shifts to higher temperatures. Additionally, metal salts such as calcium carbonate bind chlorine, thereby reducing the amount of free HCl present. This probably suppresses the autocatalytic effect of HCl as a hydrogen sink. Consequently, there may be fewer radical positions in the PVC hydrocarbon backbone, meaning it tends to react to form cross-linked macromolecules rather than undergo cyclisation. Various chlorine-containing components were also identified, presumably arising mainly from the replacement of the OH group with HCl in the cracked products of the additives. When real PVC waste containing additives is pyrolysed, fewer HCl molecules are released at lower temperatures. The reduced presence of unsaturated polyenes means that a smaller quantity of aromatic by-products is produced. Additionally, there is less coke formation. These observations will be investigated further in the future using quantitative analysis of the pyrolysis products of real PVC waste. 1 J. Yang et al., Fuel 331 (2023) 125994, doi: 10.1016/j.fuel.2022.125994

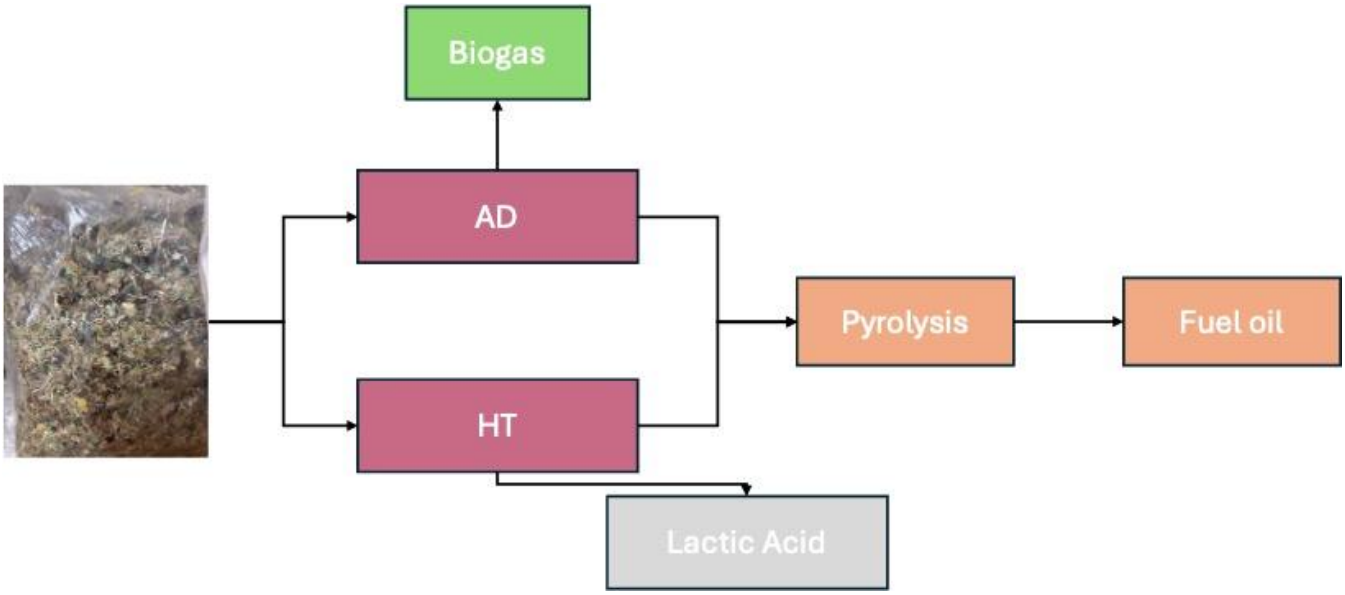
Chemical Recycling of Mixed Plastic Waste via a Two-Step Process Combining Hydrothermal Liquefaction Pretreatment and Pyrolysis for Fuel Oil Production

Benedetta de Caprariis (Sapienza University of Rome, Italy) Martina Damizia (Sapienza University of Rome, Italy)

15:30-16:30 Session S3.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Mixed plastic waste generated in municipal organic waste treatment plants represents a critical challenge for both composting efficiency and material recovery. In this study, the mixed plastic waste was collected from a waste treatment facility producing compost, where plastic carrier bags are separated during the pretreatment of the organic fraction. These bags consist of a heterogeneous mixture of biopolymers, mainly Mater-Bi and polylactic acid (PLA), together with polyethylene (PE). To enable the recovery of polyethylene through chemical recycling, two alternative processing routes are proposed and investigated. The first route involves anaerobic digestion of the mixed plastic waste, aiming to biologically convert the biodegradable polymer fraction into biogas, while producing a polyethylene-rich solid residue subsequently processed by pyrolysis for fuel oil production. The second route is based on hydrothermal treatment as a selective pretreatment to decompose PLA/Mater B, yielding a solid residue mainly composed of polyolefin, which is then converted by pyrolysis into a high-quality fuel oil. In particular, the hydrothermal degradation of PLA was systematically investigated, focusing on the effect of temperature in the range of 150–250 °C and of reaction time (0-120 min) on polymer decomposition. The objective was to promote controlled depolymerization of PLA/Mater B, enabling the recovery of its monomeric products and thus opening the possibility of material recycling. The composition and properties of the solid residues obtained after hydrothermal treatment were evaluated to assess their suitability as feedstock for pyrolysis. The results demonstrate that temperature of 180 °C and 30 min are needed to have 100 % depolymerization of PLA compounds. The main compounds obtained in HT are lactic acid and oligomers, from GC-MS analyses the maximum concentration of lactic acid was obtained at 220 °C for 10 min of reaction time. The sold residue was weighted resulting to be about 60 % of the mixed plastic waste and was analyzed by FT-IR, TGA and elemental analysis in order to assess its purity in polyolefin species. The analysis revealed that still some oxygen is present in the solid residue, probably due to the presence of PLA oligomers. However the amount of O is highly reduced from 20 % wt. of the feedstock to 7 % wt. The results of AD+pyrolysis are less attractive since Mater B and PLA are non easy to be decomposed in AD and so the reduction of oxygen in solid residue is limited going form 20 % to 14 % wt.



Production and characterization of biocrude oil from hydrothermal liquefaction of sludge digestate: findings from an intensive experimental campaign

David Gbenga Oke (Bowen University, Nigeria) Giovanni Manente (University of Salento, Italy) Giuseppe Agostino Mele (University of Salento, Italy)

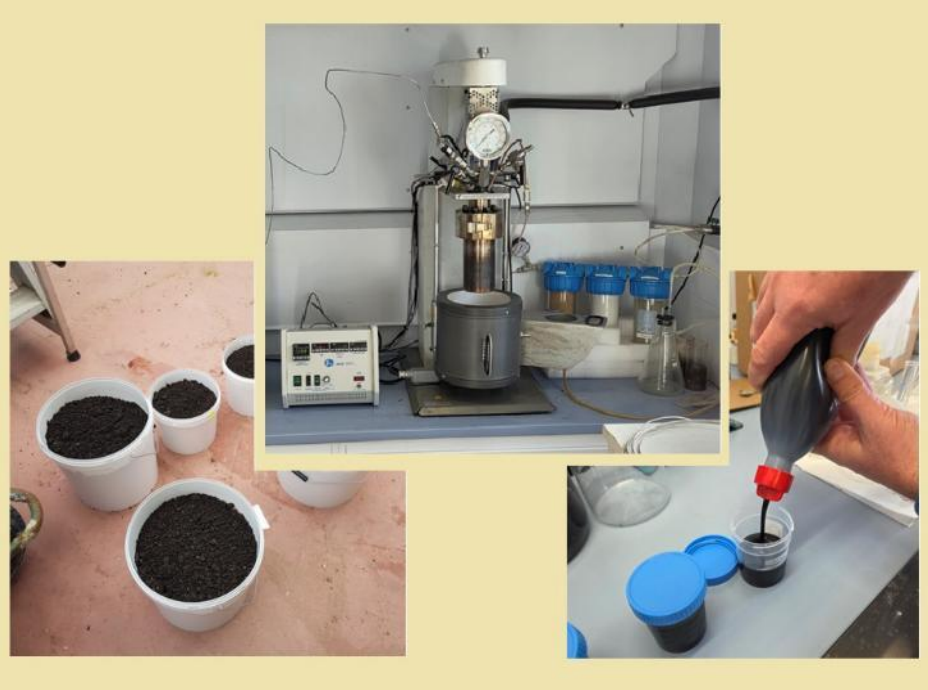
17:00-17:40 Session S3.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

In a bid to address the ever-growing quantities of industrial and domestic biomass waste, while also providing a sustainable alternative to crude oil based fuels, biomass valorization has gained increasing attention. Major thermochemical valorization pathways include gasification, pyrolysis, and hydrothermal liquefaction (HTL). Among these, HTL is particularly significant due to its ability to process wet biomass feedstocks without the need for energy-intensive and time consuming drying. It has proven especially effective for sewage sludge valorization, delivering promising results in terms of conversion efficiency and product quality. This research focused on the production and characterization of biocrude oil from sewage sludge digestate using a bench-scale HTL process. Sludge digestate was collected from a municipal wastewater treatment facility in the south Apulia region. A slurry containing 15 wt.% solid digestate was prepared with water and processed in a 500 mL high pressure/high temperature PARR reactor. Reaction temperatures were varied between 280 °C and 320 °C, with retention times of 30, 45, and 60 minutes, in order to identify the optimal conditions for maximum biocrude yield and improved product quality. Ethyl acetate was used as the organic solvent for the separation of biocrude from hydrochar. The recovered biocrude was characterized using CHNS/O elemental analysis, Fourier Transform Infrared Spectroscopy (FTIR), Gas Chromatography–Mass Spectrometry (GC–MS) and Nuclear Magnetic Resonance (NMR) spectroscopy, while the hydrochar was characterized by FTIR and Scanning Electron Microscopy (SEM). An intensive experimental campaign, which lasted more than three months and involved over seventy experimental runs, was conducted under varying operational conditions, yielding a total of approximately 650 grams of biocrude oil, targeting subsequent engine testing and/or oil upgrading. The highest average biocrude yield (24%) was obtained at 300 °C with a retention time of 30 minutes, corresponding to a hydrochar yield of 48%. The GC-MS result of this biocrude fraction showed that it is dominated by long-chain fatty acids with moderate phenolic and ketonic fractions. While the carbon chain length favors good energy density, the abundance of oxygenated functional groups necessitates additional treatment for fuel applications. The observation of the chemical and physical properties of the biocrude oil samples (8-9 grams) collected at each test allowed to identify the operating conditions for producing biocrude oil with the highest quality for direct use as a fuel as well as the upgrading requirements to be fulfilled through hydrotreating. Figure 1: Sludge digestate used as the feedstock, the HTL experimental setup based on a 500 mL batch reactor, the biocrude oil produced from repeated experiments.



Untreated Bamboo-derived carbons as sustainable anode material for sodium-ion batteries

Omar Ginoble Pandoli (Istituto Italiano di Tecnologia (IIT), Via Morego 30, 16163, Genova, Italy., Italy) Remo Proietti Zaccaria (Istituto Italiano di Tecnologia (IIT), Via Morego 30, 16163, Genova, Italy., Italy) Valeria Sperati (GAME Lab, Department of Applied Science and Technology, Politecnico di Torino, Italy) Hamideh Darjazi (GAME Lab, Department of Applied Science and Technology, Politecnico di Torino, Italy) Claudio Gerbaldi (GAME Lab, Department of Applied Science and Technology, Politecnico di Torino, Italy) Giuseppe Antonio Elia (GAME Lab, Department of Applied Science and Technology, Politecnico di Torino, Italy)

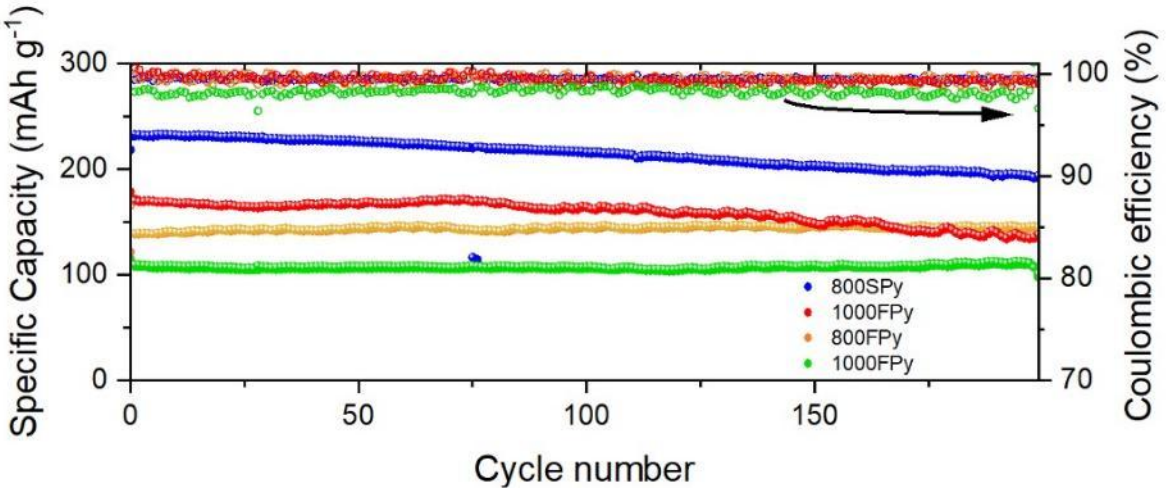
17:00-17:40 Session S3.5: Applied pyrolysis: Biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Axel Funke (Karlsruhe Institute of Technology, Germany) Mohamed Traoré (Fundación Centro Tecnológico de Investigación Multisectorial, Spain)

ABSTRACT

Plant based carbons (PCs) have emerged as promising anode materials for sodium ion batteries (NaIBs) due to their low sodiation potential (below 1.0 V vs. Na^+/Na), good reversible capacities (200–300 mAh g^{-1}), low cost, and inherently low toxicity. Biomass derived carbons are receiving increasing attention as scalable, renewable alternatives to conventional graphitic carbon, whose production remains costly and resource intensive for large scale HEV/EV applications. Among biomass sources, bamboo represents an ideal precursor: although botanically a grass, its high carbon content, hierarchical pore architecture, rapid growth rate, and global availability make it a sustainable platform for energy storage materials [1]. Previous studies have demonstrated that pyrolyzed bamboo can produce conductive, mechanically robust carbon monoliths suitable for microfluidic heaters, electrochemical devices, and even lithium and sodium ion batteries. Low temperature pyrolysis produces resistive 3D carbons ($\sigma \approx 6.6$ S m^{-1}), while higher temperature treatments up to 1000 °C yield finely tuned graphitic domains with electrical conductivity up to 250 S m^{-1}[2]. Bamboo derived carbons have also shown strong redox behavior linked to persistent free radicals, enabling efficient degradation of organic dyes through electron transfer pathways [3,4]. In this work, bamboo based biochars (BBs) were synthesized using optimized slow pyrolysis and fast pyrolysis with CO_2 activation under N_2/CO_2 atmospheres at 800 °C and 1000 °C. The resulting materials were evaluated as NaIB anodes using an environmentally friendly electrode configuration consisting of carboxymethyl cellulose (CMC) as an aqueous binder and aluminum as the current collector, replacing the more resource intensive copper. Electrochemical testing revealed that fast pyrolyzed samples with CO_2 activation (800FPy and 1000FPy) delivered superior cycling performance, maintaining stable reversible capacities of approximately 110 mAh g^{-1} and 140 mAh g^{-1}, respectively, over more than 200 cycles. In contrast, slow pyrolyzed samples (800SPy and 1000SPy) exhibited higher initial capacities but suffered from reduced capacity retention, highlighting the beneficial role of CO_2 induced porosity and defect engineering in promoting stable Na^+ storage. The results align with sodium storage mechanisms in disordered carbons, including Na^+ adsorption at defects and pores, interlayer insertion, and pore filling by quasi metallic sodium clusters. Overall, this study demonstrates that untreated bamboo derived carbons, produced through simple and scalable pyrolysis routes, represent viable and environmentally friendly anode materials for next generation sodium ion batteries. Their tunable microstructure, low cost fabrication, and robust cycling stability underscore their potential to support sustainable, large scale energy storage technologies.



Rferences [1] Pandoli, O.G. et. al., Biomass Bioenergy 2025, 107511 [2] Pandoli, O.G. et.al, Carbon 2023, 118214. [3] Pandoli, O.G. et.al, ChemCatChem 2024, e202401042. [4] Pandoli, O.G. et.al, Catalysis Science & Technology, 2025.

Sustainable Bamboo-Derived Biochar as a Functional Enzyme Support: Effect of Pyrolysis Conditions on Biocatalytic Polymerization

Lizeth Marlen Moreno Pascual (University of Genova, Italy) Alessandro Pellis (University of Genova, Italy) Omar Ginoble Pandoli (University of Genova, Italy) Natalia Nicotra (University of Genova, Italy)

17:00-17:40 Session S3.7: Biochar

Location: ROOM C1 – FIRST FLOOR

Chairs: Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy)

ABSTRACT

Bamboo is a fast-growing, renewable lignocellulosic biomass that represents a highly attractive and sustainable feedstock for the production of functional carbon materials. In this work, untreated Dendrocalamus giganteus was converted into bamboo-derived activated carbons (BACs) via fast pyrolysis under an inert nitrogen atmosphere at temperatures ranging from 300 to 600 °C, followed by in situ CO_2 activation. This combined approach enabled a fine control over the structural, morphology, porosity surface, chemical and paramagnetic properties, such as permanent free radical (PFR) formation of the resulting biochars. Comprehensive physicochemical characterization was performed using diffuse reflectance infrared Fourier transform spectroscopy (DRIFT), X-ray photoelectron spectroscopy (XPS), Brunauer–Emmett–Teller (BET) surface area analysis, electron paramagnetic resonance (EPR), and ATR-FT-IR spectroscopy. These techniques provided complementary insights into surface functional groups, elemental composition, electronic structure, porosity development, and carbon-centered radical as a function of thermal treatment. Nitrogen adsorption–desorption measurements combined with Density Functional Theory (DFT) pore size analysis revealed a strong dependence of pore architecture on pyrolysis temperature. The material produced at 600 °C (B600) was predominantly microporous, with pore widths below 2 nm. In contrast, B500 exhibited a well-developed mesoporous network with pore sizes between 2 and 50 nm, while B400 displayed a macroporous structure with pore diameters exceeding 50 nm. These structural differences were identified as critical parameters for subsequent enzyme immobilization. The biochars were then evaluated as solid supports for Candida antarctica lipase B (CaLB), an industrially relevant enzyme characterized by a highly hydrophobic surface. Enzyme immobilization occurred through a combination of surface adsorption and pore entrapment, with larger pores generally favouring higher enzyme loading. However, the results clearly demonstrate that immobilization efficiency is not dictated by pore size alone, but rather by a balance between surface chemistry, morphology, and accessibility. The immobilization process was monitored by Bradford assay, which showed a progressive decrease in free enzyme concentration in the supernatant and complete immobilization of the protein of interest on all supports after 24h. The catalytic performance of immobilized CaLB was assessed using a model polycondensation reaction of 1,8-octanediol and dimethyl adipate, producing an aliphatic polyester with methanol as a by-product. Monomer conversion and polymer physio-chemical properties were analyzed by NMR spectroscopy and Gel Permeation Chromatography (GPC). High monomer conversions were achieved across all materials (98% for B400, 94% for B500, and 77% for B600) and substantial differences were observed in the obtained polymer molecular weight. B400 enabled the formation of polyesters with a number-average molecular weight of approximately 11 kDa, compared to 7.5 kDa for B500 and only 1.5 kDa for B600. These results indicate that macroporous biochars promote more favourable enzyme orientation and accessibility, whereas microporous structures impose steric constraints that limit polymer chain growth. References: Pandoli, O; Catal. Sci. Technol., 2025,15, 6161-6178 https://doi.org/10.1039/D5CY00632E Pandoli, O; ChemCatChem, 2024, 16, https://doi.org/10.1002/cctc.202401042

Aqueous-Phase and Acid-Modified Biochar for Sustainable and Resilient Soils

Adam El-Aradi (Aston University, Energy and Bioproducts Research Institute (EBRI), UK) Daniel Nowakowski (Aston University, Energy and Bioproducts Research Institute (EBRI), UK) Agnieszka Nowak (University of Silesia in Katowice, Faculty of Environmental Science, Poland) Tala Kasim (Aston University, Department of Civil Engineering, UK) David Webb (Aston University, Aston Institute of Photonic Technologies, UK)

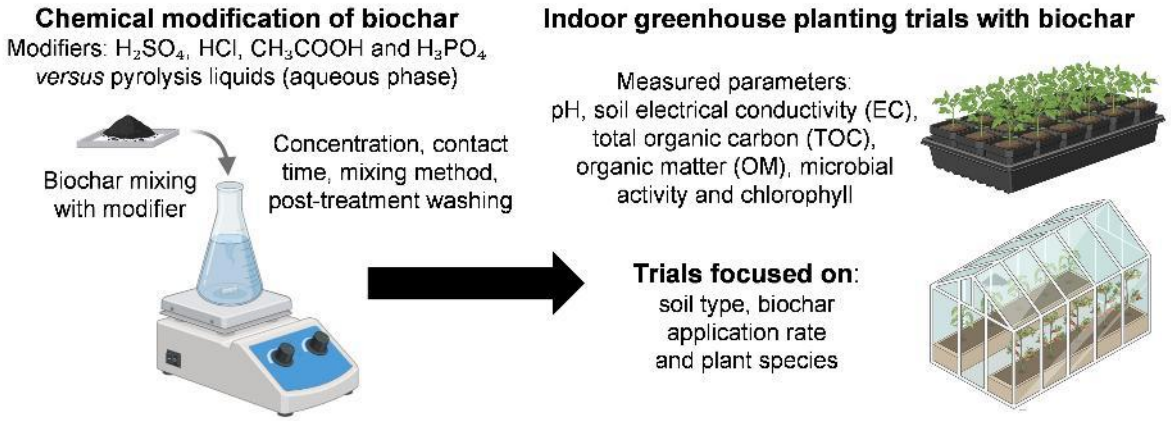
17:00-17:40 Session S3.7: Biochar

Location: ROOM C1 – FIRST FLOOR

Chairs: Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Maurizio Troiano (Department of Chemical, Materials and Industrial Production Engineering, University of Naples Federico II, Italy)

ABSTRACT

Improving soil quality is essential for sustainable agriculture and long-term soil resilience. Biochar, a carbon-rich material derived from biomass pyrolysis, has shown great potential to enhance nutrient retention, microbial activity and soil carbon storage. Its effectiveness depends strongly on its physicochemical properties and the specific soil challenges it is intended to address. Many conventional biochar materials are not optimised for targeted functions and tailoring surface chemistry, and porosity can markedly improve performance in acidic, nutrient-poor or contaminated soils while supporting circular, low-input soil management and carbon storage strategies. Preliminary experiments with unmodified biochar produced from pinewood (PWBC) and wheat straw (WSBC) evaluated their impact on soil properties and microbial activity. PWBC exhibited a high carbon content of 85.1%, suggesting strong potential for long-term carbon sequestration, while WSBC contained higher concentrations of essential nutrients. In 5% soil amendments, WSBC increased soil pH from 6.6 to 7.1, electrical conductivity from 300 to 570 μS cm^{-1} and plant-available potassium from 289 to 849 mg L^{-1}. Microbial responses varied with feedstock and incubation time. Total heterotrophic bacterial counts declined by approximately three log units across all treatments after 30 days, while dehydrogenase activity in WSBC-amended soil peaked at nearly four times the control after 90 days, compared to a twofold increase under PWBC. These findings highlighted that nutrient-rich WSBC enhances short-term microbial activity and nutrient availability, whereas recalcitrant PWBC primarily contributes to stable carbon retention. Selected biochar samples were subsequently subjected to targeted chemical modification treatments to improve their surface chemistry, porosity and cation exchange capacity. Traditional chemical reagents, including sulphuric acid, hydrochloric acid, acetic acid and phosphoric acid, were used as benchmarks to evaluate modification effectiveness. Alongside these conventional treatments, the aqueous-phase pyrolysis liquid produced during the same process will be employed as a sustainable chemical modifier, offering a circular approach to biochar enhancement. Rich in organic acids and phenolic compounds, this by-product can functionalise biochar surfaces while reducing the need for external reagents and minimising waste. Key process variables such as mixing method, liquid concentration, contact time and post-treatment removal will be optimised to enhance biochar functionality for soil applications. This research aims to establish practical, scalable methods for producing biochar that maximises both its physicochemical performance and its contribution to soil health and climate resilience. These laboratory findings will be taken forward into a scalable soil-improvement strategy. The modified biochar samples will be benchmarked against specific parameters and metrics (functional groups, porosity, cation exchange capacity and nutrient sorption. Their agronomic and biological effects will then be tested in controlled soil incubations (greenhouse and field trials), tracking pH buffering, plant-available nutrients, enzyme activities and shifts in microbial abundance over time. Direct comparison of aqueous-phase liquid modification with mineral-acid and organic-acid benchmarks will quantify whether the circular approach delivers equivalent or improved functionality with lower chemical inputs and reduced waste. The outcome will be practical guidance linking feedstock choice and modification route to specific soil constraints, supporting resilient, low-input soil management and long-term carbon storage.



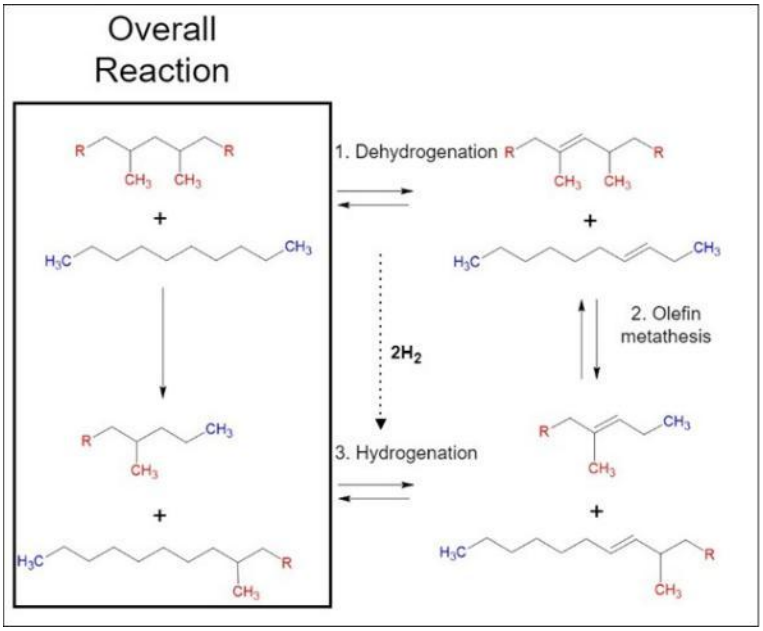
Chemical Recycling of Polypropylene via Heterogeneously Catalyzed Dehydrogenation and Metathesis

Jaco Becker (North-West University, South Africa) Naldo Meyer (North-West University, South Africa) John Bunt (North-West University, South Africa) Hein Neomagus (North-West University, South Africa)

17:00-18:00 Session S3.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

Polypropylene (PP) accounts for roughly 20% of plastic waste streams [1] and remains difficult to recycle using conventional methods [2,3]. Conventional pyrolysis is widely used in polymer chemical recycling, yet polypropylene often yields broad product distributions and unsaturated/aromatic fractions under conventional thermal routes [3]. Tandem dehydrogenation and olefin cross-metathesis (TDOCM) has recently emerged as a mild, catalyst-directed pathway for polyethylene depolymerization [4–6]. This study reports the first documented catalytic degradation of polypropylene via tandem dehydrogenation and olefin cross-metathesis, employing a Pd/γ-Al2O3 catalyst for dehydrogenation in combination with a WOx/SiO2 catalyst for metathesis, with n-decane serving as co-reactant. Under mild conditions (300 °C and ~35 bar), complete PP conversion is achieved in 3 h, yielding predominantly saturated. PP was converted to liquid hydrocarbons (81 wt% liquid; 19 wt% gas), with no solid residue remaining after 3 h. After 1 hour, 17.5 wt% wax residues were recovered, and liquid and gas yields were reduced by 12 and 5 wt%, respectively. Gel permeation chromatography (GPC) confirmed PP depolymerization and reported a reduction in molecular weight – decreasing from 250,000 g/mol (feed; PDI = 3.73) to 995 g/mol (wax; PDI = 2.6). Liquid products comprised only alkanes and were dominated by branched iso-alkanes in the C8–C18 range, consistent with PP's tertiary-carbon structure and retention of methyl substituents in fragments. The results differ from conventional pyrolysis, which produces fractions of unsaturated compounds and aromatics [3]. It was found that an excess of n-decane co-reactant suppresses polymer–polymer metathesis and β-scission pathways (minimizing wax and gas formation), whereas insufficient co-feed leads to increased yields of waxes and light gases [6]. Elevated pressures improved hydrogen retention and promoted saturation of intermediates, shifting the product distribution toward heavier alkanes. The method is effective across different PP feedstocks, including both virgin and recycled PP, fully converting them under these conditions. Overall, this application of tandem dehydrogenation and olefin cross-metathesis to polypropylene establishes a selective pathway for PP upcycling with high yields of liquid alkanes under mild operating conditions. Proposed reaction scheme for the tandem dehydrogenation and olefin cross-metathesis (TDOCM) of polypropylene (PP) and n-decane.



1. Faraca and Astrup. Plastic waste from recycling centres: Characterisation and evaluation of plastic recyclability. Waste Manag. 2019, 95, 388–398. 2. Schyns and Shaver. Mechanical recycling of packaging plastics: A review. Macromol. Rapid Commun. 2021, 42, 2000415. 3. Huang et al. Chemical recycling of plastic waste for sustainable material management: A prospective review on catalysts and processes. Renew. Sustain. Energy Rev. 2022, 154, 111866. 4. Jia et al. Efficient and selective degradation of polyethylenes into liquid fuels and waxes under mild conditions. Sci. Adv. 2016, 2, e1501591. 5. Ellis et al. Tandem heterogeneous catalysis for polyethylene depolymerization via an olefin-intermediate process. ACS Sustain. Chem. Eng. 2021, 9, 623–628. 6. Kim et al. Metathesis, molecular redistribution of alkanes, and the chemical upgrading of low-density polyethylene. Appl. Catal. B Environ. 2022, 318, 121873.

Interaction mechanism of organic components during decommissioned pv laminates oxidative pyrolysis for sustainable recycling

Yicheng Lei (Huazhong University of Science & Technology, China) Aijun Li (Huazhong University of Science & Technology, China) Yongda Huang (Huazhong University of Science & Technology, China) Qian Deng (Huazhong University of Science & Technology, China) Meiling Deng (China National Electric Apparatus Research Institute Co Ltd, China) Guangqian Luo (Huazhong University of Science & Technology, China)

17:00-18:00 Session S3.8: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

The rapid global expansion of solar energy infrastructure has created critical environmental challenges, especially the management of end-of-life (EoL) photovoltaic (PV) modules. As these modules reach the end of their functional lifespan, recovering valuable constituents such as high-purity glass, silver, silicon, and aluminum becomes essential for a sustainable circular economy. However, the primary technical bottleneck lies in the "de-encapsulation" process, where the multi-layer structure protected by ethylene-vinyl acetate (EVA) and polyvinyl fluoride composite backsheet (TPT) is notoriously difficult to separate. Traditional inert pyrolysis often suffers from poor heat transfer and slow reaction rates. Based on these, this study proposed oxidative pyrolysis as a high-efficiency alternative. This study first utilized thermogravimetric analysis (TGA) to evaluate the pyrolysis characteristics and kinetic parameters of individual EVA and TPT components, as well as their mixtures, under both inert (N2) and low-concentration oxygen environments. The results indicated that the optimal oxygen concentration for achieving a stable, autothermal reaction ranges between 2% and 4%. Specifically, the pyrolysis of pure EVA occurred in two distinct stages (290–410 ℃ and 410–515 ℃), with the average activation energy (Ea) dropping significantly from 238.64 kJ/mol in N2 to 195.81 kJ/mol in 2% O2. Similarly, pure TPT pyrolysis occurred between 375–520 °C, with Ea values decreasing from 204.42 kJ/mol in N2 to 187.84 kJ/mol in 4% O2. The co-pyrolysis of EVA/TPT mixtures followed a two-stage process (290–410 ℃ and 410–525 ℃), where the Ea was recorded at 226.91 kJ/mol in 2% O2, compared to 253.04 kJ/mol in an inert atmosphere. A notable synergistic effect was observed during co-pyrolysis, where oxidative conditions lowered the energy barrier and shifted the maximum weight loss peak temperatures forward by 20–50 ℃. To understand the underlying chemistry, thermogravimetry-fourier transform infrared spectroscopy (TG-FTIR) was employed to monitor evolved gases and reaction pathways. In an inert atmosphere, decomposition followed sequential bond scission: EVA released acetic acid, CH4, and CO2, while TPT yielded HF and CO. In contrast, the introduction of oxygen fundamentally reshaped these pathways, as oxidation became the dominant mechanism. This shift suppressed the formation of alkanes and HF while significantly increasing CO2 evolution, suggesting that oxygen catalyzes the reaction by replacing slow hydrocarbon chain cleavage with direct oxidation. Furthermore, a unique "oxidative coupling effect" was identified in the mixed components. While synergy under inert conditions stemmed from the capture of EVA intermediates by TPT-derived radicals, aerobic conditions upgraded this interaction, resulting in CO2 yields that far exceeded those of individual components. Ultimately, oxidative pyrolysis offers a dual advantage by significantly reducing energy consumption through lower activation energy and ensuring more complete decomposition of organic components. This study elucidates the complex reaction kinetics and chemical pathways involved, establishing a crucial theoretical foundation for developing efficient, industrial scale recycling processes to address next generation solar waste sustainably.

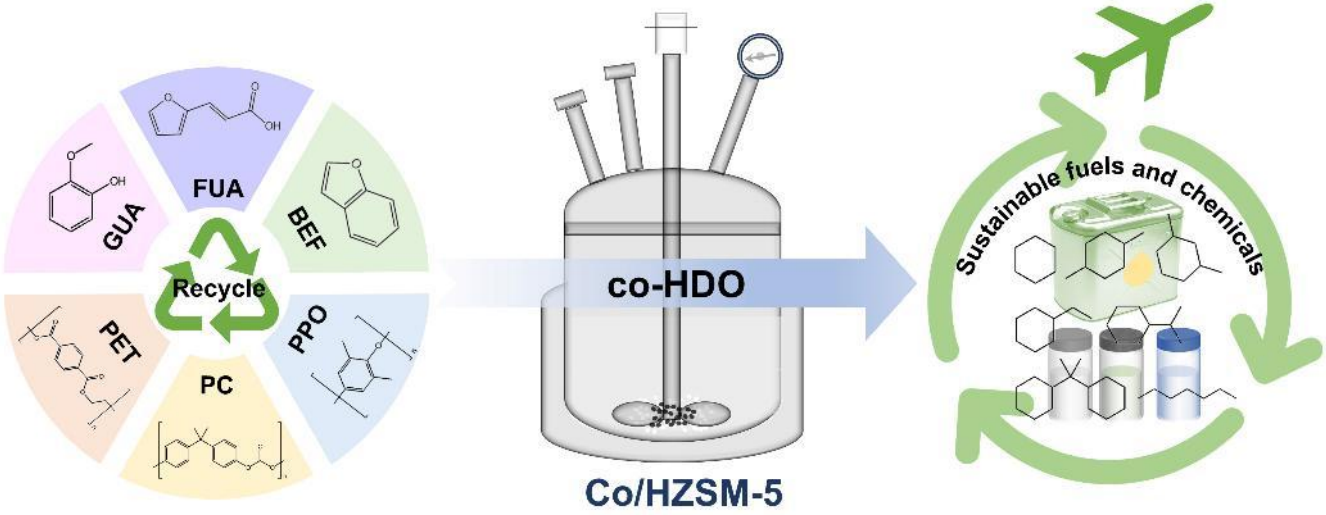
Highly efficient selective co-hydrodeoxygenation of bio-oil and plastic wastes to naphthenes over Co/HZSM-5

Xiaoyan Yin (Zhejiang University, China) Yangguang Lv (Zhejiang University, China) Hongcai Su (Zhejiang University, China) Shurong Wang (Zhejiang University, China)

17:00-18:00 Session S3.8: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Hero Jan Heeres (University of Groningen, Netherlands) Fausto Viteri (Instituto de Carboquímica (ICB-CSIC), Spain)

ABSTRACT

As the sole renewable carbon source, biomass can be pyrolyzed into bio-oil, biochar, and syngas. However, bio-oil suffers from inherently high oxygen content. Meanwhile, over 400 million tons of plastics are produced globally each year, with approximately 350 million tons ending up as waste. In the current waste treatment environment, bio-oil and plastic wastes are often found as physically blended or even intermingled complex streams. Hence, the integrated catalytic conversion of biomass-derived pyrolysis oil and polyester plastic waste into high-value fuels and chemicals represents a sustainable and circular-economy-aligned resource recovery route. Hydrodeoxygenation (HDO) is considered one of the most effective approaches for simultaneously deoxygenating bio-oil and upgrading plastic waste. However, the design of HDO catalysts that can synergistically process both feedstocks and simultaneously meet requirements for cost-effectiveness, high activity, stability, and selectivity remains a key challenge in this field. This study systematically demonstrates that the noble-metal-free bifunctional Co/HZSM 5 catalyst can directly and efficiently upgrade the mixed feedstock of bio-oil and polyester plastics into sustainable fuel components dominated by naphthenes under relatively mild reaction conditions, with a total yield as high as 94%. Moreover, the catalyst still maintains excellent catalytic activity after repeated uses, exhibiting good reusability and stability. In-depth mechanistic studies reveal that the highly dispersed metallic Co nanoparticles, serving as hydrogenation active sites, play an indispensable key role in catalyzing the cleavage of C–O bonds and C–C bonds as well as the hydrogenation of unsaturated bonds. In contrast, the abundant acidic sites provided by the HZSM 5 support effectively facilitate key tandem reaction steps such as dehydration and isomerization. Correlation analysis between catalytic performance and structural characterization further confirms that the metal-acid balance between metallic sites and acidic sites in the Co/HZSM 5 catalyst is the core factor that significantly affects its overall HDO activity, intermediate conversion pathways and final product distribution. Among them, the 10Co/HZSM 5(200) catalyst exhibits the optimal metal-acid balance . It demonstrates outstanding HDO performance in the co-conversion reaction of guaiacol and polyethylene terephthalate (PET). Under the reaction conditions of 260 °C, 4 MPa H_2 and 3 h, the yield of cyclohexane reaches 94%, the yield of 1,4-dimethylcyclohexane is as high as 86.6%, guaiacol is completely converted, and the conversion rate of PET exceeds 95%. In addition, the universality of this catalyst has been verified: it can effectively synergistically convert the mixture of heavy fractions of real bio-oil containing complex oxygenates (such as ethers, furans and furfural derivatives) and various engineering plastics (including polycarbonate and polyphenylene oxide), realizing efficient and directional conversion to naphthenic fuels while maintaining high structural stability and catalytic activity during long-term reactions. This bifunctional Co/HZSM 5 catalyst, featuring simple preparation process, low raw material cost and good reproducibility, provides a technical route with important industrial application prospects for the future synergistic, efficient and high-value chemical recycling of mixed biomass oil and complex waste plastics into valuable products.



Abstracts:

Orals Day 4

Thursday, 11th June 2026

THE POWER OF SILYLATION: TOWARD A MOLECULAR DESCRIPTION OF LIQUIDS FROM THERMOCHEMICAL PROCESSES

Cristian Torri (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy) Rui Bao (University of Bologna Xi'an Jiaotong University, China) Andrea Facchin (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy) Daniele Fabbri (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy) Federica Zimbardi (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy) Jasmine Hertzog (Université de Lorraine, LCP-A2MC, Metz, 57000, France, France) Alessandro Rombolà (Dipartimento di Chimica Giacomo Ciamician, Università di Bologna, Italy)

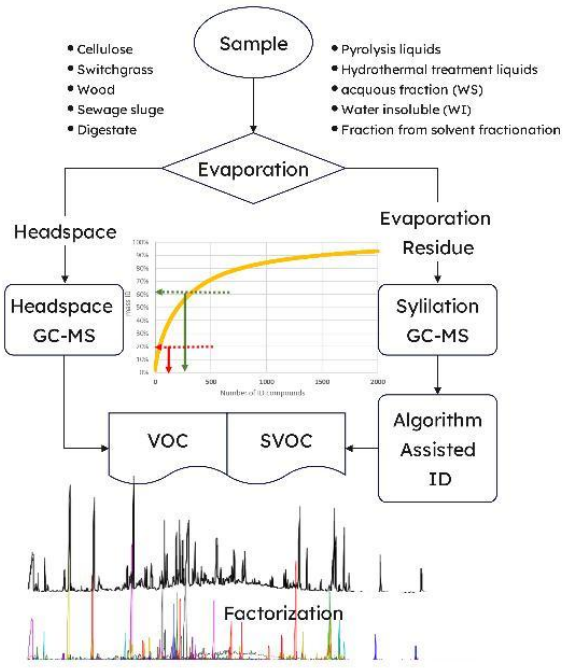
09:30-10:30 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

The fundamental investigation of thermochemistry demands for a reliable analytical tool for comparison of processes from a chemical point of view. There is a large consensus that identification of all (up to ten thousand compounds) molecular constituents of pyrolysis (Py) and hydrothermal treatment (HT) liquid requires a combination of different analytical procedures and advanced spectroscopic techniques (e.g., high resolution mass spectrometry, HRMS or GCxGC-MS techniques). This approach needs specific analytical skills, costly dedicated equipment, and it is time-intensive. This implies sub-optimal or slow feedback from chemical analysis and missed opportunities for applied thermochemistry research. For that reason, we evaluated if it would be possible to identify just one analytical procedure, potentially applicable in most of the research labs, which allows the identification/quantification of more than half (mass basis) of organic compounds in liquids. GC-MS is one of the few techniques that can be applied in almost every lab, which typically allows quantifying/identifying up to 10-20% of organics in HT and Py liquids. Derivatization increases the share of detected organic by a factor of 3 (reaching 30-45%, mainly thanks to improved separation efficiency and stabilization of reactive analytes), allowing to resolve up to 300 compounds, which is close to the theoretical limit of capillary GC. Peak deconvolution using independent GC runs (e.g., analyzing a large number of independent samples with appropriate computational capability) increases the number of resolved compounds to a value close to that detectable with FT-ICR MS [1].



Derivatization and automated deconvolution allow, in practice, to deliver information that can entirely describe pyrolysis products from a molecular point of view, but (especially for silylated derivatives) library-based identification of MS spectra is ineffective and somewhat misleading. To address this problem, a complete library of fragmentation patterns for pyrolysis products was created, providing a standardized identification strategy for unknown silylated derivatives. Although automated identification of unknown spectra is not possible at present, the presence of a silyl group provides several deterministic fragmentation patterns, which have been identified and incorporated into a semi-automatic, human-assisted algorithm that resolves and provides partial identification of the products. This procedure was validated by HRMS, demonstrating that it is possible to obtain a molecular picture of complex materials easily and, in some cases, to identify novel, relevant pyrolysis products (e.g., cyclic dipeptides and anhydrodisaccharides). The final automated procedure allowed, just with standard GC-MS equipment and without advanced analytical skills, to quantify and tentatively identify about 65% of the organics into liquid products from fast/intermediate pyrolysis and hydrothermal treatment of various representative feedstock such as cellulose, switchgrass, wood, sewage sludge and water-soluble derivatives arising from biological upgrading of thereof. Aim of this contribution is to show the potential of the approach and deliver an open-source methodology that scientists/engineers can use without a specific analytical background to obtain a molecular picture of liquids from thermochemical treatment.

Experimental investigation of non-catalytic dry reforming of representative bio-oil compounds

Maria Virginia Manna (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili (STEMS-CNR), Napoli, Italy, Italy) Giovanni Battista Ariemma (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Davide Amato (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Giovanni Fabozzi (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Pino Sabia (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Raffaele Ragucci (Institute of Sciences and Technologies for Sustainable Energy and Mobility - C.N.R, Naples, Italy, Italy) Mara de Joannon (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy)

09:30-10:30 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

The integration of carbon capture by dry reforming can offer a promising solution to both reduce the carbon dioxide emissions, thus achieving the goals of reducing global warming, and to produce valuable gases. In general, dry reforming is a catalytic process converting hydrocarbon feeds, mainly methane (CH4), into syngas over a metal-based catalyst (e.g. nickel, platinum or rhodium). Although the use of catalysts allows to increase the process performance and moderate the operating conditions, deactivation phenomena represent a critical issue, even more if bio-oils, hydrocarbon by-products or heavy hydrocarbon mixtures are considered as feedstocks, due to their higher tendency to form coke. This requires other strategies, such as non-catalytic dry reforming. Pyrolysis bio-oils are gaining increasing attention as feedstock for the dry reforming process. However, for complex mixtures as bio-oils, it is necessary to develop systematic studies using representative chemical components to gain insight into the reaction mechanism and the optimal operating condition for the non-catalytic dry reforming. In this framework, this study reports an experimental investigation of the non-catalytic dry reforming and oxidation of selected chemicals commonly present in bio-oils, providing a systematic analysis of the effect of molecular structure (i.e., carbon chain length and the presence of oxygenated functional groups) on process reactivity. To study the dry reforming of the bio-oil components, the experimental tests were carried out in a spiral-shaped tubular laminar-flow reactor, with a total length of 4 m, fixing the mixture residence time equal to 2.5 s. Experiments were performed for diluted stoichiometric fuel/CO2 mixture, with stoichiometry defined according to the dry reforming reaction for each component. The mixtures were diluted at 92%vol. in N2 and the tests were performed in the temperature range 600-1350 K. Several pure compounds and binary mixtures have been tested, such as furfural, acetol, furfural-syringol, acetol-phenol and acetol-guaiacol. The exhaust gases are fed to a condenser and cooled down to 10°C. The produced gases were analyzed online with micro-gas chromatography and FTIR, while the condensed liquids were analyzed with GC-MS and Karl Fischer titration. The obtained results showed that at temperatures below 1150 K, thermal decomposition of the fuel dominates, leading to the formation of CO, H2, CH4, and light hydrocarbons, while CO2 is only weakly affected. At higher temperatures, dry reforming reactions become increasingly important, as evidenced by the marked consumption of CO2, the higher concentration of CO and H2, and the decrease in CH4 concentration. Overall, the selected bio-oil components can be effectively converted into syngas via a non-catalytic dry reforming process, which becomes active at temperatures above 1200 K. This activation temperature remains essentially unchanged when considering either pure compounds or mixtures of different compounds.

Representation of lignin derived oligomers in pyrolysis bio-oil: Advances towards improved prediction of vapor liquid equilibria for controlling bio-oil quality

Axel Funke (Karlsruhe Institute of Technology, Germany) Ana Correa de Araujo (Karlsruhe Intitute of Technology, Germany) Amir Jalalinejad (Karlsruhe Institute of Technology, Germany) Nicolaus Dahmen (Karlsruhe Institute of Technology, Germany)

09:30-10:30 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

The production of condensates from pyrolysis, such as 'fast pyrolysis bio-oil' and 'wood vinegar' demands for control of decisive quality parameters, which are determined by their composition. Prediction of phase equilibria is of fundamental importance to achieve this aim, since it allows to design condensate composition through the choice of condensation temperature. It also opens up the opportunity to design a strategy for further downstream separation of condensate fractions or even single compounds. While phase equilibria prediction is a well established tool in chemical engineering in general, it lacks application for pyrolysis products due to several fundamental challenges: 1) A large part of pyrolysis products consists of oligomers, which are largely unknown in composition/ structure, 2) most of the compounds observed after pyrolysis (of biomass) are not used in chemical engineering, yet, and thus lack well established knowledge of their thermophysical properties, 3) consequently, surrogate mixtures need to be developed to describe the behavior of the bulk fractions in phase equilibria with adequate precision, and 4) it is largely unclear how well the various models perform for the case of phase equilibria calculation of pyrolysis products. This contribution focusses on the first of above-mentioned challenges with the aim to achieve a better representation of oligomers produced from biomass pyrolysis in phase equilibria prediction. A specific focus was set on vapor-liquid-equilibria (VLE) since they form the fundamentals for the design of the condensation step of pyrolysis liquids. It is hypothesized that an important share of oligomers is derived from lignin and, consequently, a dedicated study was conducted which aimed at producing pyrolysis condensates enriched in lignin derived oligomers. Measurements of VLE for this lignin-derived pyrolysis oil were conducted in an advanced distillation curve setup to investigate the use of varying oligomers as potential products from lignin pyrolysis. It is shown that oligomers require consideration in the prediction of VLE, not only due to their low boiling pressure but also due to their interaction with other molecules, such as e.g. water as the main compound of many pyrolysis condensates. Dimers of the biphenyl type showed good performance across various indicators, especially as compared to the larger tetramers tested in this study. These results are further supported by GC-MS/FID analyses combined with results from advanced analyses such as e.g. ultra-high resolution mass spectrometry, which reveal that a large share of these oligomers are characterized by highly oxygenated dimers/trimers. Despite the fact that including such lignin oligomer representatives in surrogate mixtures leads to an important improvement in VLE prediction, overall precision of prediction still requires optimization. Focus of future work could be on the influence of cellulose derived oligomers, which can now be efficiently studied based on the presented results.

Effect of steam and solid residence time on wood pyrolysis-gasification products

Mohamed Hechmi Aissaoui (LRGP / CNRS, France) Anthony Dufour (CNRS / LRGP, France) Yann Le Brech (CNRS / LRGP, France) Guillain Mauviel (CNRS / LRGP, France)

09:30-10:30 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

In this study, a Microfluidized Bed Reactor (MFBR) was employed to mimic the residence time and kinetics of reactions found in an industrial reactor. The novelty of this research lies in its investigation on biomass conversion with diverse carrier gases (either pure N2 or N2+H2O). The study aims to clarify the influence of these gases on both the pyrolysis mechanism and the char gasification mechanism. Beech wood pellets, measuring 6 mm in diameter and height, were employed to compare reactions and results for pyrolysis and steam-gasification at 850°C (using a mixture comprising 80% H2O vapours and 20% N2), 3.7s gas phase residence, with varying solid residence time (1, 2.5, 5, 10, 15, and 20 minutes) and varying the nature of bed (sands of Fontainebleau and Olivine). The products were characterized using advanced analytical techniques, including micro-GC and online mass spectrometry for gases, gas chromatography coupled with mass spectrometry and flame ionization detection (GC-MS-FID) for bio-oils, proximate and ultimate analysis (CHNS-O), and surface functional group analysis (IR) for biochars. This investigation confirmed that H_2O has a limited effect on methane gas-phase reforming, while emphasizing the key role of char gasification. Char gasification led to a significant increase in CO_2 and H_2 yields, with no noticeable effect on CO production.

Eucalyptus biomass valorization: evaluation of the influence of slow pyrolysis bio-oil inclusion in refining processes

Nathália Pontes (Universidade Federal do Rio de Janeiro, Brazil) Yasmin Pedro (Federal University of Rio de Janeiro, Brazil) Adriana Borges (Petrobras, Brazil) Andrea Pinho (Petrobras, Brazil) Vanessa Santos (Federal University of Rio de Janeiro, Brazil) Raquel Silva (Federal University of Rio de Janeiro, Brazil) Gabriela Vanini (Federal University of Rio de Janeiro, Brazil) Debora Azevedo (Federal University of Rio de Janeiro, Brazil)

09:30-10:30 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

Brazil established a target to reduce greenhouse gas emissions by up to 67% by 2035 compared to 2005. In this context, the incorporation of residues from forest biomass into refining processes represents a promising pathway to produce renewable products while utilizing existing refinery infrastructure and reducing fossil CO_2 emissions, which aligns with Sustainable Development Goals (SDGs) 7, 12, 13, and 9. Thus, the objective of this work is the chemical speciation of the liquid products generated in this process, an essential step for assessing the feasibility of this coprocessing route. Three delayed coking liquid products (100% petrogenic-based, PP) co-processed with 5% (BO5) and 10% bio-oil (BO10) were characterized by comprehensive two-dimensional gas chromatography coupled with time-of-flight mass spectrometry (GC×GC-TOFMS). The liquid products were fractionated, derivatized, and analyzed by GC×GC-TOFMS using DB-5MS (1D) and HP-17HT (2D) column set. Data processing was performed using ChromaTOF Tile software, applying a signal-to-noise ratio of 10:1 and a minimum mass spectral similarity of 70% for compound identification. GC×GC-TOFMS data showed the presence of oxygenated classes such as acids, phenols, and alcohols identified in their derivatized form by ions m/z 73, m/z 91, m/z 105, and m/z 117 in PP, BO5, and BO10. Methoxyphenols and dimethoxyphenols classes and thirteen biogenic compounds were identified only in BO5 and B010, such as syringol, 5-methyl guaiacol, o-cresol, catechol, and 1,6-hexanediol, which originate from the pyrolysis of cellulose, hemicellulose, and lignin, the main components of eucalyptus biomass. The application of the GC×GC-TOFMS to elucidate the individual molecular chemical composition of the samples revealed an increase in phenolic derivatives after the inclusion of bio-oil. These compounds have antioxidant activity and have potential as additives for fuels and biofuels. The liquid products generated can also be reintroduced as feedstock in delayed coking or other routes (e.g., catalytic cracking and hydrotreating), to convert these products into higher value-added compounds, with a significant biogenic contribution. Thus, the inclusion of eucalyptus bio-oil offers new perspectives for the industry integrated with the SDGs concepts, by decarbonization and the generation of renewable products.

A Tandem Micro Reactor–GC/MS Approach to Probing Catalytic Pyrolysis and High-Pressure Hydropyrolysis of Biomass

Young-Min Kim (Daegu University, South Korea) Shogo Kumagai (Tohoku University, Japan) Young-Kwon Park (University of Seoul, South Korea) Norio Teramae (Frontier Lab, Japan, Japan) Atsushi Watanabe (Frontier Lab, Japan, Japan) Chuichi Watanabe (Frontier Lab, Japan, Japan)

09:30-10:10 Session S4.3: Catalytic pyrolysis

Location: ROOM C1 – FIRST FLOOR

Chairs: Benedetta de Caprariis (Sapienza Università di Roma, Italy) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

ABSTRACT

The tandem micro reactor–gas chromatography/mass spectrometry (TMR-GC/MS) system provides a powerful and flexible analytical platform for investigating the reaction mechanisms of biomass pyrolysis and catalytic upgrading under precisely controlled conditions. By employing two independently controlled micro-furnaces arranged in series, the system allows the separation or integration of primary pyrolysis and secondary catalytic upgrading reactions. This configuration enables detailed mechanistic understanding of the effects of reaction atmosphere, catalyst properties, contact mode, and pressure, which are often difficult to isolate in conventional fixed-bed or fluidized-bed reactors. In this presentation, the applicability of the tandem micro reactor for in-situ catalytic pyrolysis, ex-situ catalytic pyrolysis, and high-pressure hydropyrolysis is demonstrated using representative publication examples. Ex-situ catalytic pyrolysis of Citrus unshiu peel illustrates the effectiveness of separating pyrolysis and catalytic upgrading steps within the tandem reactor configuration. Oxygenated pyrolyzates, including alcohols, ketones, and furan compounds, generated in the primary pyrolysis furnace were efficiently converted into aromatic hydrocarbons in the secondary catalytic furnace. Among the catalysts examined, HZSM-5 exhibited superior catalytic stability and lower formation of polycyclic aromatic hydrocarbons (PAHs) compared to HBETA, although HBETA showed higher initial aromatic yields. Sequential catalytic upgrading experiments further revealed that the slower deactivation of HZSM-5 resulted in more sustained production of BTEX (benzene, toluene, ethylbenzene, and xylenes), highlighting the importance of catalyst stability and selectivity in ex-situ catalytic pyrolysis. In contrast, studies on the catalytic pyrolysis of wood plastic composites (WPCs) emphasized the critical role of catalyst–reactant contact mode. In-situ catalytic pyrolysis, in which the catalyst is physically mixed with the feedstock, resulted in higher aromatic formation efficiency than ex-situ operation due to enhanced interaction between pyrolysis intermediates and active catalytic sites. However, aromatic yields were strongly influenced by catalyst pore architecture and coke accumulation behavior. Microporous HZSM-5 suffered from diffusion limitations, while HY experienced severe coke deposition within its larger pores, both leading to catalyst deactivation. These findings suggest that hierarchical or mesoporous zeolite structures may improve mass transfer and catalyst lifetime. The tandem micro reactor platform was further extended to high-pressure hydropyrolysis, enabling investigation of hydrogen-assisted thermal cracking and catalytic upgrading of lignin under elevated H_2 pressures. Hydropyrolysis significantly suppressed char formation and promoted the formation of monoaromatic hydrocarbons, particularly BTX, through hydrogen radical-mediated reactions that enhanced bond cleavage and inhibited condensation reactions. The presence of HZSM-5 further facilitated hydrocracking and aromatization of lignin-derived vapors; however, excessive reaction temperatures and hydrogen pressures favored hydrocarbon pool coupling reactions, leading to increased PAH formation and underscoring the need for careful optimization. Finally, integration of catalytic hydropyrolysis with downstream hydrodeoxygenation over Ni/desilicated HZSM-5 demonstrates a viable two-step upgrading strategy for biomass-derived pyrolysis vapors and oils. Overall, this presentation highlights the tandem micro reactor as a versatile analytical reactor that bridges fundamental reaction chemistry and practical catalytic process design in advanced pyrolysis and hydropyrolysis research.

Understanding Nitrogen-Induced Catalyst Deactivation in Plastic Waste Pyrolysis from Lab to Pilot Scale

Jonas Vogt (Karlsruhe Institute of Technology (KIT), Germany) Elena Rusu (Karlsruhe Institute of Technology (KIT), Germany) Daniela Merz (Karlsruhe Institute of Technology (KIT), Germany) Grazyna Straczewski (Karlsruhe Institute of Technology (KIT), Germany) Volker Fraaije (Basell Polyolefine GmbH, Germany) Shahram Mihan (Basell Polyolefine GmbH, Germany) Salar Tavakkol (Karlsruhe Institute of Technology (KIT), Germany) Dieter Stapf (Karlsruhe Institute of Technology (KIT), Germany)

09:30-10:10 Session S4.3: Catalytic pyrolysis

Location: ROOM C1 – FIRST FLOOR

Chairs: Benedetta de Caprariis (Sapienza Università di Roma, Italy) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

ABSTRACT

To increase the recycling rates of plastic waste, thermochemical recycling processes have been investigated for decades as a complement to mechanical recycling. Previous studies at the KIT have shown that the catalytic pyrolysis of polyolefin-rich plastic waste using microporous zeolites presents a promising pathway, as it yields high amounts of C2 to C4 olefins and valuable by-products such as BETX [1]. However, when heterogeneous plastic waste streams containing polyamides are pyrolyzed, the catalytic pyrolysis products begin to resemble those of non-catalytic pyrolysis, accompanied by a pronounced increase in coke formation. This behavior is attributed to catalyst deactivation [1]. To develop effective strategies mitigating this deactivation, it is crucial to elucidate the underlying mechanisms. In this study, these deactivation mechanisms were investigated through systematic and comparative catalytic pyrolysis experiments conducted on the milligram, gram, and kilogram scale. Low-density polyethylene (LDPE) was pyrolyzed in a gram scale batch reactor at 500 °C, either on its own or with the addition of 5 wt% polyamide-6 (PA-6) or ammonia as an inorganic basic nitrogen compound. The resulting pyrolysis vapors were subsequently catalytically cracked in a downstream fixed bed loaded with a microporous zeolite with a catalyst-to-plastic ratio of 0.08, and gaseous and liquid products were separated in a condenser. The gaseous products were identified and quantified using a gas chromatograph (GC) coupled with thermal conductivity (TCD) and flame ionization detector (FID), as well as a mass spectrometer (MS), while the liquid products were identified and quantified using proton nuclear magnetic resonance spectroscopy (1H-NMR) and a two-dimensional-GC coupled with a FID and MS. The resulting mass balances and the detailed gas and liquid product compositions reveal distinct shifts in product distribution toward non-catalytic products associated with catalyst deactivation when 5 wt% PA-6 or ammonia was added. Additionally, thermogravimetric analyses were carried out in which the PA-6 content in LDPE varied from 0 to 100 wt% along with the catalyst loading. A correlation between the PA-6 content and the coke deposited on the catalyst was observed. PA-6 also altered the decomposition behavior of LDPE, resulting in a three-step decomposition. The combined findings from both the gram-scale experiments and the thermogravimetric analyses reveal that coke formation alone cannot account for the observed catalyst deactivation. The results further indicate that nitrogen-containing species, which are formed by the decomposition of PA-6 are adsorbed and retained on the catalyst surface, providing an additional deactivation pathway that significantly contributes to the deterioration of catalytic performance. The findings were validated using a screw pyrolysis pilot plant operating at the kilogram scale with an integrated downstream fixed-bed reactor, demonstrating the relevance of these deactivation pathways under practical process conditions.

[1]: Netsch et al. Chemical Recycling of Polyolefinic Waste to Light Olefins by Catalytic Pyrolysis. Chemie Ingenieur Technik. 2023. 95(8).1305-1313. DOI: 10.1002/cite.202300078

Inline High-Sensitivity Analysis of Brominated Pyrolysates from TBBPA-Containing Polystyrene Using Py-GC/NICI-MS

Shogo Kumagai (Tohoku University, Japan) Kaori Akaike (Tohoku University, Japan) Siqingaowa Borjigin (Tohoku University, Japan) Patchiya Phanthong (Tohoku University, Japan) Yuko Saito (Tohoku University, Japan) Sadao Nakamura (Agilent Technologies Japan, Japan) Atsushi Watanabe (Frontier Laboratories; Tohoku University, Japan) Chuichi Watanabe (Frontier Laboratories, Japan) Norio Teramae (Frontier Laboratories; Tohoku University, Japan) Toshiaki Yoshioka (Tohoku University, Japan)

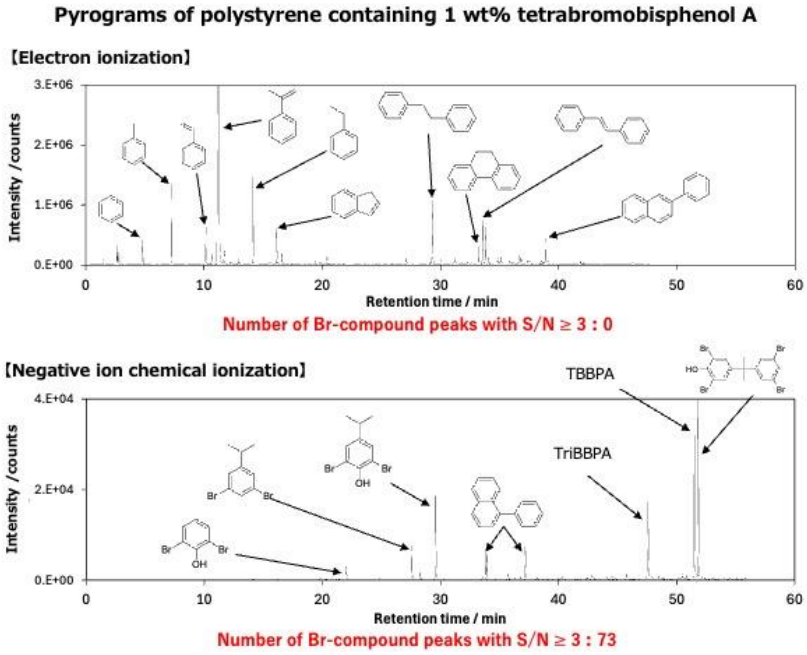
09:30-10:30 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

In the feedstock recycling of plastics containing brominated flame retardants (BFRs), evaluation of brominated compounds in the products is essential for assessing both product quality as chemical feedstocks and overall process performance. Brominated compounds formed during pyrolysis are diverse and often present at trace levels, making their detection challenging because they are masked by abundant non-brominated pyrolysates. Negative ion chemical ionization (NICI), a mass-spectrometric ionization technique, enables highly sensitive and selective detection of compounds with high electron affinity, such as halogenated species. In this study, we newly constructed a pyrolysis–gas chromatography/NICI–mass spectrometry (Py-GC/NICI-MS) system and investigated a high-sensitivity method for analyzing brominated compounds in pyrolysis products using polystyrene (PS) and tetrabromobisphenol A (TBBPA), a representative BFR, as model materials. PS containing 1 wt% TBBPA (TBBPA–PS) was pyrolyzed at 800 °C and analyzed using conventional Py-GC/electron ionization (EI)-MS and the newly constructed Py-GC/NICI-MS. The pyrolyzer was a EGA/PY-3030D (Frontier Laboratories). The GC/EI-MS system comprised an Agilent 6890N GC and an Agilent 5975C MS, while the GC/NICI-MS system comprised an Agilent 8890 GC and an Agilent 5977C MS. Pyrolysates were separated on a metal capillary column (Ultra ALLOY-1 (MS/HT), Frontier Laboratories) and then introduced into the MS. With EI, no peaks could be unambiguously assigned to brominated compounds, and the pyrogram was dominated by PS-derived aromatic hydrocarbons. In contrast, NICI detected more than 70 brominated-compound peaks with S/N ≥ 3, demonstrating the superior sensitivity of GC/NICI-MS for brominated compounds. We further examined the effect of ion source temperature on ionization behavior. At an ion source temperature of 300 °C or higher, the molecular ion of TBBPA was not observed and only bromine-derived ions at m/z 79 and 81 were detected. In contrast, at 200 °C or lower, the molecular ion was clearly observed, indicating that lower ion source temperatures are more suitable for compound identification. Overall, Py-GC/NICI-MS was confirmed to be highly effective for the sensitive detection of brominated compounds in pyrolysis products.



Unraveling the Pyrolytic Degradation Mechanisms and Recycling Potential of Non-Isocyanate Polyurethanes

Artur Bukowczan (Cracow University of Technology, Poland) Paulina Zając (Cracow University of Technology, Poland) Krzysztof Pielichowski (Cracow University of Technology, Poland)

09:30-10:30 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

In our work hyphenated techniques have been applied for the analysis of pyrolytic processes of non-isocyanate polyurethanes (NIPUs) to provide an understanding of the degradation mechanism and their chemical recycling potential. The thermal stability and volatile degradation products composition were investigated by thermogravimetric analysis coupled with Fourier transform infrared spectroscopy (TGA–FTIR) and pyrolysis–gas chromatography–mass spectrometry (Py–GC/MS) techniques. NIPUs, a novel class of polymers synthesized – contrary to the classical polyurethanes - without the use of toxic diisocyanates, have been extensively investigated with respect to their synthesis and sustainability. However, their thermal degradation behavior remains insufficiently explored, particularly regarding degradation mechanisms and the identification and characterization of volatile decomposition products. We studied NIPUs with varying amine content and chemical structure, as well as hybrid composite materials, which were subjected to pyrolytic degradation. The effect of the chemical environment of the hydroxyurethane group on polymer thermal stability was analyzed, as well as kinetic analysis of the pyrolytic degradation process was performed. Finally, the decomposition pathways were proposed, and, based on these complementary results, the potential of pyrolysis as a chemical recycling route for non-isocyanate polyurethanes was assessed in the context of a closed-loop recycling strategies.

A Novel Strategy for Recycling Waste Wind Turbine Blades under Steam and Air Conditions: Chemical Recovery and Char Removal

Chuan Ma (Chongqing University, China) Guoqing Huang (Chongqing University, China) Xin Huang (Chongqing University, China) Yunlin Shao (Chongqing University, China) Jingyu Ran (Chongqing University, China)

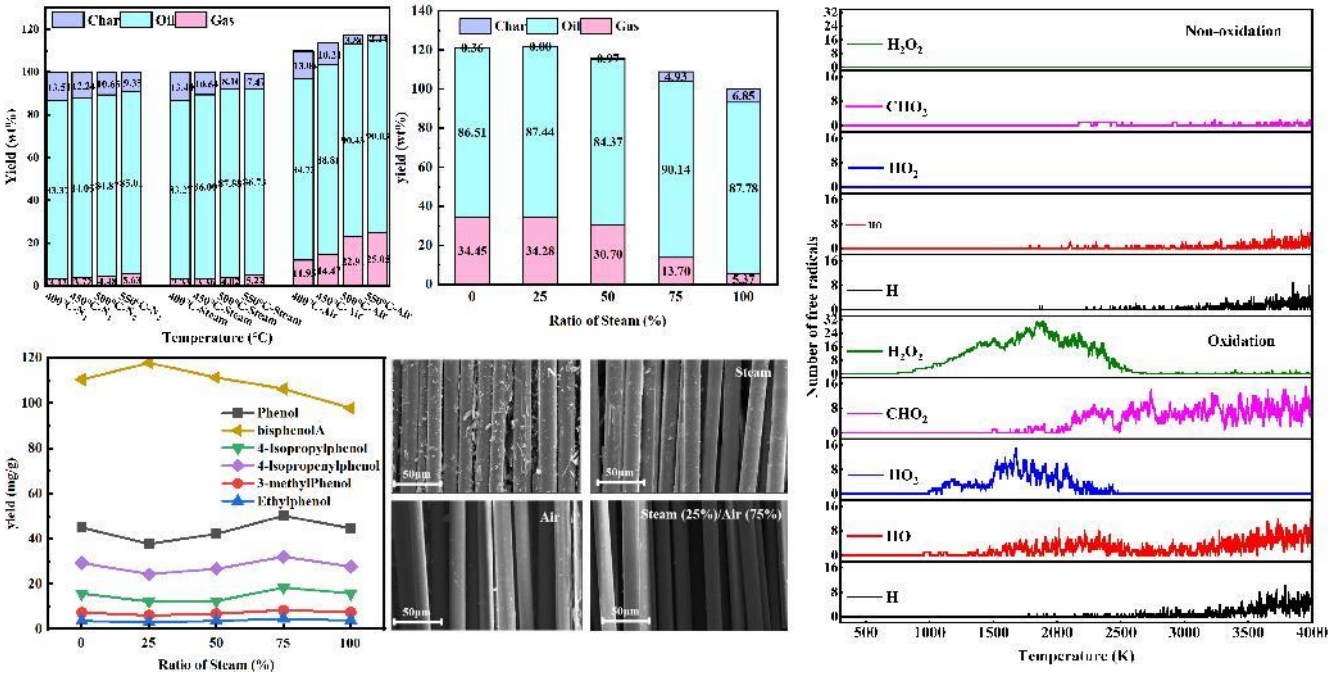
09:30-10:30 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

Thermochemical treatment of waste wind turbine blades (WTBs) is regarded as a promising approach for resource utilization, enabling the production of high-value byproducts. While the pyrolysis process allows for the recovery of valuable chemicals, the residual char could compromise the properties of recycled fibers. In this study, a one-step oxidation treatment of WTBs was conducted under steam/air conditions. The effects of various reaction parameters on the degradation behavior of WTBs were systematically investigated. Reactive force field molecular dynamics (ReaxFF MD) simulations were employed to elucidate the thermo-oxidative degradation mechanisms of epoxy resin matrix. The results indicated that under a N2 atmosphere, high temperature and elevated heating rate facilitated the reduction of char yield to 9.4 wt% at 550 °C. The liquid yield ranged from 83 to 84 wt%, with the maximum bisphenol A yield reaching 128.40 mg g-1 at 550 °C. Under an air atmosphere, 2.14 wt% residual char was obtained at 550 °C. However, when 25% steam was introduced into the air stream, the synergistic effect between air and steam enabled complete elimination of char at 550 °C while preserving 87.4 wt% of liquid product containing 117.78 mg g-1 of bisphenol A. Increasing the reactant gas flow rate from 200 to 400 ml min-1 resulted in only 0.35 wt% residual char at 500°C. SEM analysis demonstrated the clean and smooth fibers recovered under the mixture atmosphere of air and steam. ReaxFF MD simulations revealed that the degradation of the epoxy resin matrix initiated with the cleavage of the cross-linked C-N and ether bonds, followed by hydrogenation of the generated terminal phenoxy groups to produce phenolic derivatives as primary degradation products. The presence of O2 facilitated the generation of reactive radicals (•HO, •HO2, •H2O2, and •CHO2), accelerating the polymer backbone cleavage via radical chain reactions and intermediate oxidation. This research reveals the synergistic effects of air and steam for the degradation of WTBs and provides theoretical insights for chemical and clean fiber recovery from WTBs.



Analytical NMR Framework with Synthetic Lignin Oligomers for Surrogate Modelling of Fast Pyrolysis Bio-Oils and Pyrolignin Fractions

Myriam Rojas (Institute of Catalysis Research and Technology (IKFT) – Karlsruhe Institute of Technology (KIT), Germany) Axel Funke (Institute of Catalysis Research and Technology (IKFT) – Karlsruhe Institute of Technology (KIT), Germany)

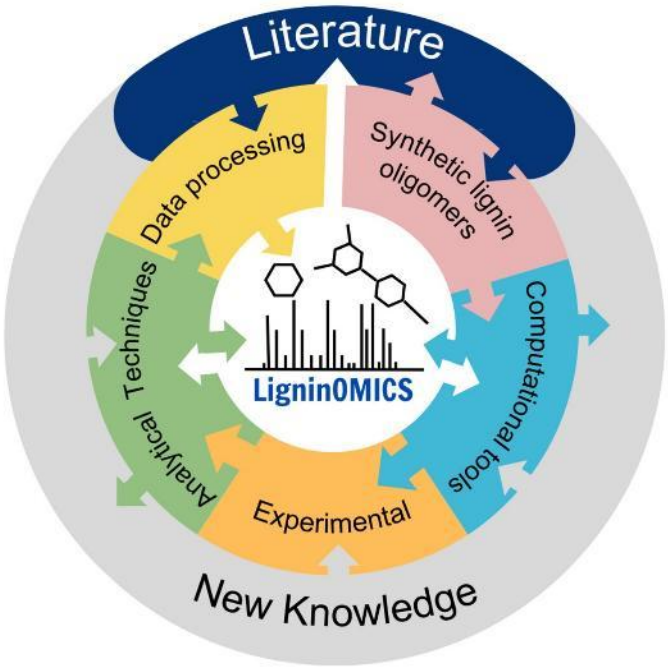
11:00-12:20 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

Thermochemical conversion routes, such as fast pyrolysis (FP) of lignocellulosic biomass or lignin, produce highly complex liquids (fast pyrolysis bio-oil, FPBO) and heavy fractions, including pyrolignin (PL). Detailed characterisation of these materials remains challenging, particularly for the high-molecular-weight fraction, owing to their oligomeric nature, the absence of appropriate reference spectra in MS/NMR libraries, and the scarcity of dedicated standards. In this contribution, we explore the use of synthetic lignin oligomers (SLOs) and curated model compounds as a practical means to improve the molecular interpretation of 1H and 13C NMR spectra of FPBO and PL fractions. We first digitised and standardised the structures and experimental NMR data in the NMR Database (University of Wisconsin/USDA) and generated predicted 1H and 13C spectra and shifts for each entry using ACD/Labs NMR Predictor (v2024.2.3). The theoretical shifts were systematically compared with the experimental values reported in the database. The spectra and shifts of the commercial pinoresinol standard (β–β linkage) and a laboratory-synthesised β-O-4 oligomer were also validated, with measurements in different NMR solvents. In parallel, the thermophysical properties of the same set of LigninOMICS molecules were estimated using Aspen Plus v14, providing a consistent property layer to support subsequent process modelling. These selected spectral and property data form the initial core of a lignin-centric reference library: LigninOMICS. On this basis, we developed a Python-based linear-additive model that simulates NMR mixture spectra by combining individual reference spectra from LigninOMICS with composition constraints derived from ultra-high-resolution mass spectrometry (UHRMS). The algorithm estimates plausible surrogate compositions for FPBO, solid and liquid PL (BTG), and column-chromatography sub-fractions of PL by minimising the deviation between simulated and experimental spectra under physically consistent constraints. Preliminary results show that the approach reproduces key spectral features of FPBO and PL and yields chemically reasonable compositions for their heavy fractions. These estimated compositions, together with the expanding LigninOMICS database and Aspen-based property predictions, open the way to rigorous liquid–liquid equilibrium modelling (e.g. UNIFAC-Dortmund) and to a more mechanistic understanding of fractionation and upgrading strategies for lignin-derived bio-oils.



Pyrolysis-Driven Combustion of Polylactic Acid in Hybrid Aerospace Propulsion

Barbara Apicella (Consiglio Nazionale delle Ricerche, Italy) Francesca Cerciello (Consiglio Nazionale delle Ricerche, Italy) Tommaso de Angelis (Space Frontier, Italy) Giovanna Gargiulo (Consiglio Nazionale delle Ricerche, Italy) Francesco Saverio Marra (Consiglio Nazionale delle Ricerche, Italy) Francesco Renzulli (Space Frontier, Italy) Carmela Russo (Consiglio Nazionale delle Ricerche, Italy) Osvalda Senneca (Consiglio nazionale delle Ricerche, Italy) Mariano Sirignano (Università degli Studi di Napoli Federico II, Italy)

11:00-12:20 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

Pyrolysis is a central process in thermal conversion technologies and plays a governing role in solid-fuel aerospace propulsion systems. In both solid and hybrid rocket motors, pyrolysis constitutes the primary mechanism by which condensed-phase materials are transformed into gaseous species that sustain gas-phase combustion. The characteristics of pyrolysis—namely decomposition pathways, kinetics, and product distribution—directly affect fuel regression rates, flame structure, and combustion efficiency. For this reason, a detailed thermo-chemical characterization of solid fuels, with specific focus on pyrolysis phenomena, is essential for the development of advanced propulsion concepts. In hybrid rocket propulsion, the coupling between heat feedback from the flame and pyrolysis at the solid fuel surface controls the generation rate and composition of gaseous fuel species. Unlike conventional solid propellants, where oxidizer and fuel are premixed, hybrid systems rely entirely on pyrolysis-driven mass transfer from the solid phase to the reacting flow. Consequently, the efficiency and stability of hybrid combustion are intrinsically linked to the thermal degradation behavior of the solid fuel. Insufficient pyrolysis rates, unfavorable melting/decomposition windows or volatiles composition may result in reduced regression rates and incomplete combustion. Recent research has increasingly focused on the pyrolysis of non-traditional polymeric materials, including thermoplastics and bio-based polymers, as alternative solid fuels. These materials offer advantages in terms of processability, reduced toxicity, and compatibility with additive manufacturing, while also enabling more sustainable material sourcing. Polylactic acid (PLA) is a biodegradable thermoplastic polymer extensively used in additive manufacturing that has recently emerged as a candidate solid fuel for hybrid aerospace propulsion. Its molecular structure suggests a well-defined thermal response, making it a suitable model material for investigating the interplay between thermal transitions, pyrolysis onset, and volatile release. In this work, PLA is characterized through a combination of differential scanning calorimetry (DSC), thermogravimetric analysis (TG/DTG), and analytical pyrolysis coupled with gas chromatography–mass spectrometry (Py-GC/MS). DSC measurements were performed to identify thermal transitions such as melting behavior, and possible pre-decomposition phenomena, providing insight into the thermal stability and heat flow associated with structural changes in the polymer. TG/DTG analysis was used to determine mass loss profiles, decomposition onset temperatures, and apparent reaction rates under controlled heating conditions. Py-GC/MS enabled the identification and quantification of volatile and condensable species released during thermal degradation, offering detailed information on pyrolysis pathways and product distribution. The results indicate that PLA undergoes a reproducible pyrolytic decomposition over a relatively narrow temperature range, preceded by well-defined thermal transitions. The pyrolysis process yields a significant fraction of low-molecular-weight combustible species, including acetaldehyde, which are expected to play a key role in sustaining homogeneous combustion when adequately mixed with common hybrid rocket oxidizers. While these laboratory-scale experiments do not directly reproduce the complex thermo-fluid-dynamic conditions of an operating hybrid rocket motor, they represent essential input for pyrolysis-driven combustion modeling. Overall, this study emphasizes pyrolysis as the key link between material properties and combustion behavior, supporting the assessment of PLA as a solid fuel for hybrid propulsion systems governed by pyrolysis-controlled mass transfer.

High-Performance Biochar: Transforming Filler Technology in Plastics

Sophie Schönfeld (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany) Christopher Graf-Kick (Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany)

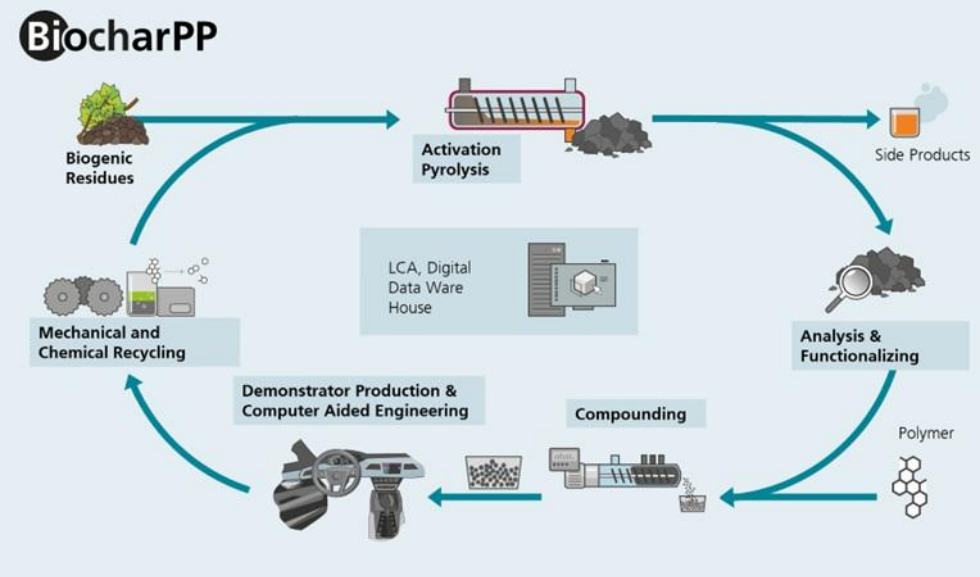
11:00-12:20 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

The plastics industry must adopt sustainable alternatives to conventional materials to reduce CO2 emissions, which reached 208 million tons in the EU in 2018. Biochar presents a promising filler material with negative greenhouse potential, significantly improving the CO2 balance of polymers like polypropylene (PP). The biocharPP project focuses on developing CO2-optimized compounds using biochar, addressing functionalization, processing, and ecological and as well as technical evaluation. Critical challenges include optimizing biochar surface properties, ensuring compatibility with polymers while at the same time, and scaling the technology from TRL 2-3 to industrial levels. Fraunhofer UMSICHT evaluated various feedstocks for its suitability to produce high-quality biochar, including walnut shells, wine pruning, waste wood, and green waste, For this, through an advanced pyrolytic conversion process using thermochemical conversioncalled the thermo-chemical reforming (TCR)-technology was used. Elemental composition, pH, porosity, and thermogravimetric behavior of the produced biochar were analyzed to assess suitability as fillers. An integrated, scalable activation module was developed to optimize biochar properties for PP applications. Activation trials were conducted in a 1.5 L model reactor simulating pilot plant flow conditions, with plans to transfer findings to a pilot plant capable of processing 30 kg/h of biochar. The objective was to achieve maximum activation effects under mild reaction conditions to ensure a cost-efficient process. For this purpose steam and CO2 introduction in the pyrolysis process were tested in several steps. Results show that all activation methods increase the BET surface area, enhancing biochar performance. A 100°C temperature increase nearly tripled surface area, while using CO2 as a mild oxidizing agent further increased surface area by 50% under identical conditions. Doubling CO2 input from 1.5 to 3 kg did not significantly affect the surface area but slightly improved the water holding capacity by altering the surface chemistry of the biochar material. Both steam and CO2 activation were included in the pyrolysis pilot plants at Fraunhofer UMSICHT allowing the production of surface optimized biochars within one process. The respective chars were tested in polypropylene compounds as filler material and could be introduced up to 30 Ma% resulting in competable biochar-polypropylene composit materials.



Model for Cellulose Pyrolysis Combining Kinetic Monte Carlo Simulation and Vapor-Liquid Equilibrium.

Sruthy Vattaparambil Sudharsan (Luleå. University of Technology, Luleå, Sweden, Sweden) Nils Erland L Haugen (Luleå. University of Technology, Luleå, Sweden, INTEF Energy Research, Trondheim, , Norway) Xiaolei Zhang (University of Strathclyde, Glasgow, UK, UK) Kentaro Umeki (Luleå. University of Technology, Luleå, Sweden, Sweden)

11:00-12:20 Session S4.1: Applied pyrolysis: other; biomass valorisation

Location: ROOM A – GROUND FLOOR

Chairs: Paola Giudicianni (Institute of Science and Technologies for Sustainable Energy and Mobility (STEMS) - CNR, Italy) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

ABSTRACT

Cellulose is a major structural component of biomass, and developing a reliable cellulose pyrolysis model is essential for advancing high-value product extraction. The degradation behavior of cellulose is influenced by its crystal structure, initial degree of polymerization (DP), and vaporization dynamics of degradation products. The bio-CPD model [1], a biomass-extended version of the chemical percolation devolatilization model, describes biomass as a three-dimensional macromolecular network, where monomer units are connected by breakable crosslinks, solving the kinetics of their breakage, molecular size distribution via lattice statistics, and bio-oil release via vapor-liquid equilibrium. While the bio-CPD model is one of the most advanced and reliable models currently available for describing biomass pyrolysis, it has key limitations when applied to cellulose. The assumption of a three-dimensional crosslinked network is not completely consistent with individual cellulose chain which has a one-dimensional linear structure, where the chain degradation is dominated by chain scission rather than network percolation. In addition, it does not explicitly account for the DP, which influences cellulose degradation behavior. The vapor-liquid equilibrium formulation is based on coal-derived compounds and does not accurately represent the volatilization dynamics of oxygen-rich pyrolysis products [2]. Finally, it lacks mechanisms to predict or optimize the formation of specific targeted products. This study proposes a new approach to model pyrolysis kinetics of cellulose, addressing the above issues. Specifically, we focused on the investigation on the effect of DP and improved vapor-liquid equilibrium formulations.

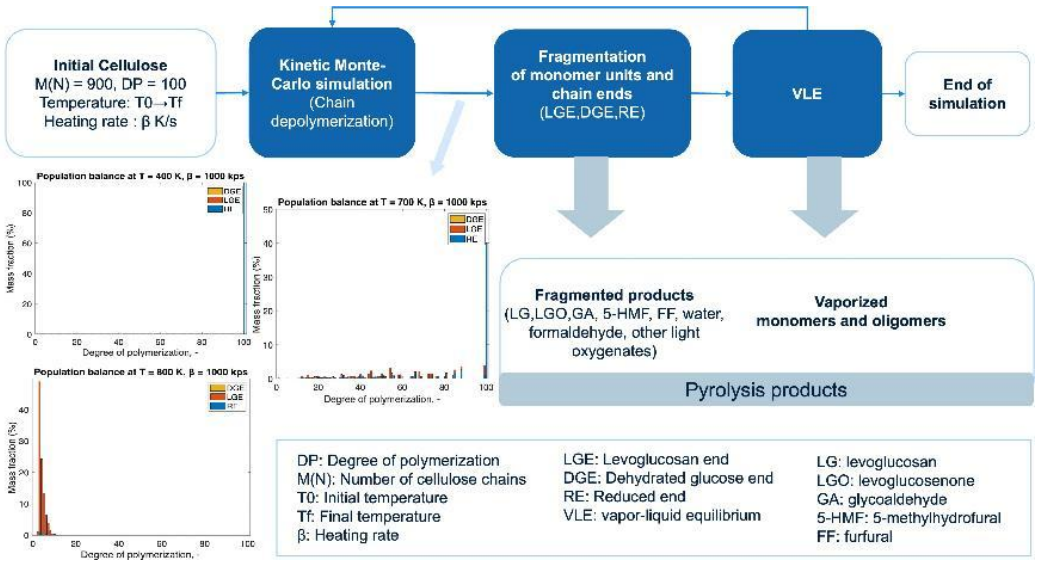


Figure 1: Scheme of the model

Cellulose depolymerization is modeled through detailed mechanistic pathways, including transglycosylation, dehydration, and hydrolysis reactions that generate characteristic reducing, levoglucosan, and dehydrated glucose chain ends. Density functional theory (DFT) derived kinetic parameters are incorporated to capture the effects of DP and chain-end chemistry on β-1,4-glycosidic bond scission and subsequent fragmentation reactions which results in the formation of products such as levoglucosan, levoglucosenone, glycoaldehyde, furans, and other light oxygenates. A kinetic Monte Carlo simulation tracks the stochastic evolution of the population balance of cellulose chains, accounting for changes in DP and end-type distributions, and fragment formation under non-isothermal conditions. Additionally, we revise the vapor liquid equilibrium parameters to better represent the volatilization dynamics of cellulose-derived oxygenated species, including glucose, levoglucosan, dehydrated glucose, and their oligomers. The new parameters account for the distinct thermodynamic behavior of these species, as the current formulations based on coal-derived aromatic compounds are insufficient for cellulose derived feedstocks. The model was validated using available experimental data from the literature, resulting in a more mechanistically sound and predictive pyrolysis kinetic model

that can better describe cellulose decomposition. This work not only advances the modeling of cellulose pyrolysis but also provides insights that could be applied to improve thermochemical conversion processes and optimize the production of specific targeted products.

References [1] Lewis, A.D. and Fletcher, T.H., 2013. Prediction of sawdust pyrolysis yields from a flat-flame burner using the CPD model. Energy & Fuels, 27(2). [2] Oja, V. and Suuberg, E.M., 1999. Vapor pressures and enthalpies of sublimation of D-glucose, D-xylose, cellobiose, and levoglucosan. Journal of Chemical & Engineering Data, 44(1).

THERMOCHEMICAL CONVERSION OF DIGESTATE WASTE FOR HYDROGEN-RICH SYNGAS PRODUCTION USING TGA

Veronica Belandria (Institut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE)-CNRS UPR3021, Orléans, France, France) Stéphane Bostyn (Institut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE)-CNRS UPR3021, Orléans, France, France) Mariem Ben Bouabsa (Institut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE)-CNRS UPR3021, Orléans, France, France) Brahim Sarh (Institut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE)-CNRS UPR3021, Orléans, France, France) Toufik Boushaki (Institut de Combustion, Aérothermique, Réactivité, et Environnement (ICARE)-CNRS UPR3021, Orléans, France, France)

11:00-12:40 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels

Location: ROOM A1 – FIRST FLOOR

Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

In recent years, alternative thermochemical conversion processes for energy recovery from agricultural residues and digestate have been increasingly investigated [1]. Gasification of these by-products, instead of being discarded, incinerated or applied in agriculture, can be used to produce synthesis gas (syngas), mainly containing hydrogen and carbon monoxide, under partial oxidation conditions. On the basis of ongoing research [2, 3], experimental investigations were conducted using a thermogravimetric analyser (TGA) coupled with micro-gas chromatography (MicroGC) to investigate the suitability of using gasification process of digestates after anaerobic digestion (AD) of agricultural waste, in order to produce hydrogen-rich syngas. Two feedstocks were examined as fuels for gasification experiments: (i) raw digestates after AD of agricultural residues, and (ii) chars produced from digestate pyrolysis. Raw digestates were first pyrolyzed under nitrogen atmosphere at about 500° C by using a pre-heated autoclave and the resulting chars were subsequently gasified. A parametric study was conducted to evaluate the effect of varying selected gasification parameters on the overall process performance. The parameters considered were the heating rate, the gasification agent, the oxidant flow rate, the reaction temperature and the type of feedstock (e.g., raw digestate and char). Pyrolysis experiments were carried out under inert (N_2) conditions and gasification tests were performed under oxygen-enriched (O_2/N_2) or CO_2 atmospheres. The main indicators of the gasification process were determined at oxygen to fuel ratios from 0.1 to 0.5. Product distributions were quantified in terms of solid residues (char and ash), liquid condensates (tar), and gaseous products. The syngas composition was analysed both qualitatively and quantitatively. The main gaseous components identified were CO, CO_2, CH4, and H_2, which were released sequentially during the pyrolysis–gasification process. The syngas obtained by air gasification of digestates in the temperature range of 40–800 °C, and after a 30 min isothermal step, contained up to 29.9% H_2 and up to 30.1% CO, with H_2/CO molar ratios between 0.7 and 1.0. The corresponding lower heating value ranged from 6.2 to 7.5 MJ/m3. In addition, char gasification experiments were performed under CO_2/N_2 mixtures containing 10–90% CO_2 at temperatures of 850, 900, and 950 °C. The influence of CO_2 concentration and temperature on char reactivity and syngas composition will be discussed and some examples will illustrate the results.

[1] M. H. Aissaoui, J. Hertzog, C. Sambusiti, P. Gauthier-Maradei, M.-N. Pons, V. Carré, Y. Le Brech, A. Dufour. J. Anal. Appl. Pyrolysis, 2025, 186, pp.106928. [2] D. Sangaré, S. Bostyn, M. Moscosa-Santillan, V. Belandria, I., P. García-Alamilla, I. Gökalp. Bioresour. Technol. 2022, 346, pp.126598. [3] D. Sangaré, V. Belandria, S. Bostyn, M. Moscosa-Santillan, I. Gökalp. Biomass Conv. Bioref., 2024, 14, pp. 9763–9775.

Advanced molecular elucidation of biogenic contributions from pyrolysis bio-oil co-processed in conventional refining: a viable and sustainable pathway for the energy transition.

Raquel Vieira Santana da Silva (Federal University of Rio de Janeiro, Brazil) Andrea Rezende Pinho (PETROBRAS, Brazil) Débora Almeida Azevedo (Federal University of Rio de Janeiro, Brazil)

11:00-12:40 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

The insertion of biogenic raw materials into conventional refineries is a promising option to increasing the green carbon content of traditional fuels and products. Co-processing low carbon footprint bio-oils with petroleum derivatives can be a faster way to decrease greenhouse gases emissions through small modifications in the oil refining existing infrastructure. However, the influence of bio-oil inclusion in the typical processes of conventional oil refineries is still understudied. This work aimed to perform individual chemical structural elucidation via comprehensive two-dimensional gas chromatography coupled to time-of-flight mass spectrometry (GC×GC-TOFMS) of liquid products from wood pyrolysis bio-oils (BO) co-processed with vacuum residue (VR) in two units: the delayed coking process and the pentane solvent deasphalting process. Effluents from delayed coking were obtained using three batch loadings: (A) 100% VR, (B) 95% VR and 5 % BO; and (C) 90% VR and 10 % BO. The effluents were then distilled, and three cuts were obtained: naphtha (up to 150 °C), light gasoil (150-380 °C), and heavy gasoil (+380 °C). The solvent deasphalting process was made by liquid-liquid extraction of BO and VR blend (1:1) with pentane at 65 ◦C and 200 psi, and two fractions were produced: deasphalted oil and asphaltic residue. Using GC×GC-TOFMS, an advanced analytical tool, it was possible to identify at the molecular level the contribution of bio-oil in different traditional fossil streams. The biomass-derived carbon inclusion in the delayed coking batch promoted the reduction of alkane, olefin, and alkyl-thiophene concentrations in the effluents. Biogenic C1-alkyl-cyclopentenones (42.7 µg g-1) and C1-C3 alkyl-cyclopentenones (392.3 µg g-1) were detected in effluents B and C, respectively. These cyclic ketones from BO can be a good additive for fossil fuels, due to their high resistance to auto-ignition characteristics. After distillation, a greater BO contribution was observed in light gasoils. The pentane solvent deasphalting process extracts mainly the apolar compounds as aliphatic and aromatic hydrocarbons, whereas the mid-polar to polar ones are partitioned in both phases, with the low molecular mass polar compounds observed in a greater proportion in deasphalted oil. Thus, coprocessing BO with the VR inserted renewable molecules in the deasphalting fraction, which aims to recover lower molecular-weight fractions that can be used to produce valuable byproducts. Deasphalted oil containing green (or biogenic) carbon can be readily co-processed in FCC units, whereas the presence of renewable molecules in the asphaltic residue demonstrated an improvement in bioasphalt stability compared to petroleum asphalt cement. Thus, co-processing biomass-derived carbon in conventional oil refining steps increases the green carbon content and represents a viable pathway for a sustainable energy transition.

Nanoscale Mixing of Cellulose and Lignin Alters Their Pyrolysis Interactions and Derived Carbon Reactivity

Chamseddine Guizani (VTT, Finland) Antti Paajanen (VTT, Finland) Jukka Vaari (VTT, Finland) Michael Hummel (Aalto University, Finland)

11:00-12:40 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

There is currently no definitive consensus on whether lignocellulosic biopolymers interact during pyrolysis, with the literature presenting contradictory conclusions. In this study, we show that these discrepancies largely stem from differences in experimental design—particularly the degree of mixing between cellulose and lignin. We demonstrate that the spatial scale of mixing—macroscale versus nanoscale—fundamentally alters the observed interactions between cellulose and lignin during slow pyrolysis within the heating rate range of 2.5–40 °C/min. Macroscale mixtures, prepared as physical blends of regenerated cellulose II fibres and Organosolv beech lignin (OSBL) particles, undergo pyrolysis independently, with no significant interactions detected in thermogravimetric measurements. In contrast, nanoscale mixtures—produced through the regeneration of hybrid fibres containing nanoscale co-localized cellulose II and OSBL—exhibit clear evidence of interactions between the two components. These interactions manifest in altered mass loss dynamics and evolved gas profiles, indicating that the pyrolysis pathways of each biopolymer are influenced by their proximity at the nanoscale. Notably, while OSBL alone undergoes softening and extensive foaming during pyrolysis, this behaviour is entirely suppressed in the nanoscale mixture, suggesting that thermal softening and gas-driven expansion are inhibited by confinement within the cellulosic matrix. This suppression points to a reduction in lignin's mobility when restricted between cellulose domains. Molecular simulations on lignin dynamics under confinement support this interpretation. Additionally, the reactivity of carbonized OSBL toward CO_2 is significantly enhanced when lignin is confined within nanoscale domains in the hybrid cellulose-lignin fibres. This finding suggests that nanoscale confinement not only affects the pyrolytic transformation of lignin but also modifies the structure and accessibility of the resulting carbon composite materials. Collectively, these results underscore the importance of considering the morphological scale when evaluating biopolymer interactions during thermochemical conversion. Additionally, they prompt a re-evaluation of how synergistic effects are understood—particularly in naturally occurring composite systems such as wood, where cellulose and lignin are inherently mixed at the nanoscale, unlike the macroscale physical blends commonly used in experimental studies.

Study on biocarbon produced from untreated and water leached bark

Liang Wang (SINTEF Energy Research, Norway) Jørn Bakken (SINTEF Energy Research, Norway) Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Yusuf Tolunay Kili (Luleå University of Technology, Sweden) Øyvind Skreiberg (SINTEF Energy Research, Norway) Bence Babinszki (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary) Robert Johnson (Hawaii Natural Energy Institute, University of Hawaii at Mānoa, United States) Kentaro Umeki (Luleå University of Technology, Sweden) Scott Q Turn (Hawaii Natural Energy Institute, University of Hawaii at Mānoa, United States)

11:00-12:40 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

Decarbonizing metal production is a critical industrial challenge that necessitates a swift transition from fossil fuels to sustainable alternatives. Biocarbon holds immense potential to reduce the sector's carbon footprint; however, its success depends on expanding and diversifying biomass sourcing to meet high industrial demand. Bark, a high-volume waste stream from the forestry industry, is a promising candidate for biochar production. Nevertheless, bark often contains high ash content which, when retained in the biochar, is undesirable for metallurgical processes. In this study, water leaching was investigated as a method to reduce inorganic elements in pine, spruce, and birch bark. Biocarbons were produced from both untreated and leached barks and subsequently characterized using a suite of analytical techniques. Chemical composition analysis results indicated that biocarbons from water-leached barks possessed lower ash content, though they also exhibited slightly lower carbon content compared to untreated counterparts. Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) confirmed that concentrations of both total and individual inorganic elements were considerably lower in the leached samples. X-ray diffraction (XRD) identified calcium carbonate as the primary mineral phase in all samples. However, peak intensities for calcium carbonate were significantly reduced in biocarbons derived from leached bark. Scanning Electron Microscopy coupled with Energy-Dispersive X-ray Spectroscopy (SEM-EDS) revealed that calcium-rich grains, prominent on the surface of untreated bark biocarbon, were rarely visible after leaching. Furthermore, leached biocarbons exhibited a coarser surface and a more open structure, suggesting that water leaching alters the physical matrix of the parental bark. Gasification reactivity was investigated using a Macro-TGA at 1100 °C in a CO2/CO gas mixture, simulating the conditions of an industrial closed submerged arc manganese alloy furnace. The Macro-TGA experiments demonstrated that biocarbons produced from leached barks had considerably lower reactivity than those from untreated barks. Post-test analysis of the conversion residues via SEM-EDS revealed significant differences; residues from untreated biocarbons contained substantial calcium-rich grains and aggregates. The presence of these inorganic elements catalyzes the gasification of the carbon matrix, thereby increasing carbon consumption. These findings suggest that water leaching is an effective pretreatment for producing high-quality, low reactivity biocarbon suitable for metallurgical applications.

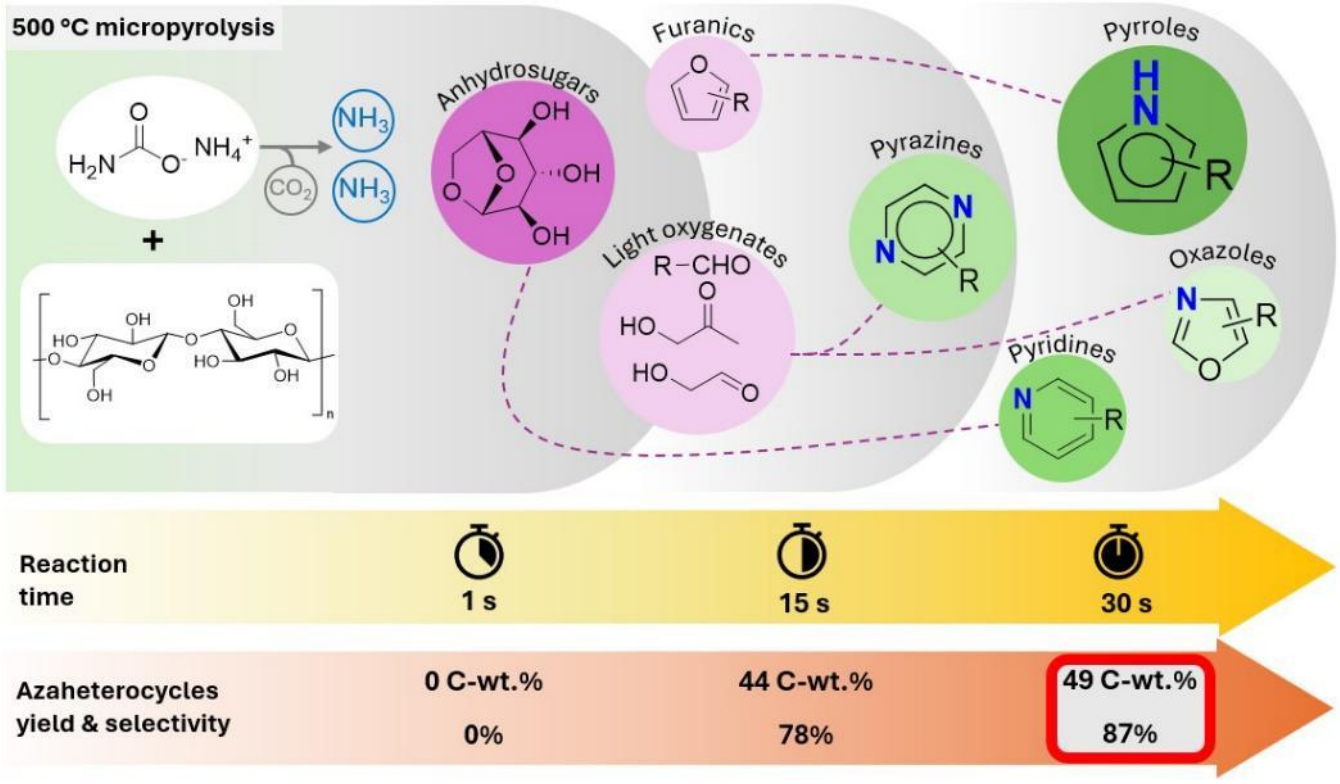
Conversion of cellulose into azaheterocycles through pyrolysis under a reactive NH3 atmosphere

Elisa Kooy (Universiteit Gent, Belgium) Sven Mangelinckx (Universiteit Gent, Belgium) Frederik Ronsse (Universiteit Gent, Belgium) Stef Ghysels (Universiteit Gent, Belgium)

11:00-12:40 Session S4.2: Applied pyrolysis: Biomass valorisation; Fossil fuels
Location: ROOM A1 – FIRST FLOOR
Chairs: Marion Carrier (CNRS, France) Joan J. Manyà (Universidad de Zaragoza, Spain)

ABSTRACT

Azaheterocycles are essential building blocks for high-value chemicals, traditionally derived from fossil fuel intermediates. This study fundamentally investigates the production of these compounds from cellulose as renewable resource, by means of fast pyrolysis at a micro-scale under a NH3-rich atmosphere. Herein is demonstrated for the first time a strategy to perform micropyrolysis under a NH3 atmosphere, while controlling the reaction time between cellulose's pyrolysis products and NH3. This is achieved by using urea and ammonium carbamate as NH3 precursors within a specific on-line micro reaction sampler for micropyrolysis . Micropyrolysis experiments were conducted at 500 °C to elucidate the importance of N-source and determine the influence of nitrogen-to-biomass ratios and reaction time on product distribution. Under optimized conditions (30 s reaction time, nitrogen-to-biomass ratio of 10:1), a remarkable yield in azaheterocycles of 49 C-wt.% was achieved with a total azaheterocycle selectivity of 87%. The main contributor was pyrrole with a selectivity of 31%. Mechanistic pathways were elucidated by reacting key cellulose-derived intermediates (cellobiose, levoglucosan, glycolaldehyde and acetol) with ammonium carbamate. The results demonstrate three competing pathways: pyrroles are predominantly formed via furanic intermediates, while pyrazines and oxazoles originate from light oxygenates and pyridines were found to be associated with anhydrosugars. These findings suggest that the NH3 release mechanism and vapor-phase residence time are critical in governing nitrogen-incorporation pathways, establishing ammonium carbamate as an effective additive for the selective synthesis of bio-based azaheterocycles.



Multi-phase kinetic modeling of LDPE pyrolysis: From condensed-phase degradation to secondary gas-phase reactions

Ke Wu (Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Andrea Locaspi (Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Alessio Frassoldati (Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Cato Pappijn (Dow Benelux B.V., Hoek, The Netherlands, Netherlands) Bruno da Costa Magalhaes (Dow Benelux B.V., Hoek, The Netherlands, Netherlands) Melissa Dunkle (Dow Benelux B.V., Hoek, The Netherlands, Italy) Georgios Bellos (Dow Benelux B.V., Hoek, The Netherlands, Netherlands) Tiziano Faravelli (Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy)

11:00-12:40 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

From a circular economy perspective, polyolefin-rich plastic waste represents an important source of valuable chemicals and energy carriers. Thermochemical routes such as pyrolysis can valorize these heterogeneous feedstocks. To enable predictive reactor-scale modeling, a consistent kinetic description is needed to link condensed-phase polymer degradation with the subsequent gas-phase evolution of released volatiles. In this work, we develop a multi-phase kinetic framework for low-density polyethylene (LDPE) pyrolysis, in which condensed-phase and gas-phase chemistries are represented by semi-detailed CHEMKIN mechanisms and simulated in OpenSMOKE++ (Cuoci et al., 2015). In the gas-phase mechanism, heavy fractions are treated via established lumping/surrogate representations (e.g., diesel-cut and wax representatives), while light products follow the CRECK semi-detailed description with updated light-olefin pathways based on recent speciation evidence (Locaspi et al., 2025).

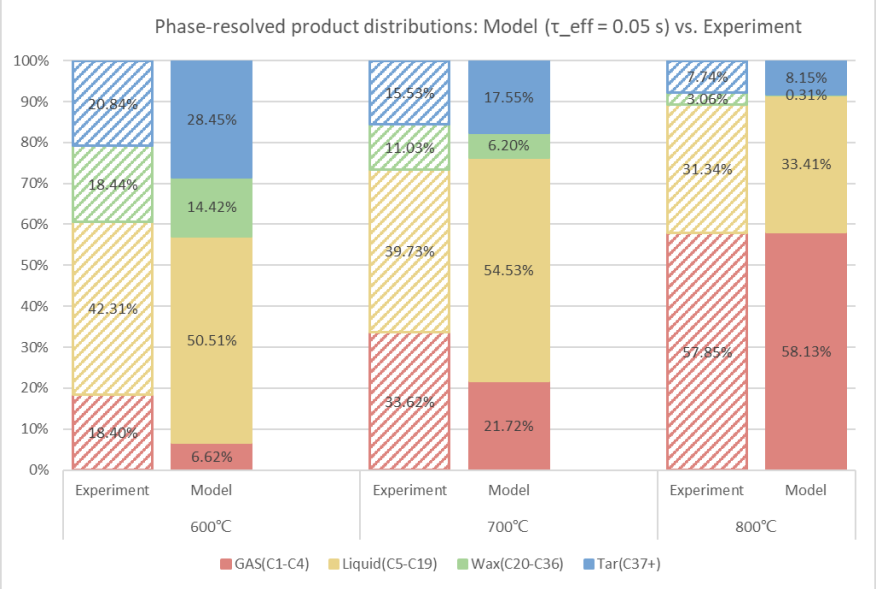


Figure 1. Phase-resolved product distributions for LDPE pyrolysis at 600,700 , and 800 °C: Comparison between experiment and model predictions.

Motivated by literature evidence that, once decomposition begins, polyethylene (PE) exhibits an endothermically buffered temperature plateau, with the particle-surface temperature stabilizing around 480–550 °C (Nakhaei et al., 2018), a two-stage modeling strategy is adopted. In Stage 1, a condensed-phase LDPE pyrolysis model provides the composition of the released volatiles, which is used to define the inlet mixture for Stage 2. In Stage 2, the released volatiles are simulated in a gas-phase plug-flow reactor (PFR) to describe secondary cracking, with the effective residence time (τ_eff) identified by iterative matching of the aromatic fraction, resulting in two candidate values. This simplified representation captures the measured phase split and its temperature trends across the investigated temperature range. Within this framework, the gas-phase stage is used to evaluate product-class distributions under different gas-phase temperatures and two candidate values of τ_eff. Product classes are evaluated using both PIONA (Paraffins/Iso-paraffins/Olefins/Naphthenes/Aromatics) and carbon number ranges (Gas: C1-C4; Liquid: C5-C19; Wax: C20-C36; Tar: C37+). The framework is assessed by comparing simulated class distributions against flash pyrolysis experimental data reported in de Korte et al. (2025). The model reproduces the phase-split trends with temperature and

matches the 800 °C distribution closely; deviations at 600–700 °C are primarily associated with the gas–liquid split, highlighting the role of τ_eff in secondary cracking.

Key references Cuoci, A. et al. "OpenSMOKE++: An object-oriented framework for the numerical modeling of reactive systems with detailed kinetic mechanisms", Computer Physics Communications 192 (2015) 237–264. DOI: 10.1016/j.cpc.2015.02.014 Locaspi, Andrea et al. "A semi-detailed pyrolytic gas-phase kinetic model for the volatiles of polyethylene thermal degradation", Proceedings of the Combustion Institute 41 (2025) 105912. DOI: 10.1016/j.proci.2025.105912 Nakhaei, M. et al. "Experiments and modeling of single plastic particle conversion in suspension", Fuel Processing Technology 178 (2018) 213–225. DOI: 10.1016/j.fuproc.2018.05.012 de Korte, R. J.et al. "Plastics pyrolysis: The impact of pyrolysis temperature on ethylene production and direct carbon dioxide footprint", Fuel Processing Technology, 267 (2025), 108148. DOI:10.1016/j.fuproc.2024.108148

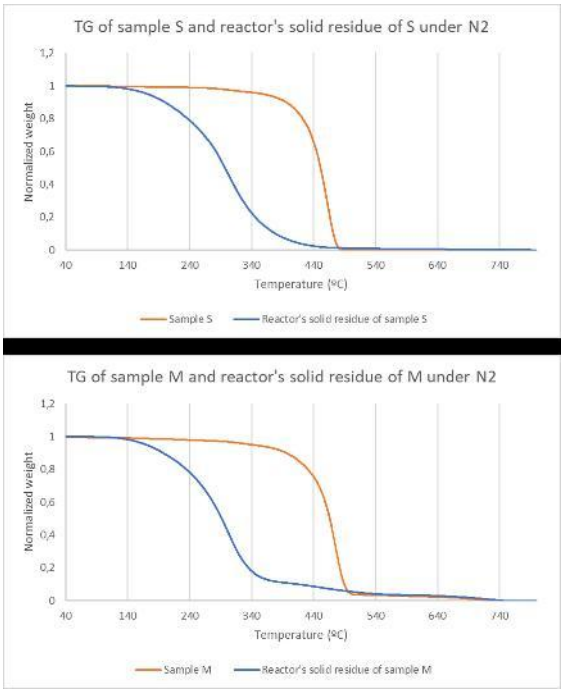
Chemical recycling of biaxially oriented PP (BOPP) films

Maria Teresa Nogueira (CERENA/IST, Portugal) Ana C. Marques (CERENA/IST, Portugal) Francisco Lemos (CERENA/IST, Portugal) M. Amélia Lemos (CERENA/IST, Portugal)

11:00-12:40 Session S4.4: Applied pyrolysis: Polymers and recycling
Location: ROOM B – GROUND FLOOR
Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

Plastic waste includes diverse materials, ranging from single-resin plastics with minimal additives to complex multilayered composites like biaxially oriented polypropylene (BOPP). BOPP has excellent barrier and durability properties. However, because of its multi-layered composition, it poses significant environmental challenges due to the difficulties in its mechanical recycling and is often marked as “to be discarded”. Advanced recycling techniques, such as chemical recycling through pyrolysis, show promise in effectively processing these materials back into reusable raw materials, addressing the limitations of traditional recycling approaches, and reducing environmental impact. [1,2] Pyrolysis has emerged as a promising route for recycling complex plastic waste streams. This study researches the use of pyrolysis as a chemical recycling method for two commercially used BOPP samples, designated M and S, employing a hybrid reactive distillation lab-scale reactor. [3] The decomposition of this material was studied by thermogravimetric analysis with simultaneous differential scanning calorimetry under nitrogen, in the range of 40 to 800°C. Maximum degradation temperatures of 463 and 464°C were observed for samples M and S, respectively. These temperatures are consistent with the expected composition of the material, mainly polypropylene. Lab-scale pyrolysis experiments were conducted using sample masses between 4 and 8g. The reactions were carried out in a Schlenk-type glass vessel of around 0.1L under nitrogen. The temperature was set to rise from 20 to 500°C, after which it was held constant at 500°C for 90 minutes to complete the thermal degradation process. [4] During the pyrolysis process in the hybrid reactive distillation lab-scale reactor, both BOPP samples yielded approximately 36 % solid residue, with the remaining fraction consisting of gaseous and liquid hydrocarbons. The gas phase primarily contained hydrocarbons in the C2 to C6 range, while about 80% of the liquid phase comprised hydrocarbons between C5 and C10 for both samples. The solid residue of the reactor contained 81-87% of volatile matter (figure). These results highlight pyrolysis as a promising technique for the chemical recycling of BOPP plastics. Furthermore, thermogravimetric analysis of mixtures containing BOPP and simpler polyolefins such as HDPE, LDPE, and PP has yielded promising results. Ongoing experiments in the reactor are being carried out to further assess the co-pyrolysis performance and validate these findings.



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High Temperature Vortex Pyrolysis of Polyethylene for Ultra High Light Olefin Yields

Hamidreza Khakpour (Laboratory for Chemical Technology (LCT), Belgium) Yihan Wang (Laboratory for Chemical Technology (LCT), Belgium) Parviz Yazdani (Laboratory for Chemical Technology (LCT), Belgium) Robin John Varghese (Laboratory for Chemical Technology (LCT), Belgium) Yi Ouyang (Laboratory for Chemical Technology (LCT), Belgium) Kevin Van Geem (Laboratory for Chemical Technology (LCT), Belgium)

11:00-12:40 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

Introduction: Plastic waste management is a crucial component of global sustainability initiatives, and the circular plastics economy promotes recycling. Pyrolysis can be a promising thermochemical process that recycles plastic waste into valuable products, such as fuel and chemical feedstocks [1]. Polyethylene pyrolysis is controlled by millisecond-scale intrinsic cracking kinetics, but conventional reactors often suffer from poor heat and mass transfer, resulting in temperature and concentration gradients. This extends effective residence time, promoting unselective conversion and secondary reactions that form aromatics and coke [2]. Pyrolysis in a vortex reactor (VR), which is built at LCT UGENT, provides intense gas–melt contact, very short residence times, and a narrow residence time distribution at high temperatures. Here, we evaluate a VR for the pyrolysis of polyethylene and quantify how operating conditions (temperature, sweep flow, and residence time) affect light olefin and pyrolysis oil selectivity. Experimental Details: The experiments were conducted in a pilot-scale vortex reactor (Figure 1).

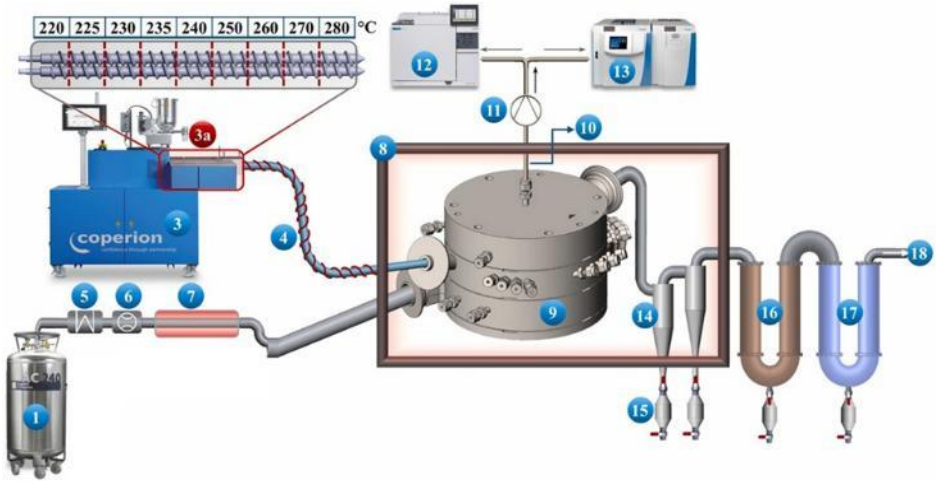


Figure 1. Schematic of pilot-scale vortex reactor setup [2]

Polyethylene (PE) pellets with a density of 0.91 g/cm³ (from Total Energies) were continuously fed into the reactor at a rate of 1 kg/h via a twin-screw extruder. The melted PE was transferred through a melt pipe and injected into the reactor. Nitrogen, provided at a rate of 7 m³/h, served as the carrier gas and helped maintain a uniform reactor temperature of 600, 650, 700, 750, and 800 °C. A mixture of Nitrogen and melted plastic was introduced tangentially into the 79 ml vortex chamber through 12 inclined slots to establish a strong vortex flow. The reactor and downstream cyclones were housed in a furnace to maintain the desired temperature. Pyrolysis products exited through a central exhaust and passed through heated cyclones, followed by two condensers for char and condensable collection, while non-condensable gases were flared. Temperature and pressure were monitored using thermocouples and pressure sensors. The product stream from the sampling line at the top of the reactor is quantified using online refinery gas analysis (RGA) and two-dimensional gas chromatography (GC×GC). Yields are reported as weight percent of fed PE. Results and discussion: As expected, C2-C4 light olefins yield significantly increased with temperature (600, 650, 700 ℃) from 4.5 wt.%, 26 wt.%, and 44 wt.%, and reaching values substantially above 50 wt. % above 750°C. Ethylene and propylene yields contributed significantly to the increase in valuable products. The temperature-driven selectivity shift could be attributed to the established radical-cracking families for PE: initial random C–C scission and intramolecular H-abstraction (backbiting) generate secondary radicals that undergo β-scission to form light olefins. The VR's short residence times, combined with rapid heat and mass transfer, limit slower secondary condensation/aromatization while permitting limited secondary cracking that further enriches C2-C4 light olefins. The carbon number distribution also highlights the kinetic dominance of end-chain β-scission and radical backbiting, which are thermally accelerated at elevated temperatures. Overall, coupling high-temperature with narrow residence-time distributions enhances light-olefin selectivity.

References: [1] Costa et al., J. Anal. Appl. Pyrolysis 191, 107168 (2025). [2] Goshayeshi et al., J. Anal. Appl. Pyrolysis 187, 107016 (2025).

Heteroatom Transfer and Product Composition of Plastic Waste Pyrolysis

Fatma Calik Ulu (Ghent University, Belgium) Mackenzie Denton (Ghent University, Belgium) Robin John Varghese (Ghent University, Belgium) Maarten Sabbe (Ghent University, Belgium) Kevin Van Geem (Ghent University, Belgium)

11:00-12:40 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

Global plastic waste generation continued its long-term upward trend, reaching an estimated 225 million tons in 20251. Among waste management technologies, pyrolysis is a viable chemical recycling route that converts plastic waste into valuable hydrocarbon fractions. However, post-consumer plastic waste is inherently heterogeneous, and compositional variability leads to the formation of oxygenated, nitrogenated, and chlorinated products during thermochemical conversion, which may limit the direct use of pyrolysis oils as steam cracker feedstocks2. Comprehensive characterization of pyrolysis products is necessary to assess the suitability of pyrolysis oil as a steam cracker feedstock, enabling closed-loop plastics circularity. In this study, three post-consumer plastic waste streams (PW1-PW3) were initially analyzed using FTIR, ICP-OES, and CIC to evaluate feedstock composition and heteroatom content. These polyolefin-rich waste mixtures contained heteroatom-containing plastics and additives, yielding measurable quantities of oxygen, nitrogen, metals, and halogens in the elemental profile. The thermal decomposition of three mixtures was investigated using a micropyrolysis unit coupled to an inline analytical section at 450 ℃ and 600 ℃. Product vapors were analyzed using comprehensive two-dimensional gas chromatography (GC×GC) with time-of-flight mass spectrometry (TOF-MS) for compound identification and a flame ionization detector (FID) for quantification. Pyrolysis products were classified into major hydrocarbon families, including paraffins, olefins, naphthenes, aromatics, as well as oxygenates and nitrogenates. The PIONA distribution exhibited a strong dependence on feedstock composition (Figure 1) and pyrolysis temperature. Across all feedstocks, the products were predominantly olefinic, comprising both linear and branched species. At 450 °C, the product distribution was dominated by heavier hydrocarbons (C21–C60), reflecting limited thermal cracking under mild conditions. Increasing the temperature to 600 ℃ significantly suppressed the formation of heavy wax fractions (C21+) while maximizing overall volatilization, primarily due to intensified secondary cracking and higher conversions. For PW1 and PW2, which contained substantial polypropylene fraction, characteristic PP derived fingerprints were observed, particularly the strong presence of branched C_9 olefins (Figure 1b, c), formed via β-scission of tertiary polypropylene radicals. PW3 exhibited distinctly different behavior due to its higher PET content, characterized by elevated levels of oxygenated pyrolysis products, including benzoic acid. The increased aromatic fraction in PW3 is consistent with PET's aromatic backbone via the ester bond cleavage decomposition pathway, followed by decarboxylation and secondary aromatization reactions. Here, the formation of caprolactam, benzoic acid, and related derivatives confirmed the transfer of heteroatom-bearing contaminants originating from non-polyolefin plastics within the feed. By linking feedstock composition and temperature to PIONA distribution of pyrolysis products, the study provides insights into contaminant transfer and underscores the importance of detailed compositional analysis for integration into downstream chemical recycling pathways.

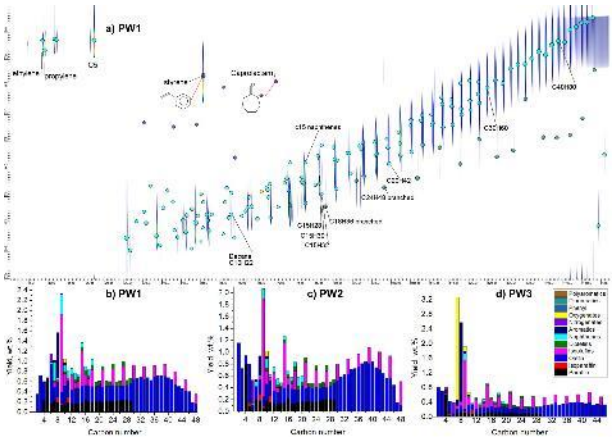


Figure 1. Two-dimensional GCxGC/FID/TOF-MS chromatogram of a)PW1 and PIONA distribution of the pyrolysis products, b)PW1, c)PW2, and d)PW3 at 450 °C.

References 1. Plastic Overshoot Day – Report 2025, EA-Earth Action, 2025. 2. M. Kusenberg, A. Eschenbacher, M.R. Djokic, A. Zayoud, K. Ragaert, S. De Meester, K.M. Van Geem, Opportunities and challenges for the application of post-consumer plastic waste pyrolysis oils as steam cracker feedstocks: To decontaminate or not to decontaminate?, Waste Manag 138 (2022) 83-115.

Co-pyrolysis of Polypropylene and asphalt waste: insights into synergistic effects and oil yield optimization

Youssef Ech'Chalh (Lorraine University, France) Raymond Michels (Lorraine University, France) Valérie Vitzthum (Lorraine University, France) Catherine Lorgeoux (Lorraine University, France)

11:00-12:40 Session S4.4: Applied pyrolysis: Polymers and recycling

Location: ROOM B – GROUND FLOOR

Chairs: Katarzyna Januszewicz (Gdańsk University of Technology, Poland) Osvalda Senneca (CNR, Italy)

ABSTRACT

Pyrolysis offers a promising route for valorizing plastic and bituminous waste within a circular economy framework. This study examines the pyrolysis of polypropylene (PP), road asphalt waste and their mixtures to evaluate potential chemical synergies and optimize liquid product yields. Experiments were carried out in a glass semi-batch reflux reactor under nitrogen, heating from ambient temperature to 500°C at 10°C.min^{-1}. Product characterization was performed using GC–MS/FID, μ-GC, and ^{1}H-NMR analyses. The addition of asphalt notably affected product yields, though the overall composition of the volatile fraction remained similar. Co-pyrolysis of PP with asphalt exhibited a clear synergistic effect, enhancing the oil yield by up to 6.3 ± 0.7 wt% at a PP/bitumen ratio of 2:1, compared with pure PP pyrolysis. This improvement is attributed to the stabilizing influence of bitumen, which mitigates catalytic degradation induced by mineral fraction. The resulting oils retained chemical characteristics comparable to PP-derived oils, with only minor changes in viscosity, confirming that asphalt incorporation does not compromise oil quality. These findings highlight the potential of PP/asphalt co-pyrolysis as an effective pathway for the simultaneous conversion of plastic and bituminous waste into valuable hydrocarbons, contributing to sustainable chemical recycling strategies

Operation and results of a pilot-plant carbon-moving-bed methane cracking reactor for the production of sustainable hydrogen and solid carbon

Alessio Riorda (Politecnico di Torino, Italy) Amr Sanad (Politecnico di Torino, Italy) Viviana Negro (Politecnico di Torino, Italy) Alessio Miniati (RE-CORD (Renewable Energy Consortium for R&D), Italy) Andrea Maria Rizzo (RE-CORD (Renewable Energy Consortium for R&D), Italy) David Chiaramonti (Politecnico di Torino, Italy)

11:20-12:20 Session S4.3: Catalytic pyrolysis; Applied pyrolysis: other

Location: ROOM C1 – FIRST FLOOR

Chairs: Benedetta de Caprariis (Sapienza Università di Roma, Italy) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

ABSTRACT

Catalytic methane cracking is a heterogeneous reaction in which the gaseous hydrocarbon is converted into hydrogen and solid carbon particles over a catalyst bed. The advantage of this process lies in the ability to obtain carbon in a solid state rather than as CO2, which greatly facilitates its separation and sequestration. Both metal and carbon-based catalysts can be used for this purpose, with the latter offering higher thermal stability, greater sulfur resistance, and lower cost, despite lower methane conversion. Various studies were carried out at lab-scale to analyze the process and identify the effects of different parameters on the reaction efficiency and deactivation behavior. However, the number of studies on higher-maturity plants is limited. As part of an European-funded project (H2STEEL), a 20 kg/h moving-bed methane cracking reactor (Proof Of Concept, POC) was designed to study the reaction over a carbon-based catalyst. The work presents the first results of pilot-plant tests carried out at atmospheric pressure and temperatures in the range of 800-900°C, in order to assess the technical viability of sustainable hydrogen production together with solid-state carbon by-products. Different operational conditions were analyzed to compare and validate the results with lab-scale tests. Due to the POC limitation of a maximum 2 Nm3/h gas capacity and bed volume of 3-6L, a GHSV in the range of 126 to 313 h-1 was used. Methane was diluted with nitrogen at volume percentages ranging from 10% to 50%. Two commercial activated catalysts, with specific surface areas of 700 and 1000 m2/g, were initially used to test the plant and establish a fossil-based benchmark for the following materials. To evaluate catalyst deactivation and compare it with the experimental curve, residence times of 10, 20, and 30 minutes were used. The tests showed promising results from a technical standpoint, confirming the plant's ability to carry out the reaction at the desired operational conditions, with methane conversion ranging from 92% to 62%. The conversion decreased with increasing GHSV, methane concentration, and catalyst residence time. This behavior is consistent with the results of the lab-scale analysis, conducted on a wide range of carbon-based materials.

Impact of Oxygen Content on the Storage Stability of Catalytic Fast Pyrolysis Oils: Insights from Pilot Scale Production

Tooran Khazraie (Valmet Technologies, Finland)

11:20-12:20 Session S4.3: Catalytic pyrolysis; Applied pyrolysis: other

Location: ROOM C1 – FIRST FLOOR

Chairs: Benedetta de Caprariis (Sapienza Università di Roma, Italy) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

ABSTRACT

Valmet's development of pyrolysis technology spans nearly two decades, beginning with the commercialization of a fast pyrolysis plant in Joensuu, Finland, in 2013. Building on this foundation, the company has intensified its focus on catalytic fast pyrolysis (CFP) to produce more refined, energy-dense, and stable bio oils suitable for advanced industrial applications. As part of this strategic shift, Valmet has comprehensively revamped its pilot facility in Tampere into a dedicated catalytic fast pyrolysis unit. Commissioned in 2023, the upgraded unit has since supported multiple test campaigns aimed at unit availability and performance, bio oil quality and production for downstream treatment. A key challenge for pyrolysis derived oils—particularly those originating from catalytic pathways—is their storage stability, which influences applicability in downstream upgrading, and logistics chains. In this study, we present results from recent CFP test campaigns conducted at Valmet's Tampere pilot plant. The analysis focuses on the storage stability of bio oils produced under varying operating conditions. The primary emphasis is on understanding how the oxygen content of the produced oils correlates with their stability during storage. Bio oils were monitored over defined storage periods, and stability was evaluated using parameters such as viscosity development, phase behavior, and chemical aging indicators. Preliminary results show distinct relationships between oxygen content and aging behavior, highlighting critical thresholds beyond which storage stability deteriorates more rapidly. Process conditions that effectively affect oxygenation were found to significantly improve oil robustness over time. The findings contribute to a broader understanding of how catalytic fast pyrolysis can be steered toward higher quality, more storage-durable bio oils. These insights support the continued development of scalable, reliable CFP technologies and strengthen Valmet's ongoing role in advancing thermochemical conversion processes for sustainable fuels and chemicals.

Influence of fluid bed operating conditions on waste pyrolysis products

Peter Arendt Jensen (DTU, Chemical Engineering, Denmark) Brian B. Hansen (DTU, Chemical Engineering, Denmark) Arooj Asif (University of Salento - Department of Engineering for Innovation, Italy) Giovanni Manente (University of Salento - Department of Engineering for Innovation, Italy) Giuseppe Mele (University of Salento - Department of Engineering for Innovation, Italy) Anker D. Jensen (DTU, Chemical Engineering, Denmark)

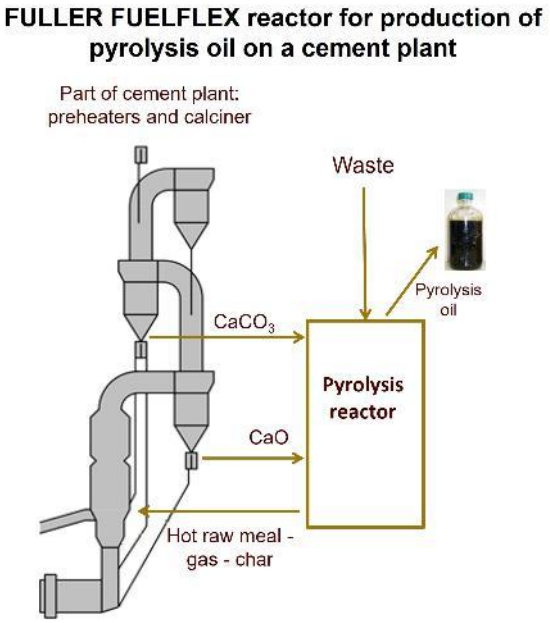
11:20-12:20 Session S4.3: Catalytic pyrolysis; Applied pyrolysis: other

Location: ROOM C1 – FIRST FLOOR

Chairs: Benedetta de Caprariis (Sapienza Università di Roma, Italy) Stylianos Stefanidis (Chemical Process and Energy Resources Institute, Centre for Research and Technology Hellas, Greece, Greece)

ABSTRACT

Integration of a waste pyrolysis unit at a cement plant can bring several advantages such as a decreased use of fossil fuel and the production of a liquid fuel product that can bring an extra revenue to the cement plant. In this study, laboratory fluid bed pyrolysis experiments of different waste types and applying a range of different operating conditions were conducted to investigate the influence on product yields and product liquid properties. The results obtained are important for the further industrial development of cement plant pyrolysis technology. Experiments were conducted on an electrically heated laboratory fluid bed reactor at a feeding rate of 0.35 kg/h using two waste types with different biomass contents and controlled fuel mixtures of wood and plastic. The investigated operating conditions included: Use of sand, cement raw meal and calcined cement raw meal as bed material; change of reactor temperature from 550 to 640℃, changes of freeboard residence time from 2 to 5 seconds and experiments with oxygen addition to simulate the extent of air ingress typically unavoidable in full scale plants. The optimal pyrolysis reactor temperature with respect to organic liquid yield for the waste samples were observed to be 550 to 570℃ where dry organic liquid yields of 44 to 49 wt. % were obtained. This optimal temperature is somewhat higher than typically observed value of 500 ℃ for biomass pyrolysis. At those conditions decreased liquid yield was observed for feeds with an increased biomass fraction. Increasing the temperature of the waste pyrolysis up to 640 ℃ led to a reduction in dry organic liquid yield down to 24 wt. %, an increased water and gas yield and also led to a large reduction in the dry oil oxygen content from 13 wt. % to 2 wt. %. Using calcined raw meal opposed to using sand as bed material led to a small decrease in the organic liquid yield and the liquid oxygen content. Reducing the freeboard gas residence time from 5 to 2 seconds only lead to a small reduction in gas yield and a small increase in oil oxygen content. Applying oxygen injection corresponding to λ = 0.1 led to a reduction in dry organic yield down to 22 wt. % and a reduction in oil TAN value. Selected oil samples were analyzed with respect to marine fuel relevant properties such as TAN, flash point and wax content. TAN analysis showed values from 25 to 80 mg KOH/g with oil produced at high temperatures, with calcined raw meal as bed material and with oxygen ingress applied leading to the lowest TAN values. Flash point values were mainly influenced by the waste type used, waste 1 (biomass lean) giving values from 38-47 ℃ and waste 2 (biomass rich) leading to values of 63-81℃. All oil samples had no visual wax content at 40℃ while samples produced at a pyrolysis temperature of 640 ℃ only showed traces of wax when cooled to 5℃ where wax appeared in all other samples.



Abstracts: Posters

Effects of phase separation and storage temperature in slow pyrolysis bio-oils: insights from a 145-days monitoring study

Davide Amato (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Paola Giudicianni (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Corinna Maria Grottola (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Maria Virginia Manna (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Giovanni Fabozzi (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy) Raffaele Ragucci (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Given its nature, bio-oil from lignocellulosic biomass pyrolysis is a promising source of both biofuels and biochemicals, even if it often needs further processing after its production. The high content of oxygenated species and the complex physical-chemical equilibrium of the whole bio-oil system makes the material unstable. During storage, bio-oil undergoes a series of chemical reactions that progressively alter its physical properties and chemical composition; this phenomenon is commonly referred to as bio-oil aging. Bio-oil obtained from slow pyrolysis, which is typically optimized for biochar production tailored to specific applications, has been far less investigated than bio-oil produced under fast pyrolysis conditions. Although bio-oil obtained under slow pyrolysis conditions has long been regarded as a low-value by-product, it has recently attracted increasing attention as a potential feedstock for the production of bio-based materials and, in some cases, for energy applications. Consequently, a proper understanding and assessment of its aging behavior during storage has become increasingly important. Slow pyrolysis bio-oil composition differs from fast pyrolysis bio-oil in terms of chemical species distribution and, in particular, it has a higher water content usually ranging between 40 and 60 %. The high water content of slow pyrolysis bio-oils can easily cause the phase separation of the whole bio-oil in an aqueous and an oily phase. However, phase separation can be considered from a different perspective as a strategy for the further valorization of this type of liquid. Indeed, centrifugation after water addition is a low-cost and environmentally friendly method for achieving effective phase separation. This process allows the separation of an aqueous phase, enriched in low molecular weight polar compounds such as carboxylic acids, ketones, and sugars, from an oily fraction that is nearly water-free and contains heavier, less polar and more aromatic compounds. Due to their differing composition and water content, the two phases are expected to exhibit different aging behaviors. This work aims to assess the influence of phase separation on slow pyrolysis bio-oil aging, considering how the chemical composition of the whole bio-oil and of the two phases, aqueous and oily, changes over a storage time of 145 days. Bio-oil produced from the slow pyrolysis of poplar at 600°C is generated in a lab-scale fixed bed reactor and subjected to characterization and phase separation through water addition and centrifugation. Samples of the whole bio-oil and of the two separated phases were stored at room temperature or refrigerated at 4 °C, aiming to evaluate how the storage temperature can affect aging. The primary organic species in all bio-oil samples (whole bio-oil, aqueous fraction, and oily fraction) were identified and quantified using GC-MS analysis and grouped into classes (carboxylic acids, ketones, phenols, etc.). All samples were analyzed repeatedly throughout the storage period. The results reveal an initial phase characterized by pronounced fluctuations in the concentrations of the identified compounds, followed by a general decrease after storage times exceeding 20 days. Storage temperature influenced only selected compound classes, with noticeable effects observed mainly for furans.

Structure–Activity Relationships in the Reductive Amination of Furfural over $Pd/ZrO_2–TiO_2$ Bifunctional Catalysts

Luis Arteaga-Pérez (Department of Chemical Engineering, Faculty of Engineering, Universidad de Concepción, Concepción, Chile., Chile) Konstanza Ortiz (Department of Chemical Engineering, Faculty of Engineering, Universidad de Concepción, Concepción, Chile., Chile) Alex Fernández Andrade (Department of Process Engineering and Bioproducts, Engineering Faculty, Universidad del Bío-Bío, Chile, Chile) Marcelo Domine (Instituto de Tecnología Química, UPV-CSIC, Valencia, Spain., Spain)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

The catalytic reductive amination of aldehydes and ketones derived from lignocellulosic biomass represents a sustainable alternative to petrochemical-based amines. In this context, the amination of furfural (FUR) with aniline has attracted increasing attention due to its renewable origin and industrial relevance. However, reductive amination involves two reaction steps that require acidic and metallic sites: (i) Imine formation and (ii) subsequent C=N bond hydrogenation to produce furfuryl aniline (FFA). $Pd/ZrO_2–TiO_2$ catalysts are attractive for this reaction due to their bifunctional nature, combining Lewis-acid sites and metallic Pd^0 domains. In this system, the imine may interact with the catalyst surface through σ-type coordination via the nitrogen lone pair to Lewis-acid sites, while hydrogen activation occurs on Pd^0. The balance between these interactions strongly affects reaction selectivity.

Herein, we assess the bifunctional role of $Pd/ZrO_2–TiO_2$ catalysts in furfural reductive amination by decoupling acidity and metal particle size effects. In a first catalyst series, Zr loading on TiO_2 was varied between 0 and 25 wt.% to tune Lewis's acidity while preserving comparable textural and structural properties. Catalytic performance was evaluated in terms of turnover frequency (TOF), imine conversion, product selectivity, and catalyst stability. The most active support composition was subsequently selected to prepare a second catalyst series with controlled Pd nanoparticle sizes (2–20 nm), enabling the assessment of structural sensitivity. Catalysts were characterized by XRD, TEM/HRTEM, N_2 physisorption, CO-Chemisorption, NH_3-TPD, FTIR-pyridine, H_2-TPR, ICP-OES, and XPS. Catalytic tests were conducted between 30 and 100 °C under 5 bar H_2 using equimolar furfural and aniline solutions.

Regardless of Zr loading, all catalysts exhibited similar textural and structural properties, including specific surface areas (S_{BET} = 35–56 $m^2\ g^{-1}$), mesoporosity, and predominant anatase TiO_2 phases. In contrast, acidity characterization revealed that Zr incorporation selectively strengthened Lewis's acid sites without significantly altering the total acid site density (5.0–8.7 μmol $NH_3\ m^{-2}$). Secondary amine selectivity and TOF showed no clear correlation with bulk acidity; however, maximum FFA selectivity (~60%) and TOF (6.7 s-1) were achieved for $Pd/(15\ wt.\%)\ ZrO_2–TiO_2$, which exhibited the a weak-to-total Lewis's acid site ratio (W/T = 3). This suggests that σ-type coordination of the imine on moderately strong Lewis sites favors selective hydrogenation, whereas stronger acidity leads to excessive stabilization of reaction intermediates, in agreement with Sabatier's principle.

For the catalysts with different particle sizes, we found that the TOF (measured under initial conditions) increased from 1.5·10-3 s-1 to 2.5·10-1 s-1 for catalysts with 14.1 and 60% Pd dispersion respectively. Assuming an icosahedron structure, the outperformance of 60% dispersion Pd is correlated with its higher fraction of low-coordinated sites (>90% Edge+Corner) and demonstrate that FUR amination is sensitive to the structure. The pronounced structure sensitivity, together with the weak dependence on total acidity, indicates that the rate of furfural reductive amination is controlled by the initial hydrogenation of the imine coordinated to Lewis-acid sites. This step, involving σ-activated imines and hydrogen transfer from coordinatively unsaturated Pd sites, constitutes the kinetically relevant step of the reaction.

Pressurised pyrolysis of sugarcane bagasse for hydrogen-rich syngas production

Quan Sun (the university of newcastle, Australia) Salman Khoshk Rish (The University of Newcastle, Australia) Arash Tahmasebi (The University of Newcastle, Australia) Jianglong Yu (Monash University-Southeast University Joint Graduate School and Monash Suzhou Research Institute, Australia)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study compares the pyrolysis behaviour of sugar bagasse in a pressurised fixed-bed reactor. The effects of temperature, heating rate and pressure were studied. The primary objective of this study was to investigate the feasibility of enhancing the selectivity of high-value-added products, including H-rich syngas, activated carbon, and other chemical raw materials, at high pressures. The pyrolysis temperature and pressure ranged between 400-700 ℃ and 0.1-1.6 MPa, respectively. Temperature, heating rate and pressure were found to dramatically impact the yield and composition of pyrolysis products. The secondary reaction pathways and elemental transformation mode during pyrolysis were also investigated. The results showed that, for sugarcane bagasse, the concentration of H2 in the gas fraction increased drastically with pyrolysis temperature, heating rate and pressure, which indicated that those parameters enhanced the transfer of hydrogen from char and tar into the gas phase. Tar samples generated at the tested conditions were mainly composed of sugars, phenols, and other oxygenated compounds. While pressure and temperature promoted the formation of Polycyclic aromatic hydrocarbons (PAHs), they were suppressed at higher heating rates due to shortened residence time for secondary reactions, such as cyclisation, aromatic ring growth mechanism and other polycondensation reactions. The results obtained in this study implied that the pyrolysis of sugarcane bagasse at elevated pressures and heating rates can be an effective method for poly-generation of hydrogen-rich syngas and other chemical feedstocks.

Development of new forms of carbonaceous adsorbents suitable for water purification: activated biochar for Congo red adsorption

Roman Marsalek (University of Ostrava, Czechia) Boleslav Taraba (University of Ostrava, Czechia) Martin Mucha (Unievrsity of Ostrava, Czechia)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study focuses on the development and characterization of novel carbon-based adsorbents derived from animal manure for the removal of azo dyes from aqueous solutions. Biochar was prepared from camel manure by torrefaction at 300 °C under oxygen-free conditions. The resulting material was subsequently chemically activated with sulfuric acid and modified with Fe^{2+}/Fe^{3+} ions to enhance its surface properties and adsorption performance. The prepared adsorbents were characterized using Fourier-transform infrared spectroscopy (FTIR), zeta potential measurements, and scanning electron microscopy (SEM) to evaluate changes in surface functional groups, surface charge, and morphology.

The adsorption performance of both non-activated and activated biochar was investigated using Congo red as a model anionic dye. Adsorption experiments were conducted under batch conditions, and equilibrium data were evaluated using the Langmuir adsorption isotherm model. The results showed that chemical activation and iron modification led to a significant increase in adsorption capacity, from 48.4 mg g^{-1} for non-activated biochar to 77.2 mg g^{-1} for the activated and modified material. The enhanced adsorption performance was attributed primarily to the change in surface charge, as the zeta potential shifted from −31 mV to +12 mV after activation, increasing the affinity of the adsorbent toward negatively charged dye molecules.

The findings demonstrate that biochar derived from animal manure, especially after appropriate activation and modification, represents a promising low-cost and sustainable adsorbent for the removal of anionic pollutants from wastewater. In addition, non-activated biochar with a negative surface charge may be suitable for the adsorption of positively charged contaminants, such as heavy metal cations.

Study of liquid and solid product formation after hydrothermal processing of carbohydrate and aromatic biomass derivatives

Aivars Zhurinsh (Latvian State Institute of Wood Chemistry, Latvia) Ance Plavniece (Latvian State Institute of Wood Chemistry, Latvia) Kristine Meile (Latvian State Institute of Wood Chemistry, Latvia) Kalvis Liepins (Latvian State Institute of Wood Chemistry, Latvia) Galina Dobele (Latvian State Institute of Wood Chemistry, Latvia)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Various types of renewable lignocellulosic biomass are a common source of carbon and are of great interest as a precursor to various carbon materials and a source of green energy . Efficient valorisation of biomass and its by-products has set the task for scientists and the industrial community to use them for the development of cheap and environmentally friendly functional materials with high added value. The presence of carbohydrates and aromatic polymers in the biomass allows obtaining carbon materials and precursors for their synthesis of various structures, and the flow of by-products can be used to synthesize chemicals , . Carbonaceous materials play a promising role in the energy sector due to their unique properties such as high surface area, good electrical conductivity and corrosion resistance . Various types of biomass carbonization have a great potential to become an eco-friendly process for producing carbon products for environmental, catalytic, electronic and agricultural applications. Hydrothermal carbonization (HTC) is an environmentally friendly technology for producing solid carbon material, e.g. hydrochar, with attractive properties, as well as water-soluble products of biomass components hydrolysis. The aim of this study is to investigate the effect of the composition of different biomass derivatives (anhydrosugars and lignin) on the morphology and properties of solid products and composition of liquid products obtained in the process of HTC. The study of processing of these model derivatives will contribute to the understanding of the reaction mechanisms of the synthesis processes. Hydrothermal carbonization will be carried out in a 250 ml high pressure autoclave. After separation the carbonized solid particles will be studied by elemental analysis, Py-GC/MS and SEM. Liquid by-products will be tested by potentiometric titration of acids and aldehydes, spectrophotometric analysis, GC-FID/MS and HPLC-UV/ELSD/MS. The research was funded by project lzp-2024/1-0525 “Lignin-containing products for synthesis of N-doped carbon microspheres as electrochemical catalyst and electrode materials (LIGsp)”

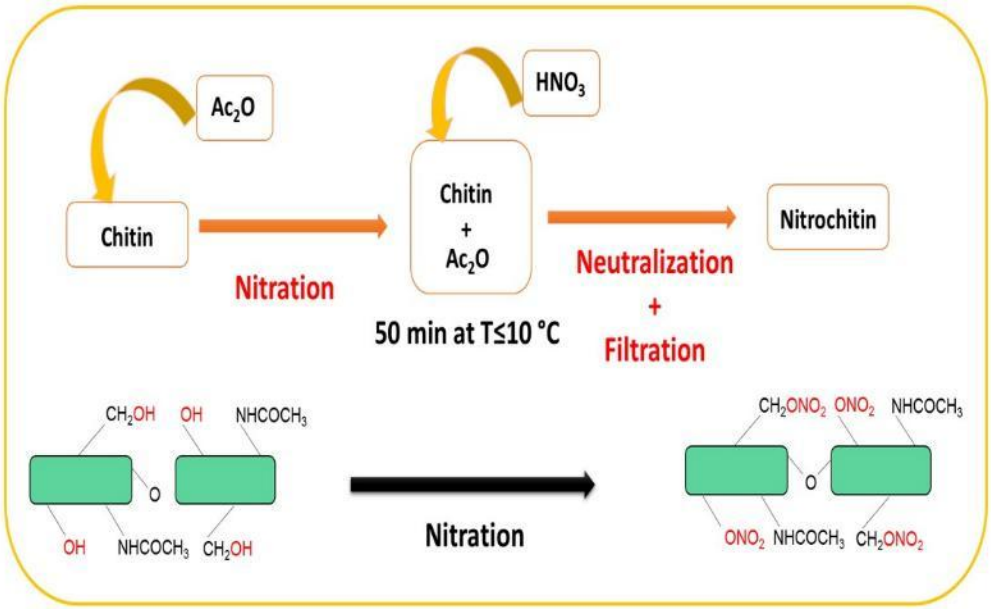
Design and characterization of a promising chitin-based energetic polysaccharide

Sylia Ouahioune (Ecole Militaire Polytechnique, BP 17, Bordj El-Bahri, 16046, Algiers, Algeria, Algeria) Ahmed Fouzi Tarchoun (Ecole Militaire Polytechnique, BP 17, Bordj El-Bahri, 16046, Algiers, Algeria, Algeria) Djalal Trache (Ecole Militaire Polytechnique, BP 17, Bordj El-Bahri, 16046, Algiers, Algeria, Algeria) Fouad Benaliouche (Ecole Militaire Polytechnique, BP 17, Bordj El-Bahri, 16046, Algiers, Algeria, Algeria) Thomas M Klapötke (Ludwig Maximilian University, Butenandtstrasse 5-13 (D), 81377 Munich, Germany, Germany)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study investigates the synthesis and characterization of nitrochitin (NCT), a promising energy-rich biopolymer derived from chitin. The nitration process was adapted from previous work on nitrochitosan. The chemical structure and morphology of NCT were analyzed using infrared spectroscopy, elemental analysis, scanning electron microscopy, and X-ray diffraction. Thermal behavior was evaluated by differential scanning calorimetry, revealing two consecutive decomposition events between 135–185 °C and 192–244 °C. The designed NCT (nitrogen content = 13.63%) demonstrated notable properties, including a higher crystallinity index compared to the conventional nitrocellulose, a density of 1.71 g/cm³, a nitrogen content of 13.63%, and an impact sensitivity of 18 J. These results highlight the significant potential of NCT for use in energetic formulations.



Energetics of torrefied droppings of ZOO animals

Boleslav Taraba (University of Ostrava, Dpt of Chemistry, Czechia) Roman Maršálek (University of Ostrava, Dpt of Chemistry, Czechia) Martin Mucha (University of Ostrava, Dpt of Chemistry, Czechia) Eva Kinnertová (University of Ostrava, Dpt of Chemistry, Czechia)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Droppings of four ZOO animals (giraffe, deer, camel, reindeer) and a sample of pellets of zebra manure were torrefied at 250°C and 300°C to study their potential as an alternative fuel. Combustion calorimetry and thermal (DTA/TG) analysis were used to quantify heating parameters and dynamics of the combustion process of the biomass materials, respectively. Marked increase in heating values of torrefied droppings was found, by about 20% in comparison with non-torrefied, original state. However, differences between heating values of the samples torrefied at 300°C and 250°C were rather insignificant.

Process Integrated Valorization of Fast Pyrolysis Co-Products: Enhancing the textural and Environmental Quality of Biochar via Post-Pyrolysis Treatment.

Iqra Aziz (Karlsruhe Institute of Technology, Germany) Dr. Axel Funke (Karlsruhe Institute of Technology, Germany) Prof.Dr. Nicolaus Dahmen (Karlsruhe Institute of Technology, Germany)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Fast pyrolysis is widely employed for bio-oil production, yet the efficient utilization of its solid and condensable by-product remains a challenge. It is desirable to valorize the char but it lacks the essential surface properties needed for high-value applications. The aim of this study is to develop an integrated post-pyrolysis activation reactor that valorizes fast pyrolysis by-products and yields a high-quality activated biochar. No studies so far, have reported the utilization of pyrolysis by-products as biochar activation agents. Biochar from wheat straw and beechwood will be activated using liquid and gaseous by-products of pyrolysis and will then be characterized using surface and functional techniques. The integrated activation is expected to enhance the surface characteristics of the biochar produced in the pyrolysis unit, demonstrating the feasibility of this approach. This approach will omit the need for additional inputs (both material and less energy) for activating the biochar being produced in the fast pyrolysis process. Moreover, it will provide an economically feasible alternative to the field burning of the harvest residues. As a first step towards enhancing the utilization of char, a simple thermal post treatment strategy was applied to improve its physiochemical and environmental performance. The two main factors that restrict the valorization of fast pyrolysis char are the surface area and the presence of PAH content. Characterization results from the post-treatment revealed the enhancement of the textural properties and a substantial reduction in PAH content for both feedstocks. The specific surface area increased from 6 to 375 m2g-1 and 1 to 447 m2g-1 for wheat straw and beechwood derived chars respectively. In parallel, the polycyclic aromatic hydrocarbon (PAH) content for both the samples were reduced from 13mg/kg to less than 1 mg/kg after the post treatment. In conclusion, this simple thermal post treatment is already a promising step to control biochar quality parameters. (Future work will focus on the physical activation).

Torrefaction of the ZOO animals droppings

Martin Mucha (Department of chemistry, Faculty of Science, University of Ostrava, Czechia) Roman Marsalek (University of Ostrava, Czechia)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Utilization of the droppings from the animals which are kept in the ZOO represents serious issue. Thermal treatment of the material such as pyrolysis can stabilize contained pollutants as well as kill microbes which can otherwise limit the utilization of the droppings. Traditional pyrolysis is highly energy-intensive, therefore another approaches (torrefaction, hydrothermal processes) are tested. Torrefaction represents process of formation of carbonaceous material at relatively low temperatures and often without use of inert gas as atmosphere. Resulting materials can be used for soil improvement, as adsorbents or source of energy [1, 2]. Droppings from camel (Camelus bactrianus), giraffe (Giraffa camelopardalis), deer (Elaphurus davidianus) and reindeer (Rangifer tarandus) were supplied by ZOO Brno (Czech Republic), they were dried at 80 °C to the constant mass in the laboratory dryer. Camel droppings were torrefied at 2 temperatures (250 and 300 °C) and at 2 times (1 hour and 2 hours) in the ceramic crucibles with caps without use of inert atmosphere. It was found out, that both temperature and time have statistically significant effect on the torrefaction yield for camel droppings but the effect of time is lower than the effect of temperature. Therefore, experiments with other types of droppings were carried out at torrefaction time 2 hours and for both temperatures. The type of animal has the significant effect on the torrefaction yield as well. The yield of torrefaction was between 50 and 75 % depending on animal and temperature. Both torrefaction temperature and type of animal influences bulk density of prepared materials as well as contents of organic functional groups in the resulting materials, which was proven by infrared spectrometry and elemental analysis.

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Co-Pyrolysis of Greenhouse Tomato Plant Waste Contaminated with Plastics: Influence of Process Parameters and Biochar Potential for Thermal Plasma Treatment

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study investigates slow pyrolysis as a potential thermochemical valorization pathway for mixed greenhouse agricultural waste streams, consisting of tomato plant harvest residues contaminated with polypropylene (PP) supports for plant growth. Co-pyrolysis was applied to the waste stream as a pretreatment step prior to further plasma gasification of the produced biochar. The influence of reaction temperature and residence time on the char yield and properties were evaluated, with particular emphasis on the biochar suitability for syngas production during subsequent treatment in a plasma torch. The experimental work was performed on mixed biomass composed of waste plant material from the Xandor XR tomato cultivar contaminated with PP clips and ropes, with plastic-to-biomass ratio of 0.35 on dry basis. The feedstock was collected after the harvest season, dried at 60 °C for 48 h and subsequently ground to 2 mm particle size. The ground material was pyrolyzed in a Carbolite Gero tube furnace at temperatures of 400, 500, 600 and 700 °C for residence times of 30 and 90 min, under a constant nitrogen flow of 20 mL/min and a heating rate of 10 °C/min. Elemental and proximate analyses were performed on both the feedstock and the produced biochars to determine composition and higher heating value (HHV). The metal and mineral contents were quantified by ICP-OES. The results showed average biochar yields ranging between 30.7 and 42.7 %, with carbon contents between 53.0 and 58.0 %. The calculated HHVs ranged between 18.6 and 21.4 MJ/kg. Based on the outcomes of the current research activity, optimization criteria for downstream biochar conversion in plasma torches were determined according to char yield, energy yield and carbon enrichment. The combined application of pyrolysis and plasma gasification provides a promising alternative to conventional disposal practices for mixed agricultural residues, most of which are currently landfilled due to plastic contamination, and promotes more improved value recovery from this challenging biomass.

Green hydrothermal synthesis of catechol from 2-acetylfuran

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Catechol is an important platform chemical, with an annual production between 40 000 – 50 000 tonnes per year, due to its central role as key chemical intermediate for various applications in the pharmaceutical and agrochemical sector. The current production of catechol virtually entirely depends on fossil-based carbon: benzene is first converted into phenol, and is then hydroxylated. This yields not only catechol, but also hydroquinone in a ratio of 3:2 catechol:hydroquinone. Hence, it is most worthwhile to develop new production routes for catechol, which tackle both the dependency on fossil feedstock and the selectivity of the conversion. This conference contribution therefore addresses both hurdles by demonstrating and optimizing the conversion of 2-acetylfuran into catechol. 2-Acetylfuran is a furan that can be obtained from renewable resources. In early work, Vargha et al. (1943) observed the conversion of 2-acetylfuran into catechol (Fig. 1). Some years later, Luijkx et al. (1993) revisited this conversion, aiming the optimization of catechol production, using a continuous subcritical reactor, operated at 340°C and 27.5 MPa for 16 min, using no or 5 mM HCl as catalyst. However, they observed at best a catechol yield of 4.6 mol% (at 13.2% conversion), which caused this route to remain dormant – until now. Acknowledging the demand for green and innovative catechol synthesis, we optimized the hydrothermal conversion scheme. In this work, we increased the residence times to between 40 – 150 minutes, and operated at temperatures between 300 °C – 380 °C. Also, we used $ZnCl_2$ as catalyst. After optimization, the best results were obtained at 360 °C, after 120 min reaction time, resulting in a catechol yield of 46.1 mol% at 88.5% selectivity (Fig. 2). This is an increase of one order of magnitude, compared to earlier results of Luijkx et al. Hence, this conference contribution demonstrates the viability of using hydrothermal conversion technology to provide green catechol.

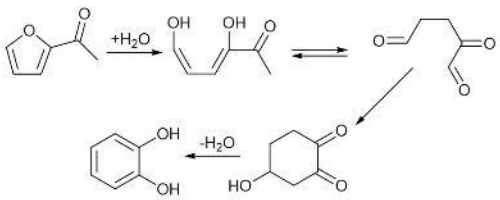


Fig. 1

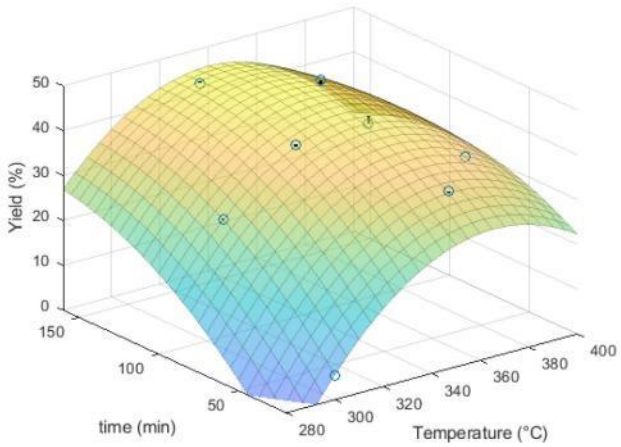


Fig. 2

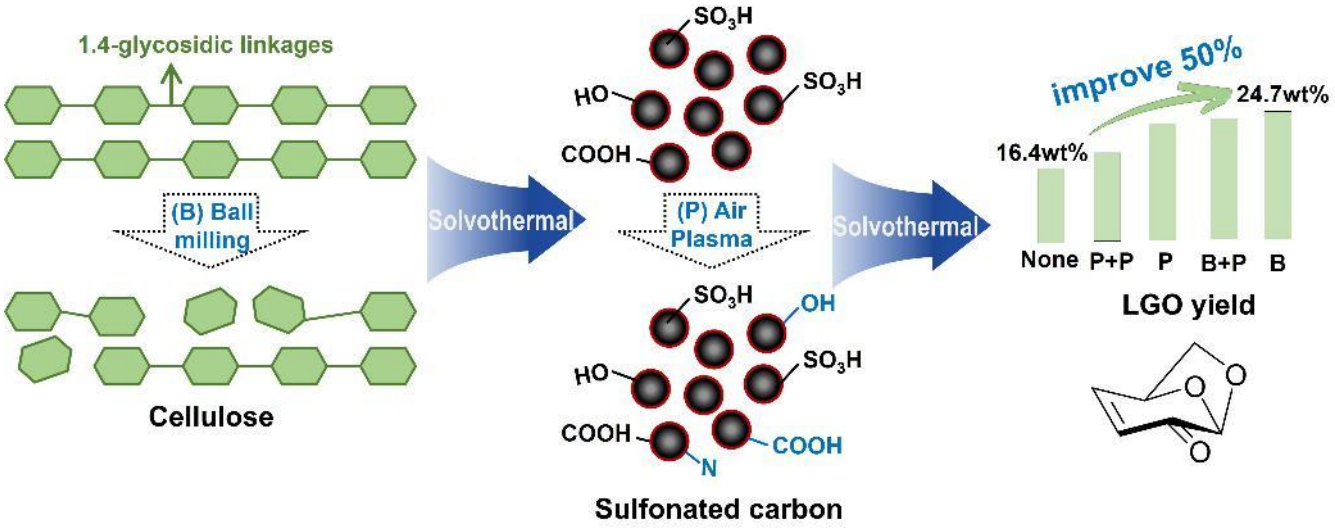
Plasma and ball milling pretreatment for enhanced production of levoglucosenone from catalytic conversion of cellulose over a sulfonated carbon catalyst

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

As a key bio-based platform chemical, levoglucosenone (LGO) holds great promise for sustainable chemical synthesis. This study demonstrates the enhanced production of LGO from cellulose via solvothermal catalysis over sulfonated carbon, empowered by tailored pretreatments. Air plasma modification of the catalyst introduced nitrogen doping and additional oxygen-containing groups (-COOH, -OH), which facilitated cellulose adsorption and strengthened glycosidic bond cleavage. This boosted the LGO yield to 22.5 wt%, a significant increase from the 16.4 wt% obtained with the untreated system. Alternatively, ball milling pretreatment of cellulose dramatically reduced its crystallinity and particle size, achieving an even higher LGO yield to 24.7 wt% (31.8% mole yield), which increased by 50% compared to untreated system. Interestingly, applying both pretreatments simultaneously did not yield a synergistic effect, indicating that the observed enhancements are predominantly governed by single-mode modifications. Furthermore, the sulfonated carbon catalyst exhibited excellent stability, retaining high activity over five consecutive recycling cycles. This work provides efficient pretreatment strategies and insight into their distinct roles, highlighting a practical pathway for valorizing cellulose into high-value chemicals.



Acid Washing and Carbonization of Biomass Bottom Ash for Recycling into Bio-coke

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Ash generated from biomass power plants in Korea is treated as power plant waste and mostly landfilled, resulting in significant environmental and economic losses. This biomass ash possesses high carbon content and can be recycled into bio-coke by reducing ash and volatile matter content. Therefore, this study aimed to remove ash and volatile matter from biomass bottom ash through acid washing and carbonization processes, ultimately increasing its fixed carbon content. In addition to acetic acid, commonly used for biomass acid washing, lactic acid and citric acid which biodegrade in natural environments were used to mitigate environmental and safety concerns associated with strong acids, such as facility corrosion and waste liquid discharge. Particle size analysis of the raw material determined the optimal particle size range to be 850 μm – 2 mm based on ash content per size fraction. Acid washing was performed at 40–80 °C with the acid solution pH set to 1–3. Subsequently, the washed samples were carbonized in a horizontal reactor under a nitrogen atmosphere to remove residual volatile matter. The washing and carbonization processes confirmed that the ash reduction rate increased with rising washing temperature and decreasing solution pH. It was also confirmed that volatile matter could be effectively removed by increasing the carbonization temperature and time. These research results will serve as foundational data for future recycling of biomass bottom ash into bio-coke.

Structure–Performance Relationships in Ni/C Catalysts for Power-to-Gas Applications

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

The transition toward a carbon-neutral energy system requires innovative strategies that integrate renewable energy use with carbon capture and recycling. CO_2 methanation, a key Power-to-Gas (PtG) technology, enables the conversion of captured CO_2 and renewable hydrogen into synthetic methane, a storable and grid-compatible fuel. Realizing its full potential depends on the development of robust catalysts. Nickel-based catalysts are widely employed due to their high activity and low cost; however, their performance is strongly influenced by the physicochemical properties of the support, which affect metal-support interactions, reducibility, dispersion, and resistance to sintering. Biochar and activated carbon are of particular interest as catalyst supports because of their tunable surface chemistry and porosity, but the relationship between biochar surface properties, metal-support interactions, and methanation performance remains insufficiently understood.

This research systematically investigates a series of Ni catalysts supported on biochar and activated carbon, prepared from different feedstocks and pyrolysis conditions. Three lignocellulosic feedstocks—pine wood, wheat straw, and lignin-rich digested stillage—were pyrolyzed at 400°C, 550°C, and 700°C and subsequently activated with CO_2 to obtain a range of contrasting materials. The resulting biochars and activated carbons were thoroughly characterized using CHNS analysis, proximate analysis, N_2- and CO_2-physisorption, ICP-MS, FTIR, TPD-MS, XPS, and Raman spectroscopy to assess their surface chemistry, porosity, and structural properties. For catalytic testing, Ni was deposited onto the biochars and activated carbons, and CO_2 methanation was performed at 300°C and 10 bar. Conversion, selectivity, and stability data were then correlated with the physicochemical properties of the supports to establish structure–performance relationships.

This work provides a systematic comparison of nine distinct biochar matrices and their activated carbon counterparts, exploring how feedstock composition and pyrolysis temperature influence metal-support interactions and catalytic behavior. By combining comprehensive surface characterization with catalytic testing, the study aims to clarify how biochar surface chemistry affects Ni dispersion and methanation performance.

The insights gained from this research contribute to the rational design of biobased catalyst supports for synthetic methane production. They also strengthen the role of biochar valorization within the carbon circular economy and provide guidance for optimizing carbon-based supports for scalable CO_2 utilization and renewable energy storage via Power-to-Gas technologies.

Effect of pre- and post-treatments on the pyrolysis condensate of pine bark

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

There is a growing demand for biocarbon in metallurgical applications. The production of biocarbon via pyrolysis of biomass feedstock generates significant amounts of liquids and gases as byproducts. The liquid condensate, however, can be a valuable material with detailed characterization and proper upgrading. Biocarbon for metallurgical applications is currently produced primarily from stem wood, but it is important to exploit different biomass materials for feedstock of sufficient quality, high availability and low costs deriving from a sustainable source. Wood bark is a considerable waste stream from forestry and can be a potent feedstock for biocarbon production.

In the present work, pine bark chips were pyrolyzed in a fixed bed reactor to produce pyrolysis condensate besides biocarbon. Prior to carbonization, some of the pine bark feedstock was leached by water to reduce the inorganic contents, which are higher in bark than in stem wood. The effect of water leaching on the condensate composition produced was evaluated by the GC/MS analysis. Direct utilization of raw pyrolysis condensates is challenging, as one of their issues is that they contain large amounts of water. Therefore, subsequent thermal treatments were also performed on the collected pyrolysis condensates of both leached and unleached pine bark. The thermal treatment of the condensates was performed in a muffle furnace at 140 and 160 °C for 2 h. The composition of volatile organic compounds in the thermally treated condensates was also determined by GC/MS analysis. The condensates heated at 140 °C showed a significant improvement in the ratio of organic contents as the intensity of the compounds identified was measured with a much higher intensity than it was found on the chromatograms of raw condensates. A similar tendency was observed in the cases of the condensates treated at 160 °C. The presence of larger compounds (e.g., levoglucosan) increased to a higher extent than in the samples treated at 140 °C. However, the fraction of the compounds of higher volatility was measured in a considerably lower ratio (e.g., acetic acid).

The evaluation of leaching effects on the condensate of pine bark and the thermal treatment of the liquid byproducts was performed to provide useful data for the biocarbon industry to widen feedstock selection and for the utilization of the pyrolysis condensates.

Characterization and Antifungal Activity of Wood Vinegar Produced from Slow Pyrolysis of Canola Stalk

Tamer Akçay (Namik Kemal University, Turkey) Turkan Aktas (Namik Kemal University, Turkey) Arzu Coskuntuna (Namik Kemal University, Turkey)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This research aims to investigate the production of wood vinegar from canola stalk, a common agricultural residue in the Thrace region of Turkiye, via slow pyrolysis, and to assess its antifungal properties. Laboratory scale fixed bed pyrolysis system was designed and used to pyrolyze canola stalks at eight different temperatures ranging from 280°C to 600°C. The chemical composition of the wood vinegar, separated from the pyrolysis liquid, was characterized using Gas Chromatography-Mass Spectrometry (GC-MS) and Fourier Transform Infrared (FT-IR) spectroscopy. The antifungal efficacy of the wood vinegar was tested in vitro against the economically significant phytopathogenic fungus Alternaria alternata at three different dilution ratios (1/100, 1/300, and 1/500). The experimental results showed that the pyrolysis temperature significantly influenced both product yield and the distribution of constituents within the vinegar. While the maximum wood vinegar yield (31.51%) was obtained at 350°C, chemical analyses revealed that the vinegar possessed a complex composition, primarily consisting of phenols, acetic acid, and ketones. Notably, the relative quantity of phenolic compounds was observed to increase with rising pyrolysis temperatures up to 500°C. Antifungal assays indicated that the wood vinegar significantly inhibited the mycelial growth of A. alternata in a clear dose-dependent manner. The most pronounced inhibitory effect was consistently achieved with the 1/100 dilution across all production temperatures. Furthermore, wood vinegar produced at mid-range temperatures, particularly between 400°C and 500°C, exhibited the strongest antifungal activity. This enhanced efficacy correlated well with the higher concentrations of phenolic compounds identified in the chemical profiles of these samples. In conclusion, slow pyrolysis has proven to be an effective method for transforming canola stalk waste into wood vinegar with considerable antifungal potential. *This abstract was derived from Tamer Akçay's PhD Thesis.

Turning agro-industrial pruning residues into biochar: insights from slow pyrolysis and value chain analysis

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Agro-industrial pruning residues represent an underexploited biomass resource that can play a key role in circular economy strategies at farm and cooperative scale. This study investigates the valorisation of agricultural residues generated by a fruit-processing cooperative located in Vitulazio (Italy), using real production and management data to assess the feasibility of biochar production via pyrolysis for internal agricultural use and carbon credit generation. The analysis focuses on three representative pruning residues, kiwi branches (KB), peach branches (PB) and apple branches (AB), selected based on their annual availability, physicochemical properties and temporal distribution. Production data indicate significant and stable biomass streams, associated with cultivated areas of tens to hundreds of hectares, with pruning availability spanning different seasons of the year. Proximate and ultimate analyses show comparable elemental compositions with a carbon content around 48-49 wt% dry basis (db) and relatively low ash contents (1.9-2.7 wt% db), making these residues suitable feedstocks for thermochemical conversion. Pyrolysis experiments were conducted in the temperature range 500–700 °C to quantify biochar yields and co-product formation. Biochar yields were found to range approximately between 23 and 29 wt% db, depending on feedstock and operating temperature, while significant fractions of liquid and gaseous by-products were also produced. The energy content of gases (8-12 MJ/kg) and liquids (18-20 MJ/kg) highlights the potential for internal energy recovery, contributing to the overall efficiency of the value chain.

Biochar characterisation focused on parameters relevant for agronomic application and long-term carbon sequestration, including elemental composition, ash content, pH and indicators linked to stability. The results support the suitability of the produced biochars as soil improvers and as carbon sink.

A comprehensive technoeconomic value chain analysis is presented to assess the economic viability of various feedstock and conversion pathways (pelletization or pyrolysis), covering residue generation, collection, pre-treatment, pyrolysis conversion, and potential carbon credit acquisition. The study demonstrates how an integrated, locally based pyrolysis system can enable the internal valorisation of pruning residues, closing nutrient and carbon loops while providing environmental and economic benefits to agro-industrial cooperatives.

Effects of Pyrolysis Temperature on Biochar Yield, CO2 Adsorption Capacity and Kinetic from Coconut Husk Biomass

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study investigated potential of biochar derived from coconut husk (CH), an abundant agricultural waste in tropical regions, in terms of biochar yield, CO2 adsorption performance, and adsorption kinetics. The effects of pyrolysis temperature were examined at 500 °C and 600 °C, selected based on thermogravimetric analysis (TGA) results. Pyrolysis was conducted under a nitrogen atmosphere with a heating rate of 5 °C min-1, a residence time of 1 h, and a nitrogen flow rate of 100 mL min-1. Characterization techniques, including ultimate analysis, Brunauer-Emmett-Teller (BET) surface area analysis, TGA, Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM), were employed to evaluate the composition and structural changes of the biochar. The CO2 adsorption performance was determined using a quartz-tube fixed-bed reactor packed with 1 g of adsorbent. Adsorption experiments were conducted at an initial CO2 concentration of 500 ppm, a temperature of 25 °C, and a pressure of 1 bar. The CO2 adsorption kinetics were analyzed using the Avrami kinetic model, while adsorption equilibrium behavior was evaluated using the Toth isotherm model. The results demonstrate that pyrolysis temperature significantly influenced the physicochemical properties of coconut husk biochar. Ultimate analysis revealed an increase in carbon content from 38.50% in raw coconut husk (Raw CH) to 54.53% at 500 °C (CH-500), followed by a slight decrease to 50.15% at 600 °C (CH-600). In contrast, oxygen content decreased progressively with increasing temperature, indicating enhanced deoxygenation during pyrolysis. Biochar yield decreased from 53.55% at 500 °C to 44.84% at 600 °C due to intensified devolatilization and thermal degradation at higher temperatures. XRD analysis illustrates the structural evolution of the material from its raw state (Raw-CH) through pyrolysis. The diffraction pattern of Raw-CH confirmed its amorphous nature, characterized by a broad diffraction halo centered at 2θ ≈ 22°, attributed to lignocellulosic components, along with a minor native crystalline silica (SiO2) phase. Upon pyrolysis, the amorphous halo diminished and sharp diffraction peaks corresponding to potassium chloride (KCl) emerged, indicating thermal decomposition of the organic matrix and crystallization of inorganic salts. FTIR analysis was employed to investigate changes in surface functional groups of coconut husk biomass before and after pyrolysis. Increasing pyrolysis temperature led to modification of oxygen-containing functional groups and promoted the development of aromatic carbon structures. Hydroxyl, phenolic, ether, and aromatic functional groups were identified on the biochar surface, providing active sites for CO_2 adsorption through hydrogen bonding and π–π interactions. The optimal pyrolysis condition was observed at 600 °C, providing a balance between biochar yield and pore structure development. The maximum CO2 adsorption capacity reached 0.079 mmol g-1. Kinetic analysis showed that the Avrami model adequately described the breakthrough behavior (R^2 = 0.74-0.94), indicating that both surface interactions and diffusion processes govern adsorption. Isotherm analysis using the Toth model (R2 = 0.96–0.99) confirmed favorable adsorption behavior. This study demonstrates that coconut husk biochar produced via optimized slow pyrolysis represents a promising, low-cost, and environmentally sustainable adsorbent for CO2 capture, contributing to biomass valorization and climate change mitigation.

Optimized lignin-derived pyrolytic oils enhance oxidative aging resistance of asphalt binders

Jose Rodolfo Colina (Universidad San Sebastián, Chile) Cristina Segura (Unidad de Desarrollo Tecnológico, Universidad de Concepción, Chile) Alex Fernandez (Universidad del Bío-Bío, Chile) Jose Luis Concha (Universidad del Bío-Bío, Chile) Gonzalo Valdes (Universidad de la Frontera, Chile) Luis Ernesto Arteaga-Pérez (Department of Chemical Engineering, Faculty of Engineering, Universidad de Concepcion, Chile, Chile)

14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Lignin is one of the most abundant aromatic polymers on earth and shows promising potential for the development of bio-based phenolic products through pyrolysis. In this study, a central composite design and response surface methodology were employed to evaluate the effect of pyrolysis temperature and heating rate on the phenolic yield in bio-oils obtained from pyrolysis of Kraft lignin. Pyrolysis experiments were carried out in a fixed-bed reactor at temperatures of 400-600 °C and heating rates of 5–25 °C.min^{-1}. The bio-oils were mostly composed of phenolic compounds (selectivity > 70%), mainly guaiacol, 4-methyl guaiacol and 4-ethylguaiacol, and exhibited remarkable antioxidant activity. The optimization model indicated that maximal phenolic yield from Kraft lignin pyrolysis is reached at 542 °C and 12 °C.min-1. An innovative phenolics-rich bio-additive was subsequently obtained by distilling the optimized bio-oil in order to remove water and light compounds. The antioxidant effectiveness of bio-additive was evaluated in an asphalt binder subjected to oxidative aging. The results showed that the incorporation of the bio-additive improved the binder's resistance to oxidative aging, reducing the carbonyl index by 25%. The aging mitigation effect was attributed to high phenolic content of bio-additive, particularly guaiacyl type phenols. This work highlights the potential of bio-oils derived from Kraft lignin as functional bio-based additives for the formulation of sustainable pavement materials and proposes a novel pathway for the valorization of technical lignin.

Biomass pyrolysis in a fixed-bed reactor: effect of pressure and sweep gas velocity

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Understanding the effect of operating conditions during biomass pyrolysis is very important. The role of heating rate and final temperature has been extensively studied in the literature and is well understood. However, few studies have specifically addressed the impact of pressure on biomass pyrolysis and conflicting results have been reported. Most findings suggest that increasing pressure favors the formation of char and enhances exothermic phenomena [1], while others indicate that it primarily affects product quality rather than the overall yields [2]. Therefore, this work investigates the effect of pressure (ranging from 1 to 30 bar) and sweep gas velocity (ranging from 1 to 14 cm/s) on the yields and composition of products resulting from the slow pyrolysis of cellulose as a macromolecular model, as well as real lignocellulosic biomass particles including oak and miscanthus, in a fixed-bed reactor. Since the velocity of the carrier gas plays a crucial role in controlling mass transfer within the fixed bed, the experimental setup was designed to provide precise control over both gas flow rate and pressure, while also accounting for bed properties. The composition of the products has been characterized using micro gas chromatography for permanent gases, gas chromatography-mass spectrometry (GC-MS) for bio-oils, and proximate and ultimate analysis alongside scanning electron microscopy (SEM) for biochars. Additionally, the effect of pressure on vapor-char secondary conversion of primary volatiles has been investigated using a double-bed configuration (with a second bed of char).

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ENERGY RECOVERY FROM SLAUGHTERHOUSE WASTE: GASIFICATION PERFORMANCE AND DIGESTATE VALORIZATION

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

The slaughterhouse industry generates large amounts of solid waste and wastewaters, posing both environmental challenges and opportunities for energy recovery [1, 2]. Coupling biochemical and thermochemical processes, such as anaerobic digestion (AD) and digestate gasification, seems to be a promising alternative to convert slaughterhouse waste (SHW) and solid digestate into energy carriers including biogas, char, and syngas. This work investigates the potential of using SHW digestate to produce energy as an alternative to fossil fuels. Two feedstocks were examined: raw, and previously pyrolyzed SHW digestate. They were first characterized by proximate and ultimate analysis. Calorific values were also determined. The SHW digestate exhibited a high carbon content (46 wt%), H/C (1.6) and O/C (0.4) molar ratios, and a higher heating value (HHV) of 18.7 MJ/kg, making it well suited for gasification. Isothermal gasification tests (800 °C) were performed in a thermogravimetric analyzer (TGA) using an O2/N2 mixture as a gasifying agent. The gas composition was simultaneously analyzed by micro-gas chromatography (MicroGC) [3]. The effect of key process parameters such as feedstock loading, gas flow and heating rates was carefully examined to maximise gasification efficiency and improve syngas quality, allowing to reach hydrogen-rich syngas composition (~48 mol%) with H_2/CO molar ratios between 1.4 and 2.4, and lower heating values (LHV) of producer gas up to 7.8 MJ/m3, for ideal energy recovery. These results highlight the potential of coupling AD and digestate gasification (AD-gasification) as an alternative route for upgrading digestates into hydrogen-rich syngas, supporting their integration into advanced biomass valorization and waste-to-energy systems.

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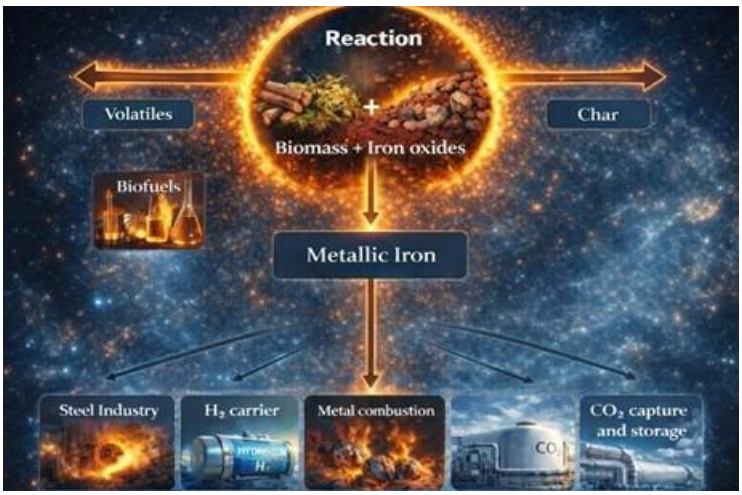
Pyrolysis-Driven Iron Redox Systems: A Multifunctional Approach to Hydrogen, Biofuels, and Carbon Capture

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Energy transition demands integrated thermochemical platforms delivering low-carbon carriers and managing carbon. Hydrogen underpins decarbonization but faces safety, infrastructure, and water limits. Biofuels complement hard-to-electrify transport. Carbon capture and storage is increasingly vital for achieving climate-neutral energy systems across aviation, shipping, and heavy-duty sectors globally today. In this framework, an integrated biomass–metal redox approach in which products of biomass pyrolysis act as reducing agents for metal oxides, enabling the co-production of hydrogen, biofuels, and functional materials. As highlighted by the Ellingham diagram, the best metal that allows this type of energy transition, for its kinetic and thermodynamic characteristics, and for its availability in the world is iron. Pyrolysis converts biomass and residual organic materials into biochar and a spectrum of volatile compounds whose composition and reactivity can be tailored through operating conditions. These carbonaceous products drive the reduction of iron oxides through coupled solid–solid reactions, generating metallic iron as a stable and transportable solid. Subsequent oxidation of the reduced iron with steam releases high-purity hydrogen on demand, eliminating the need for molecular hydrogen production, compression, storage, or long-distance transport. Beyond hydrogen generation, metallic iron also shows potential as a novel combustible in advanced metal burners, Scheme 1. The paper presents experimental results obtained by combining the pyrolysis of different biomass feedstocks and solid carbonaceous materials with iron-based solids under controlled conditions, using thermogravimetric apparatus and lab-scale reactors. The kinetics of the redox reactions are analyzed, with particular attention also devoted to the physicochemical properties of the solid and gaseous products formed during the pyrolysis/redox reactions. Solid products are characterized in terms of phase composition, microstructure, porosity, and surface chemistry, highlighting the impact of biomass type and pyrolysis conditions on iron reduction efficiency and material evolution. The microstructure, porosity, and surface chemistry of iron-based solids indicate promising perspectives for the production of multifunctional materials, linking energy conversion and CCS within a circular framework.



Thermo-Catalytic Co-Pyrolysis of Waste Rain Tree Pods and Natural Rubber: Influence of Temperature, Feed Ratio, and Catalysts on Bio-Oil Yield and its properties

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

The present study explores the catalytic co-pyrolysis of rain tree pods (SS) and natural black rubber (NBR) in a semi-batch reactor for sustainable bio-oil production. Experiments were conducted over a temperature range of 450-650 °C, with NBR blending ratios of 10-40 wt.% and catalyst loadings of 5-15 wt.% using Al_2O_3 and ZnO. Physicochemical characterisation confirmed the suitability of SS and NBR as promising feedstocks for biofuel generation. Thermogravimetric analysis revealed that SS exhibited a maximum mass loss of 61.21% between 150 and 600 °C, while NBR showed elastomeric chain degradation of 43.33% between 170 and 470 °C. FTIR analysis further identified key functional groups, including C=C, C–H, –OH, and C=O, associated with both the biomass and polymer components. Thermal pyrolysis of SS resulted in a maximum bio-oil yield of 30.45% at 600 °C, which increased by 3.19% upon blending with 40 wt.% NBR. The produced pyrolysis oil demonstrated enhanced fuel quality, with increased carbon and hydrogen contents of 82.05% and 12.27%, respectively, alongside a 29.56% reduction in oxygen content. Moreover, the incorporation of 10 wt.% Al_2O_3 and ZnO improved the carbon content and higher heating value (HHV) of the pyrolysis oil, while significantly reducing its moisture content compared to thermally produced oil. The addition of NBR at varying ratios marginally increased char yield, whereas catalytic co-pyrolysis led to an approximate 8% increase in char production. The resulting catalytic char exhibited an alkaline pH and elevated ash content, suggesting its potential for soil amendment and fertility enhancement. The findings highlight the effectiveness of catalytic co-pyrolysis in converting waste biomass and rubber into value-added products, supporting sustainable resource utilisation and circular economy principles

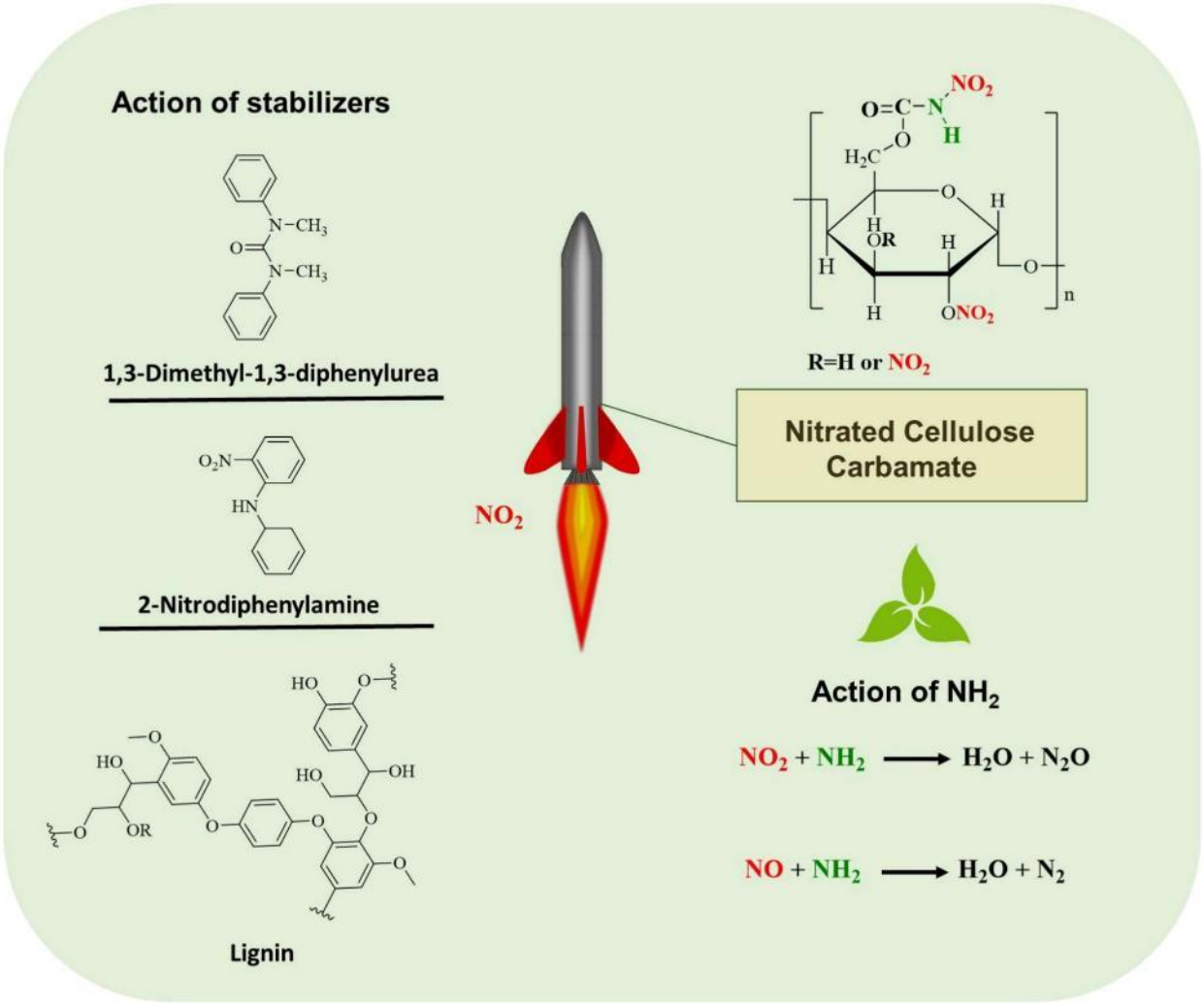
Unraveling the Characteristics and Pyrolysis Mechanism of Energetic Cellulose Carbamate Nitrate Supplemented with Organic Stabilizers

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

This study examines the stabilizing performance of lignin, extracted from Eucalyptus globulus, on nitrated cellulose carbamate (NCC), compared with conventional stabilizers 2-nitrodiphenylamine (2-NDPA) and 1,3-dimethyl-1,3-diphenylurea (C-II). FTIR spectroscopy confirms that lignin efficiently scavenges nitroxyl radicals generated during thermolysis of nitrocarbamate and nitrate ester bonds, thereby suppressing autocalytic decomposition. Thermal analyses (DSC and TGA) reveal a systematic increase in the main decomposition peak temperature following NCC < NCC/C II < NCC/lignin < NCC/2-NDPA, indicating progressively enhanced thermal stability. TGA-FTIR further demonstrates that stabilizer identity modulates the intensity of gaseous products without altering their composition. NH2 intermediates formed during NCC degradation facilitate nitrogen conversion and reduce toxic NO emissions. Collectively, these findings establish lignin as an effective bio-derived stabilizer, providing a sustainable alternative to conventional stabilizers while improving both thermal performance and safety of energetic cellulose derivatives.



Enabling a global view of reaction class in hydrocarbon pyrolysis with ReaxFF MD and machine learning

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

The reactive molecular dynamics using ReaxFF force field (ReaxFF MD) is becoming an effective means in unraveling the detailed reactions at molecular level for pyrolysis of realistic fuel mixtures [1]. However, understanding the pyrolysis chemistry of radical-driven process remains challenging due to the large number of intermediates and reactions involved. To discover the major pathways and kinetics contained in simulations, a new method of SRG-Reax (Skeleton Reaction network Generation for ReaxFF MD) was developed. SRG-Reax can predict reaction classes automatically in pyrolysis and oxidation mainly by machine learning on basis of reaction centers [2-3]. With SRG-Reax, the major species distribution in PP pyrolysis detectable experimentally become explainable by the predicted major reaction classes [4], which demonstrates the application potential of SRG-Reax in understanding the complex chemistry of polymer pyrolysis. The comparison of reaction class distributions predicted by SRG-Reax allows for explaining pyrolysis chemistry differences among similar fuel surrogates. The reaction class distributions for RP-3 surrogates in Fig. 1 shows a visual confirmation that the optimized 3-component model by machine learning and ReaxFF MD simulations [5] is more proper a surrogate to real fuel representative of the 45-component model of RP-3 fuel. Extension of SRG-Reax in predictions of oxidation reaction class [3] enhanses evaluation capability of diesel fuel surrogates with varied component structures and composition. In a word, in addition to as an potential alternative approach in generating the skeleton reaction network of pyrolysis directly from ReaxFF MD simulations for kinetic modeling, SRG-Reax can be an feasible approach in evaluation the global pyrolysis chemistry differences of fuel surrogates that helps in refining fuel surrogate or development of new fuels.

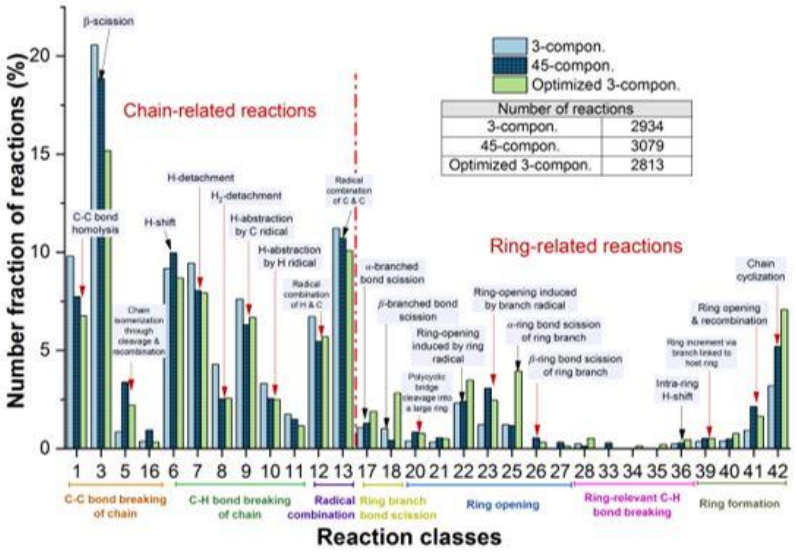


Fig. 1 Global reaction class distributions in pyrolysis automatically predicted by SRG-Reax for RP-3 fuel models of a 3-component surrogate, 45-component model, and a optimized 3-component surrogate

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Accounting for Structural Variability of Lignin in CRECK-S-B Kinetic Models for Pyrolysis across Different Extraction Methods

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Lignin is the most structurally heterogeneous component of lignocellulosic biomass, and its thermal decomposition behavior is strongly influenced by the method and severity of extraction. Lignins obtained through different isolation routes such as kraft, organosolv, soda, and milled wood processes exhibit substantial variations in elemental composition, functional group content, and interunit linkages. These structural differences pose a major challenge for the development of transferable kinetic models capable of reliably predicting lignin devolatilization behavior and product distributions during pyrolysis. In the CRECK-S framework, lignin is represented by three pseudo-components (LIGC, LIGH, and LIGO), whose distribution is determined via elemental CHO balance (Faravelli et al., 2010). This work presents the development of an improved kinetic modeling framework for lignin pyrolysis that accounts for structural variability arising from different extraction methods. A comprehensive literature survey was conducted to compile reported elemental analysis data and structural descriptors for a wide range of lignins, enabling the identification of systematic trends linking extraction severity to changes in lignin composition and thermal behavior. In particular, the analysis indicates that lignin extraction severity systematically alters elemental O/C ratios, which effectively differentiates the relative contributions of the carbon-rich, hydrogen-rich, and oxygen-rich pseudo-components used in the CRECK-S representation. Less severely treated lignins, such as milled wood and mild alkali lignins, retain a higher proportion of ether linkages (Zhao et al., 2019) and oxygenated functional groups, resulting in higher O/C ratios and earlier devolatilization. In contrast, lignins obtained through more severe extraction routes exhibit increased carbon content, enhanced structural condensation, and reduced oxygen functionality, leading to lower O/C ratios and higher thermal stability. These severity-dependent elemental trends can therefore be used as proxies for structural variability in the proposed kinetic model updates.

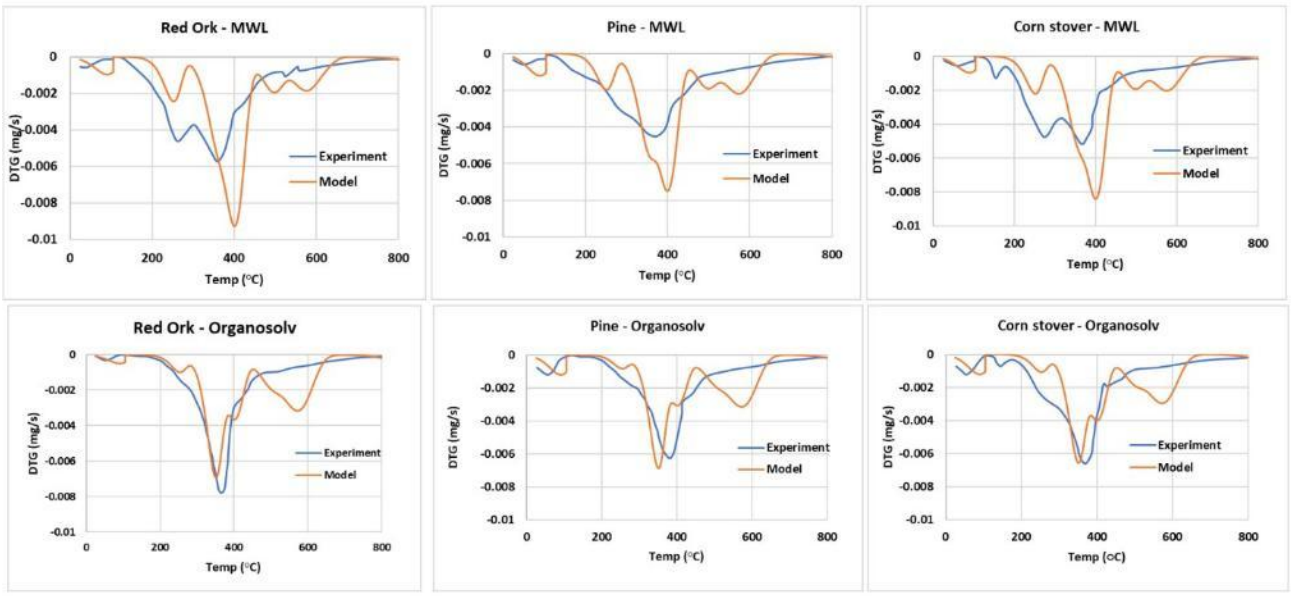


Figure 1 compares the thermal stability of different lignins extracted using milled wood and organosolv processes, with milled wood lignins having higher O/C ratios of 0.613, 0.537 and 0.574 for red ork, pine and corn stover compared to 0.393, 0.38 and 0.399 for organosolv lignins, respectively and a higher intensity of the low temperature DTG peak. The proposed framework aims to improve predictions of mass loss kinetics, volatile release rates, and detailed product distributions across different lignin types and biomass sources. Adjustment of global kinetic parameters and key reaction pathways according to elemental composition and structural characteristics in the proposed model will provide a more flexible and physically consistent representation of lignin pyrolysis. Preliminary simulations using the existing CRECK-S-B lignin model indicate lack of agreement with reported devolatilization trends and less consistency in the prediction of phenolic and aromatic product classes across lignins derived from varying extraction routes. The proposed approach represents a step toward more robust and transferable lumped kinetic models for lignin pyrolysis, bridging

the gap between experimentally observed structural heterogeneity and predictive thermochemical modeling. Figure 1: Comparison of thermal degradation characteristics of lignins extracted using milled wood process and organosolv process for different biomass types

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Evaluating the ReaxFF reactive force field for simulations of cellulose carbonization

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14:00-15:00 Session Posters P-S1F0: Fundamental pyrolysis reactions and kinetics/modelling; Applied pyrolysis: Biomass valorisation
Location: Ground floor

ABSTRACT

Capability for large-scale reactive molecular simulation would be beneficial for understanding the complex pyrolysis reactions of cellulose and other carbohydrates. Quantum mechanical methods are a tool of choice for accurately studying reactions, but their high computational cost limits their applicability. Reactive force fields, on the other hand, are a tool for studying reactions in large systems, involving sequential reactions and gradual structural changes. The ReaxFF reactive force field [1] has been one of the few tools applicable to pyrolysis and carbonization simulations of cellulose, and polymers in general. In our ongoing study on the chemical and structural pathways of cellulose carbonization, we utilize the ReaxFF force field for atomistic simulations and have observed several possible challenges in its ability to describe the reactions and structural changes. Our first modelling studies using (unbiased) molecular dynamics (MD) simulations [2, 3] showed predictions that were compatible with mechanisms proposed for cellulose fast pyrolysis, but the absence of reactions forming anhydrosugars, and particularly levoglucosan (LGA), were seemingly inconsistent with experimental results. To confirm that this is not a shortcoming of the force field or its parameter set, we are performing systematic force field evaluation for cellulose pyrolysis studies. Our work follows an earlier evaluation study related to cellulose condensed phase properties [4]. To assess the performance of ReaxFF, we generated a systematic set of glucose conformers and evaluated their optimized relative energies against density functional theory (DFT) calculations and the (non-reactive) CHARMM carbohydrate force field [5]. The analysis focused on the 4C1 and 1C4 ring forms due to the expected role of transitions between the two in the LGA forming reaction [6]. We observed that ReaxFF, using currently available parameter sets, was not able to sufficiently replicate the set of stable conformers found with both DFT and CHARMM optimizations. More accurate description of the early-stage pyrolysis reactions of cellulose, and carbohydrates in general, would thus benefit from dedicated force field training. Our resulting glucose conformer data can be utilized as a starting point for such training ReaxFF carbohydrate simulations. For more thorough evaluation, we also compare ReaxFF, DFT and CHARMM predictions for the potential energy surface of glycosidic linkage rotations in cellobiose, and the stability and structure of crystalline forms of cellulose, including microfibrils – the natural form of plant cellulose. The purpose of these analyses is to assess how well ReaxFF describes the dynamics of individual cellulose chains, and their relevant condensed phase structures, at elevated temperatures. The comparability between high-temperature simulations and pyrolysis in natural and industrial processes remains a central question for future studies. Systematic force field evaluation should, in our opinion, begin from the pyrolysis chemistry of simple sugars, especially that of glucose.

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Analytical pyrolysis of bamboo resiudes: a case in point of climate variation in North China Plain during 4th century BC

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

The natural structure of bamboo, characterized by hollow stems and densely interspersed nodes, contributes to its lightweight yet high-strength material properties through longitudinal fiber arrangement. Its rapid growth and widespread distribution further confer unique ecological, economic, and cultural values. As a vital biological resource, the distribution and utilization of bamboo reflect both technological craftsmanship and regional climatic conditions. A prevalent hypothesis in paleoclimatology posits that the North China Plain experienced a relatively warm and humid period during the 4th century BC—commonly referred to as the "Warring States Warm Period." Bamboo species exhibit notable sensitivity to climatic variations, including temperature and precipitation fluctuations, rendering them effective indicator species for climate change studies, providing direct archaeological evidence for climate variability of the North China Plain in that era. However, the severe degradation of excavated bamboo artifacts often eliminates their morphological features, thereby complicating their identification. To address this, the current study systematically employed pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) to analyze organic residues from tombs dating to the Warring States period in Yiyuan, Shandong Province, aiming to determine material composition and infer paleoenvironmental conditions. Py-GC/MS analysis conducted at a pyrolysis temperature of 500°C revealed that the thermal decomposition products predominantly consisted of phenolic compounds, identified as derivatives of guaiacyl (G-type) and syringyl (S-type) lignins, typical chemical signatures of Poaceae bamboo subfamily plants. Notably, a characteristic ion fragment at m/z 418 was stably detected in archaeological samples, corresponding to a compound identified as syringaresinol. Its presence aligns with modern bamboo material, indicating its specificity as a biomarker for bamboo. Integrating morphological characteristics, high lignin content, and biomarker detection, we preliminarily identified the sample as bamboo. Further plant anatomical analysis examined the microstructure using scanning electron microscopy (SEM). The observation of vascular bundle arrangements and fiber characteristics confirmed the residue as bamboo, which was consistent with the Py-GC/MS findings. Compared to traditional anatomical methods that rely on whole-structure preservation, Py-GC/MS requires only minute sample quantities, offers rapid analysis, and is particularly suited for highly degraded archaeological materials. The characterization of bamboo presence in Yiyuan during the 4th century BCE holds significant environmental implications. Located at the eastern fringe of the North China Plain, Shandong’s modern climate no longer favors extensive natural bamboo growth. Archaeological bamboo artifacts from this period strongly imply a regional climate that was subtropical and humid enough to sustain bamboo forests and facilitate resource utilization. This microarchaeological chemical evidence substantiates the macro-level paleoclimate model of the Warring States Warm Period, directly linking specific archaeological sites to regional climate transitions. In summary, this study not only introduces innovative methodological approaches within archaeobotany but also provides direct evidence supporting key paleoclimatic variations. It exemplifies the critical role of pyrolysis-based analysis in addressing complex environmental questions within archaeological science.

Cosmetic Residues in Greek Lekythoi from the Necropolis of Spina Investigated by Analytical Pyrolysis

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

The chemical analysis of ancient cosmetic products is challenging, as the original substances are rarely preserved, often leaving only trace residues sequestered within the pores of their containers. Iconographic and literary evidence is essential for associating these vessels with cosmetic and ritual practices and for obtaining information on the most widely attested perfumes and ingredients. However, such evidence does not always resolve the issue of their original contents, particularly given that the same containers may have been used for different products. Therefore, selective and sensitive analytical techniques are required to gain insight into their chemical composition and production processes. In this research, the contents of ancient Greek vessels known as lekythoi were investigated. These small balsamaria were recovered at Spina (Ferrara, Italy) from the Etruscan necropolis of Valle Trebba, inside a tomb belonging to a sub-adult individual, thus representing a closed funerary context. Samples were collected by scraping the inner bottom of the vessels and analyzed by gas chromatography–mass spectrometry (GC–MS) combined with analytical pyrolysis, the latter performed with and without TMAH. A wide array of pyrolytic markers characteristic of both animal- and plant-based materials was identified. Their origin could be associated with typical components of ancient cosmetic products, such as balms, ointments, and others [1,2]. Linear alkanes, long-chain fatty acids, and branched aryl hydrocarbons suggested the use of oils, fats, and/or waxes to create the perfume base, together associated with the presence of PAHs. The pyrolysates of several samples exhibited alkylated (benzo)thiophenes and sulfur dioxide suggesting the presence of sulfur-containing components. Other samples displayed nitrogen-containing compounds (pyrrole, indole, pyrocoll) indicative of proteinaceous materials, suggesting their involvement in the preparation of the final products. Although factors such as recipe complexity and ingredient variability complicate data interpretation, this study demonstrates that a targeted analytical approach can be successfully applied to obtain preliminary information on ancient cosmetics.

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Thermoanalytical techniques for the knowledge of plastic heritage: from chemistry to conservation

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

The introduction of plastics in the 19th century marked the onset of a revolutionary era, characterised by the widespread use of semi-synthetic and synthetic polymers across all fields of human activity. Originally used in the production of everyday and technological objects, these materials soon expanded into art and design. Today, plastic artworks and design objects represent a significant component of modern and contemporary museum collections. However, the limited long-term stability of plastic materials poses major challenges, that are difficult to address also due to their heterogeneous and complex composition. The development of effective analytical and investigative methods, recognised as a priority in Heritage Science, is therefore even more critical for plastic artworks, given their vulnerability, heterogeneity, and material complexity. These factors hinder the standardization of reliable and repeatable conservation and restoration procedures. Within the interdisciplinary project PRIN2022 PERSPECTIVE—PolymEr Research Studies for PreventivE Conservation Through non-invasIVe analytical strategiEs (https://perspective.cnr.it), aimed at developing multimodal analytical approaches for the study, monitoring, and preservation of plastic heritage, several samples from 20th-century plastic objects in the Triennale Milano (Milan) collection were analysed, and the results are presented in this work. The adopted analytical protocol relies on thermoanalytical techniques, namely analytical pyrolysis–gas chromatography–mass spectrometry (Py-GC/MS) and evolved gas analysis–mass spectrometry (EGA-MS), which have been reported in the literature as unsurpassed methods for the molecular-level characterization of heritage plastics and textiles with high chemical detail [1,2]. The results achieved from this diagnostic campaign enabled the identification of different materials representative of the 20th-century universe, including cellulose acetate [3], polyurethanes [4], and polycarbonates [1], added with various plasticizers ranging from phthalates to adipates. Most importantly, comparison of the thermoanalytical results from the Triennale samples with those obtained for artificially aged reference materials developed within the PERSPECTIVE project allowed us to assess the degradation state of the investigated artworks. Acknowledgments The Centre for the Instrument Sharing of the University of Pisa (CISUP); Grazia De Cesare from the Academy of Fine Arts of L'Aquila (Italy), and Rafaela Trevisan from the Triennale Design Museum of Milan (Italy). Funding was provided by Italian Ministry for Research (MUR), PRIN2022 project "PERSPECTIVE - PolymEr Research Studies for PreventivE Conservation Through non invasIVe analytical strategiEs", https://perspective.cnr.it coordinated by Francesca Rosi CNR-SCITEC Perugia.

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Py-GC-MS in Archaeometry: Identifying Materials, Degradation, Restorations, and Authenticity Markers in Cultural Heritage

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Analytical pyrolysis coupled with gas chromatography–mass spectrometry (Py-GC-MS) has become a powerful tool in the molecular investigation of organic materials in artworks and archaeological artefacts. Its ability to directly analyse microsamples without chemical pre-treatment allows researchers to access the insoluble and cross-linked fractions of materials such as resins, drying oils, proteins, polysaccharides, and synthetic polymers. Beyond identifying the original materials employed by artists and artisans, Py-GC-MS provides crucial insights into degradation products, ageing mechanisms, and residues from past restoration campaigns. With appropriate experimental setups, the technique can be combined with accelerated ageing under UV radiation and controlled temperature to reproduce natural degradation processes. These studies are fundamental to understanding how both ancient and modern materials evolve over time, helping conservators to predict their stability and design compatible preservation strategies. The technique also supports art historians and conservators by revealing anachronistic or incompatible compounds that can indicate later interventions, restorations, or even modern falsifications. Through the characterization of materials ranging from archaeological adhesives, ambers, and lacquers to binders and coatings in paintings, Py-GC-MS contributes to reconstructing artistic practices, authenticating cultural objects, and documenting the transformation of organic matter through time. Recent instrumental advances, including thermally assisted derivatization and evolved gas analysis (EGA-MS), have expanded its analytical potential, enabling semi-quantitative studies of complex ageing and interaction phenomena. As a minimally invasive, highly sensitive approach, Py-GC-MS bridges chemistry, conservation, and art history—offering a comprehensive tool for the preservation, interpretation, and safeguarding of cultural heritage.

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Air Quality Monitoring in Museum Environment Using Magic Chemisorbers

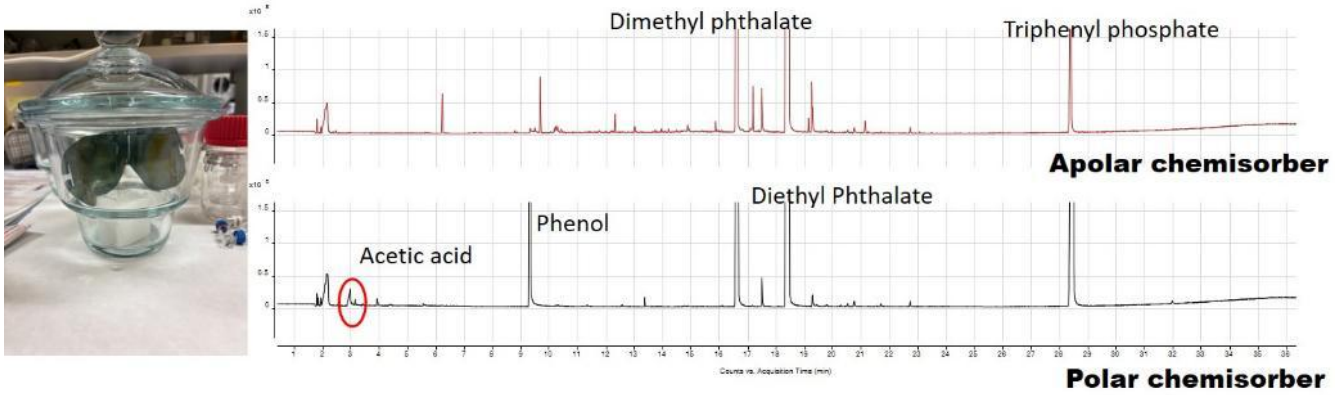
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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Magic Chemisorbers are solid-phase extraction (SPE) devices useful for analyzing trace amounts of volatile compounds in air or aqueous solutions. Their distinctive feature, compared to other solid-phase extraction devices, is the use of a pyrolyzer to desorb the extracted components, to be analysed by gas chromatography/mass spectrometry (GC/MS). Although applications have been reported in the fields of food analysis, materials emissions, and environmental analysis, only few applications have been reported in the field of cultural heritage. This study presents the results of the first air quality monitoring campaign conducted at the Deutsches Museum in 2025. Polar and apolar Magic Chemisorbers were used to investigate air composition in three showcases and in a historical car. Prior to the in situ campaign, laboratory tests were conducted on cellulose nitrate and cellulose acetate objects to evaluate the methodology´s ability of these devices to detect problematic plastic emissions and to gain experience for in situ applications. The results are discussed and compared with those obtained using Radiello passive sampling devices exposed in parallel. The data indicate that Magic Chemisorbers were able to detect several target pollutants of interest both under laboratory conditions and during in situ measurements. In laboratory tests, compounds associated with the degradation of malignant plastics were identified, including camphor and nitrogen oxide for cellulose nitrate, and acetic acid, phthalates, and triphenyl phosphate for cellulose acetate (Fig. 1).



During the in situ monitoring in display cases and inside a historic car, the results were more complex to interpret due to the presence of multiple potential emission sources. These were related both to the materials used in the construction of the display cases—often based on wood-derived products—and to the heritage objects themselves, which are frequently made of natural or synthetic organic materials. Aldehydes, phthalates, organic acids, and acetates are typical volatile compounds associated with the degradation of these materials, and were also detected in this study. No clear overall superiority has been established between polar and apolar Chemisorbers, as their performance varied depending on the specific case study; consequently, the combined use of both types is advisable to obtain a more comprehensive qualitative characterization of air composition. Magic Chemisorbers proved to be a useful tool for the qualitative characterization of air composition and represent a promising technique for preventive conservation. They are effective for preliminary screening and selection of case studies for further investigation with more costly techniques, supporting an efficient use of museum resources. Their application appears particularly suitable for laboratories that routinely perform Py-GC/MS analyses and are interested in extending their activities to air quality monitoring. Fig 1: Chromatograms obtained using Magic Chemisorbers during laboratory tests on a cellulose acetate historical object from the 1940ies. Plastic additives (dimethyl and diethyl phthalate and triphenyl phosphate) were detected by both polar and apolar Chemisorbers, while acetic acid was only detected by the polar one.

Scientific Analysis of Lacquerware Bearing Stamp Patterns Excavated from Different Archaeological Sites

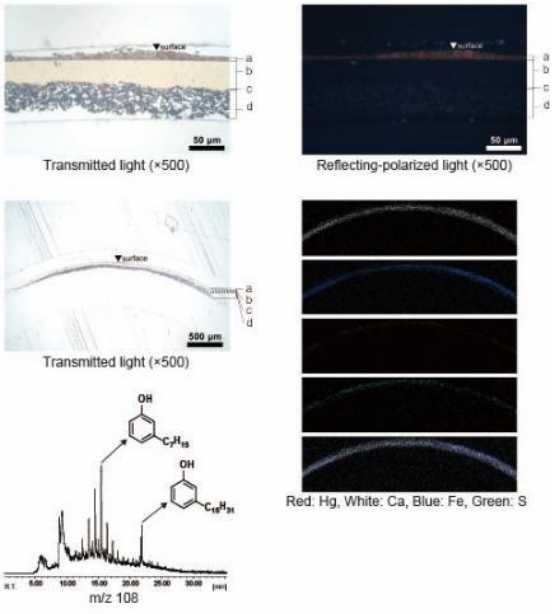
Ryuta Tanaka (Graduate School of Science and Technology, Meiji University, Japan) Takayuki Honda (School of Science and Technology, Meiji University, Japan) Kaori Shimizu (School of Humanities and Social Science, Iwate University, Japan)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Lacquerware, prized for its durability, adhesive properties, and decorative appeal, has played a vital role from ancient times to the modern era as both ceremonial objects and daily necessities. Therefore, elucidating the materials and production processes of lacquerware provides a crucial foundation for understanding the historical and cultural context of the period. During the Kamakura period (1185–1333), while high-end lacquerware like maki-e lacquerware—decorated by painting patterns with lacquer and sprinkling metallic powders like gold or silver on top—was produced, mass production of common tableware also advanced. Alongside this, stamped patterns emerged as a decorative technique enabling efficient production and uniform decorative quality. Stamped patterns are a lacquerware decoration technique where designs—such as plant motifs, animal motifs, or abstract patterns—are applied using carved stamps. This technique was widely used from the late 13th to the 14th century. However, due to the difficulty in expressing complex designs and the unknown materials used for the stamps, many aspects of its production techniques and material properties remain unclear [1]. This study aimed to elucidate the production techniques of stamped patterns by analyzing and comparing lacquered fragments from the Kamakura period, featuring stamped patterns, lacquer painting, and multicolored designs, excavated from an archaeological site in Kamakura City, Kanagawa Prefecture, using scientific methods. The analytical methods employed included cross-section observation under transmitted light and reflected polarized light for examining the layered structure, energy-dispersive X-ray fluorescence (ED-XRF) for elemental composition analysis, and pyrolysis gas chromatography-mass spectrometry (Py-GC/MS) for identifying organic materials. Cross-section observations revealed a four-layer structure in transmitted light. Under reflected polarized light, red interference colors were observed in the upper layer, suggesting the use of red pigments. Py-GC/MS analysis revealed a group of peak-shaped peaks with 3-heptylphenol as the peak at m/z 108 and a peak for 3-pentadecylphenol in the ion chromatogram extraction results, suggesting the use of Toxicodendron vernicifluum from Japan, China, or Korea. The detection of palmitic acid (C16) and stearic acid (C18) in the m/z 60 ion chromatogram extraction suggested the use of drying oils. Furthermore, differences in the intensity ratios of fatty acid peaks were observed in samples of stamped patterns, lacquer paintings, and multicolored patterns. In drying oil analysis using Py-GC/MS, the peak intensity and peak ratio of fatty acid-derived components serve as effective indicators for identifying drying oil types [2]. Based on this, the differences in fatty acid peaks observed in this study also suggest that the lacquer preparation methods and added materials may have differed for each decorative technique, providing important clues for elucidating the production techniques of stamped lacquerware.



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Artificial and natural UV aging of beeswax: new insights into its chemical composition from Py-GC/MS and SPME-GC/MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Beeswax was widely used in antiquity due to its versatile properties and nevertheless its chemical lability was reported in the literature [1], [2], [3], its long-term degradation remains under-researched. This study addresses this gap by investigating the photo-oxidative susceptibility of beeswax. An analytical approach, integrating double-shot Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS), and Solid-Phase Microextraction Gas Chromatography/Mass Spectrometry (SPME-GC/MS) was employed. Double-shot Py-GC/MS was used to sequentially analyse volatile fraction followed by the polymer matrix, with an online UV irradiator enabling real-time monitoring of degradation products. SPME-GC/MS tracked the evolution of volatile organic compounds under natural aging conditions. The results indicate that beeswax undergoes significant chemical degradation, yielding smaller, oxidized compounds upon exposure to UV and solar radiation [4].

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From Waste to Resources: Product Valorization and Elemental Evolution during Hydrothermal Liquefaction of Food Waste

Rui Bao (University of Bologna & Xi'an Jiaotong University, China) Shuzhong Wang (Xi'an Jiaotong University, China) Cristian Torri (University of Bologna, Italy)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis
Location: First Floor

ABSTRACT

Hydrothermal liquefaction (HTL) provides a promising pathway for the efficient valorization of food waste (FW) owing to its ability to directly process wet biomass and simultaneously recover energy and nutrients. In this study, the product distribution, fuel characteristics, elemental migration, and environmental stabilization behaviors during HTL of FW were systematically investigated at 250–370 °C. The results demonstrated that temperature played a critical role in regulating multi-phase product evolution and resource recovery. The maximum bio-oil yield reached 36.75% at 310 °C, with a high heating value of 39.68 MJ/kg and an energy recovery efficiency of 78.55%, indicating excellent fuel potential. Elevated temperatures promoted deoxygenation, aromatization, and the formation of light hydrocarbon fractions in bio-oil. Elemental migration analysis revealed distinct phase-selective behaviors of N, P, K, and metals during HTL. Nitrogen was progressively enriched in the bio-oil phase, accompanied by the transformation of protein-derived nitrogen into stable heterocyclic compounds such as pyridines and pyrroles. In contrast, phosphorus was predominantly retained in biochar and gradually converted into stable apatite minerals, while potassium preferentially migrated into the aqueous phase due to its strong hydrophilicity. Moreover, heavy metals were transformed from reactive fractions into stable residual forms, significantly reducing environmental risks and contamination potential. The obtained products exhibited diversified utilization potentials, including renewable liquid fuel, nutrient-rich liquid fertilizer, adsorbent materials, and clean gaseous energy. This work provides mechanistic insights into the comprehensive utilization of FW via HTL and highlights the synergistic realization of energy recovery, nutrient recycling, and environmental stabilization.

Field Applicability Evaluation of Size-Segregated Microplastics in Air in Representative Metropolitan Areas Using Analytical Pyrolysis–GC/MS

Soyeon Kim (Korea Testing & Research Institute, South Korea) Muhyun Jung (Korea Testing & Research Institute, South Korea) Nayoung Kim (Korea Testing & Research Institute, South Korea) Kyeonglo Lee (Korea Testing & Research Institute, South Korea) Hojin Choi (Korea Testing & Research Institute, South Korea) Juhee Lee (Korea Testing & Research Institute, South Korea)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Microplastics in air have recently gained attention as an emerging environmental contaminant with potential implications for human exposure and atmospheric transport. Reliable characterization of microplastics in air requires analytical methods that can be effectively applied to field-collected samples while accounting for particle size and site-specific environmental characteristics. Analytical pyrolysis coupled with gas chromatography and mass spectrometry (Py-GC/MS) offers a powerful approach for polymer-specific identification and quantification; however, its field applicability for size-segregated microplastics in air remains insufficiently evaluated. In this study, the field applicability of analytical pyrolysis–GC/MS for microplastics in air was assessed using size-segregated particulate matter samples collected at representative sites in the Seoul metropolitan area. Sampling was conducted separately for PM10 and PM2.5 fractions to evaluate particle size–dependent characteristics of microplastics in air. Prior to instrumental analysis, a series of pyrolysis-oriented pretreatment experiments was performed to optimize sample handling and thermal degradation conditions for the analysis of microplastics in air, focusing on minimizing matrix interference while preserving polymer-specific pyrolysis signals. Field samples were collected from two contrasting environments. A residential area in Gwacheon, characterized by low industrial activity and proximity to Mt. Gwanak, was selected to represent an urban background influenced by natural surroundings. In contrast, an industrial complex in Ansan was selected to represent an industrialized urban environment with potential contributions from manufacturing activities and traffic-related sources. These sites enabled comparative evaluation of microplastics in air under different regional and environmental conditions. Py-GC/MS analysis targeted characteristic pyrolysis products and marker ions of major polymer types commonly reported in microplastics in air. The occurrence and composition of microplastics were evaluated according to sampling site and particle size fraction, allowing assessment of size-dependent distribution patterns and site-specific features. The results demonstrate distinct differences in polymer composition between PM10 and PM2.5 fractions as well as between residential and industrial environments, highlighting the importance of particle size–resolved sampling for microplastics in air assessment. This study demonstrates that analytical pyrolysis–GC/MS, combined with optimized pretreatment and size-segregated sampling, is an effective and practical tool for field-based characterization of microplastics in air. The findings provide methodological insights for future monitoring studies and contribute to the development of standardized approaches for microplastics in air analysis.

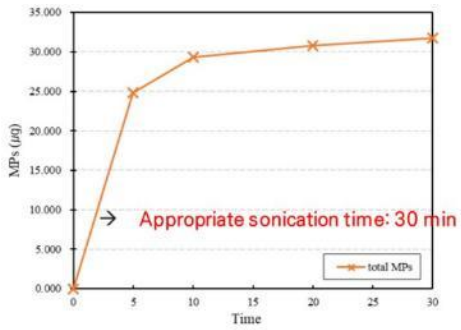


Fig. Total Microplastic (MP) Mass Released by Sonication Time

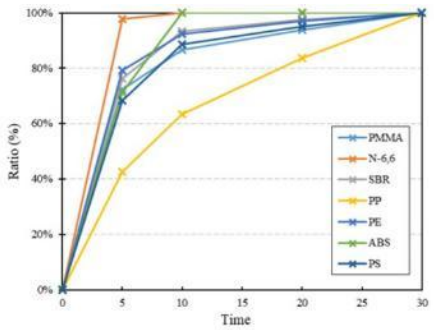


Fig. Release Ratio of Individual Polymers According to Sonication Time

Quantification Table(μg)

No.	Polymer	PMMA	N-6,6	SBR	PP	PET	PVC	N-6	PC	PAN	PE	ABS	PS
	R.T. (min)	3.527	4.359	4.925	5.013		8.703				13.947	15.102	16.393
1	MP_{10} 5 min	0.640	1.837	7.437	0.225	-	3.267	-	-	-	13.709	0.173	0.768
2	MP_{10} 10 min	0.126 (< LOD: 0.214)	0.043 (< LOD: 0.309)	1.664	0.110 (< LOD: 0.126)	-	3.061	-	-	-	2.284	0.070 (< LOD: 0.153)	0.227
3	MP_{10} 20 min	0.065 (< LOD: 0.214)	-	0.396	0.108 (< LOD: 0.126)	-	1.205	-	-	-	0.823	-	0.072 (< LOD: 0.100)
4	MP_{10} 30 min	0.054 (< LOD: 0.214)	-	0.242	0.086 (< LOD: 0.126)	-	0.819	-	-	-	0.502 (< LOD: 0.622)	-	0.055 (< LOD: 0.100)

Characterization of Microplastics in Ambient Air and Their Relationship with PM2.5 Organic Components Using Pyrolysis–GC/MS

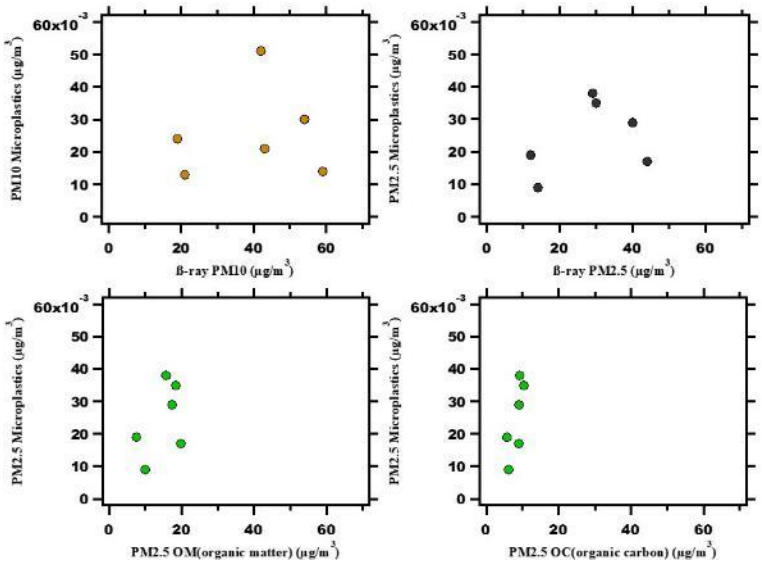
Soyeon Kim (Korea Testing & Research Institute, South Korea) Muhyun Jung (Korea Testing & Research Institute, South Korea) Nayoung Kim (Korea Testing & Research Institute, South Korea) Kyeonglo Lee (Korea Testing & Research Institute, South Korea) Hojin Choi (Korea Testing & Research Institute, South Korea) Juhee Lee (Korea Testing & Research Institute, South Korea)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Microplastics in air have recently emerged as an important environmental concern due to their potential impacts on human exposure and atmospheric processes. While analytical pyrolysis coupled with gas chromatography and mass spectrometry (Py-GC/MS) has been increasingly applied for polymer-specific identification of microplastics, its field applicability and its relationship with organic components of fine particulate matter remain insufficiently understood. In particular, the role of microplastics within the organic fraction of PM2.5 has not been systematically evaluated under real atmospheric conditions. In this study, the field applicability of analytical pyrolysis–GC/MS was evaluated for the characterization of microplastics in air, with a specific focus on their compositional features and spectral characteristics within PM2.5. Size-segregated particulate matter samples (PM10 and PM2.5) were collected at representative metropolitan sites in the Seoul metropolitan area, including a residential area in Gwacheon influenced by natural surroundings and an industrial area in Ansan affected by industrial and traffic-related emissions. Prior to instrumental analysis, pyrolysis-oriented pretreatment experiments were conducted to optimize sample handling and thermal degradation conditions, aiming to minimize matrix interference while preserving polymer-specific pyrolysis signals. To investigate the relationship between microplastics and organic aerosol components, PM2.5 samples collected in Ansan were analyzed in parallel using a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), an OC/EC analyzer (OCEC), and Py-GC/MS-based microplastic analysis. Organic matter (OM) measured by HR-ToF-AMS exhibited pronounced short-term variability at high temporal resolution, reflecting the influence of local emissions and secondary organic aerosol formation. In contrast, organic carbon (OC) derived from filter-based OCEC analysis showed smoother temporal variations due to its integrated sampling characteristics. Microplastic concentrations in PM2.5 ranged from approximately 9 to 38 ng/m3, corresponding to about 0.04–0.16% of the PM2.5 mass. Although the absolute mass contribution of microplastics was minor, periods with elevated microplastic concentrations generally coincided with higher average OM and OC levels. Scatterplot analyses further indicated that microplastic concentrations tended to increase under conditions of enhanced PM mass and organic dominance, suggesting that microplastics are not entirely independent of the organic fraction of PM2.5. However, short-term OM peaks were not always accompanied by increases in microplastic concentration, reflecting differences in formation mechanisms and temporal response characteristics between gaseous organic aerosols and solid polymer particles. Characteristic pyrolysis products and marker ions enabled the derivation of polymer-specific spectral features of microplastics in air. The results suggest that microplastics can be conceptualized as a distinct but co-varying subcomponent within the organic fraction of PM2.5 rather than as an isolated particulate species. This study demonstrates that analytical pyrolysis–GC/MS is a practical and effective tool for field-based characterization of microplastics in air and provides insights into their compositional role within fine particulate matter. The findings contribute to the development of standardized analytical frameworks and improved understanding of microplastics in atmospheric environments.



Microwave-assisted treatment to convert commercial polyethylene microbeads into a liquid suspension used as reference material for Py-GC-MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Due to its high sensitivity and selectivity, Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) is a powerful tool for quantifying micro- and nanoplastics (MNPs) in environmental and biological samples at sub-microgram levels. Polymers can be diluted using inert solids or by dissolving them in a solvent. The latter is often unfeasible because many polymers, especially polyolefins such as polyethylene (PE), are poorly soluble in common organic solvents. For this purpose, microwave-assisted extraction (MAE) has been explored by Hermabessiere & Rochman (2021)[1] as an alternative for extracting polyolefins from environmental samples, achieving high recovery rates (>90%) with dichloromethane (DCM) under high-pressure, high-temperature conditions. The effects of this treatment on the particles' physicochemical properties remain unexplored, as does its applicability to PE of varying characteristics. Additionally, recent studies have examined how different polymer reference materials affect the accuracy of Py-GC-MS when analyzing real samples.[2] This is especially true for PE, which encompasses polymers with very different properties (e.g., low-density PE (LDPE), high-density PE (HDPE), ultra-high-molecular-weight PE (UHMWPE)). More recently, Chae & Choi (2025)[3] explored how PE of different molecular weights exhibits different pyrolysis behaviors, leading to distinct Py-GC-MS responses. This overlooked factor can introduce additional uncertainty into MNP quantification when analyzing samples with known polymer characteristics, such as commercial materials and ecotoxicological assessments. In this ongoing work, we use the MAE strategy to produce a polymer suspension in DCM from commercial PE microbeads. This suspension can later serve as a reference material to build calibration models for Py-GC, achieving a low limit of quantification without requiring expensive weighing equipment. The tests are performed using HDPE and UHMWPE microbeads (130 and 50 µm, respectively) to assess the method's efficiency across different starting materials. All particles are characterized before and after the MAE treatment using Fourier-Transform Infrared Spectroscopy (FTIR, for chemical composition), Scanning Electron Microscopy (SEM, for size and morphology), Py-GC-FID (for pyrolysis behavior), Dynamic Light Scattering (DLS, for Zeta potential), and Differential Scanning Calorimetry (DSC, for thermal transitions). This array of analyses allows us to explore the impact of thermal treatment on the physical-chemical properties of PE particles, the mechanisms underlying the stability of the PE suspension, and, lastly, the extent to which different PE types yield distinct pyrolysis products in Py-GC-MS. MAE treatment successfully produced a PE suspension in DCM, yielding a polydisperse suspension with an average particle size below 10 µm and a recovery rate of 95%. Moreover, HDPE and UHMWPE showed distinct pyrolysis profiles, with different alkane, alkene, and dialkene ratios, highlighting the importance of carefully selecting the reference polymer when building regression models for the analysis of environmental samples.

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Soot formation and polycyclic aromatic hydrocarbons in soot during p-cymene pyrolysis

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Aviation decarbonization is a key challenge in mitigating climate change due to its emissions of greenhouse gases and fine particulate matter, as well as its strong reliance on energy-dense liquid fuels and the limited availability of scalable low-carbon alternatives compatible with existing infrastructure. In this context, the European Union has established strict mandates for the progressive use of Sustainable Aviation Fuels (SAF). p-cymene, a terpenoid compound with potential as a SAF, has emerged as a promising candidate in this transition. To support its evaluation, it is necessary to study its thermal conversion and the products it generates. Therefore, this work investigates p-cymene pyrolysis and the formation of light gases, soot, and polycyclic aromatic hydrocarbons (PAHs) in soot. Experiments were performed in a flow-reactor installation using a p-cymene concentration of 2000 ppm over a temperature range of 973–1473 K. Selected light gases, such as, hydrogen and acetylene, were analyzed using an Agilent Technologies gas chromatograph. Soot particles were collected at the reactor outlet using a quartz fiber filter with a pore size below 1 μm. The collected soot was subjected to Soxhlet extraction to analyze the 16 EPA-priority PAHs, which were quantified using an Agilent 7890A gas chromatograph coupled with a 5975C mass selective detector (GC–MS). The results indicate that p-cymene exhibits a high soot formation propensity. Soot yield increases with rising temperature, whereas the yields of gaseous species and PAHs contained in soot reach a maximum. At all temperatures, low-molecular-weight PAHs (LMW) (2–3 rings) dominate, followed by medium-molecular-weight PAHs (MMW) (4 rings) and, to a much lesser extent, high-molecular-weight PAHs (HMW) (5-6 rings). The LMW fraction is mainly dominated by naphthalene (NAPH), acenaphthylene (ACNY), and phenanthrene (PHEN), whereas fluoranthene (FANTH) and pyrene (PYR) are the most abundant compounds within the MMW group, and benzo[a]pyrene (B[a]P) is the dominant species among the identified HMW PAHs.

Multi-analytical and multi-matrix approach for microplastics characterization: the synergy of Py-GC/MS and μ-FTIR

Elena Gregoris (Institute of Polar Sciences, National Research Council of Italy (ISP-CNR), Italy) Beatrice Rosso (National Interuniversity Consortium for Environmental Sciences of Italy (CINSA), Italy) Fabiana Corami (Institute of Polar Sciences, National Research Council of Italy (ISP-CNR), Italy) Andrea Gambaro (Dept. Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Italy)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

The ubiquitous presence of microplastics (MPs) in the environment represents a global challenge, requiring accurate analytical protocols for their identification and quantification. MPs must be unequivocally and unambiguously identified and quantified. Vibrational spectroscopy enables optimal identification and morphological analysis of MPs, micro- and nanoplastics, and plastic additives. However, the size's LOD is related to the instrument and the pretreatment employed. Additionally, in Micro-FTIR, dark or opaque particles, such as tire wear particles, can be challenging to identify. Conversely, Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS) provides robust mass-based quantification and detailed polymer identification, including additives, but loses all information regarding particle shape and size distribution; and it requires a meticulous selection of specific pyrolytic tracers and quantification ions to avoid over- or underestimation of concentrations caused by matrix interferences or co-eluting peaks. Our research group is implementing an integrated analytical workflow that leverages the strengths of both spectroscopic and thermoanalytical platforms. The core of our approach is the sequential or parallel application of EGA/Py-GC/MS (Frontiers EGA-Py 3030D, coupled with Agilent GC 8890 – MS 5977c) and microFTIR (Nicolet iN 10, Thermo Fisher Scientific), on samples of various environmental matrices. This synergy allows us to cross-validate results. Each matrix requires specific pre-treatment and purification steps, optimized to maintain the integrity of the plastic particles for subsequent analysis. Preliminary applications focus on samples collected from various environmental compartments (e.g., sediments, snow), highlighting that the integration of Py-GC/MS significantly improves the quality of the results, cross-validating spectroscopic identification. This integrated approach significantly enhances the robustness of our findings compared to standalone techniques, providing a more comprehensive assessment of the plastic mass balance. However, several methodological challenges are currently under evaluation, including the potential influence of the pretreatment employed formicro-FTIR analysis, on the overall recovery of target polymers in Py-GC/MS. Investigating this aspect is crucial to enable a truly sequential analytical workflow (performing Py-GC/MS directly on the same sample previously analyzed by micro-FTIR), thereby avoiding the need for sample splitting during the preparation phase. Furthermore, we are focusing on optimizing the sample transfer efficiency from the filter to the pyrolyzer cup. Addressing these technical hurdles is essential to harmonize spectroscopic and thermoanalytical data, ultimately providing a more accurate and intercalibrated assessment of microplastic pollution across the environmental compartments investigated.

References

1 La Nasa et al., 2020. https://doi.org/10.1016/J.JAAP.2020.104841. 2 Dümichen et al, 2017. https://doi.org/10.1016/j.chemosphere.2017.02.010. 3 Elert et al. 2017 https://doi.org/10.1016/j.envpol.2017.08.074.

Characterization and quantification of Tire and Road Wear Particles (TRWP) in environmental samples: Integration of Py-GC/MS and Rock-Eval® techniques

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Analytical techniques based on pyrolysis are now widely recognized as powerful and sensitive tools for characterizing and quantifying polymers in environmental samples. Among all microplastics, Tire and Road Wear Particles (TRWP) form a distinct class of polymeric microparticles, generated through the friction between tires and road surfaces during driving and braking. Tires are complex industrial formulations, composed of rubber polymers such as Styrene-Butadiene copolymer (SBR), and Butadiene rubber (BR), alongside carbon black, silica, vulcanisation agents, and various additives. Despite their prevalence, the transport pathways, environmental fate, and toxicological impacts of TRWP remain poorly understood. However, TRWP are believed to contribute significantly to the microplastics (MP) load in terrestrial environments. In 2017, an ISO/TS 21396:2017 technical specification based on pyrolysis coupled to gas chromatography and mass spectrometry (Py-GC/MS) was published, establishing several recommendations for TRWP quantification. However, challenges remain, and several improvements are still ongoing with significant refinements published since. In this work, a robust and thorough instrumental development was carried out, integrating two thermal analytical devices based on pyrolysis: Rock-Eval® and Py-GC/MS (CDS 6200 Pyroprobe Pyrolyzer). Polymer standards and deuterated internal standards were used to calibrate the instruments. Pyrolysis conditions were optimized, and the complementarity of both instruments was especially useful to accelerate this step. Characteristic dimers were proposed, and specific ions (both target and diagnostic m/z) were identified for Py-GC/MS analysis. Once the method was optimized, it was applied to real tire formulations representative of the current market. A dedicated sample preparation workflow was developed, including cryomilling. The method demonstrated satisfactory recoveries, with biases remaining below 20% in soil samples spiked with 200 µg of crushed tire material. Additionally, ageing processes were examined through a comparative analysis of the inner and outer layers of a tire retrieved from a landfill. The inner layer, protected from weathering, exhibited a distinctly different molecular fingerprint compared to the outer layer, which had undergone environmental exposure. These findings highlight specific alterations in the outer layer and raise concerns regarding the leaching of compounds into the environment during tire ageing.

Quantitative Analysis of Trace PTFE in Polymer Materials by Double-Shot Pyrolysis-GC/MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Per- and polyfluoroalkyl substances (PFAS) are increasingly regulated because of their persistence and potential risks to human health. With the proposed EU Packaging and Packaging Waste Regulation (PPWR), polymeric PFAS such as polytetrafluoroethylene (PTFE) are now subject to stricter regulatory requirements in packaging materials, driving the need for reliable analytical methods for complex polymer systems. For polymeric PFAS, qualitative analysis by pyrolysis-GC/MS (Py-GC/MS) and quantification of total fluorine by combustion ion chromatography (CIC) are commonly used. However, CIC has limitations in the analysis of mixed polymer systems. In this study, we aimed to improve the quantitative performance of Py-GC/MS for polymeric PFAS by optimizing analytical conditions for PTFE in different polymer matrices. Polystyrene (PS)-0.17 % PTFE mixture was prepared by weighing 500 mg of PS powder and 0.85 mg of PTFE powder and homogenizing them at 2000 rpm for 1 h using a rapid cryogenic mill (IQ MILL-2070). Nylon-6,6 (N66)-0.18 % PTFE mixture was prepared in the same manner using 500 mg of N66 powder and 0.90 mg of PTFE powder. Measurements were carried out using a Py-GC/MS system equipped with a pyrolyzer (EGA/PY-3030D, Frontier Laboratories), an Auto-Shot Sampler (AS-2020E, same above), a Selective Sampler for temperature-fractionated gases (SS-2010E, same above), and a MicroJet Cryo-Trap (MJT-2030E, same above). A deactivated pre-column (0.25 mm i.d., 2 m length, same above) was connected to a metal capillary separation column (5% diphenyl polysiloxane, 30 m length, 0.25 mm i.d., 0.25 µm film, same above). Conventional Py-GC/MS (PY) measurements were carried out by introducing the mixture sample into a furnace preheated at 650 °C, followed by cryogenic trapping and chromatographic separation of pyrolyzates. For double-shot Py-GC/MS (DS), the sample was initially heated from 100 to 540 °C to remove PS- or N66-derived fractions. Subsequently, the residue containing PTFE was pyrolyzed at 650 °C, and the pyrolyzates were cryogenically trapped and analyzed. Quantitative analysis was performed using the peak area of the extracted ion chromatogram (EIC) at m/z 81 which is a characteristic ion of tetrafluoroethylene derived from PTFE. Reproducibility was evaluated by five repeated measurements of 1 mg each of mixture samples. 10 µg of PTFE standard sample was measured before and after the measurements of the mixture samples, and responses were compared after correction by the sample amount. Pyrograms of the PS-based sample obtained by both PY and DS methods are shown in Figure 1. In PY, various pyrolyzates derived from both PTFE and the polymer matrix were detected. In contrast, DS showed very simple pyrograms, with tetrafluoroethylene being the dominant peak, indicating the significant reduction of polymer matrix interferences. However, even in the DS measurements, the N66-based sample showed a lower response of tetrafluoroethylene than the PS-based sample. This difference is likely attributable to co-pyrolysis of PTFE with partially undecomposed N66 remaining after the 1st heating step in DS. Since the reduction of the response of tetrafluoroethylene was much smaller in DS compared to PY, the use of double-shot pyrolysis improves the quantification of trace PTFE in polymer materials.

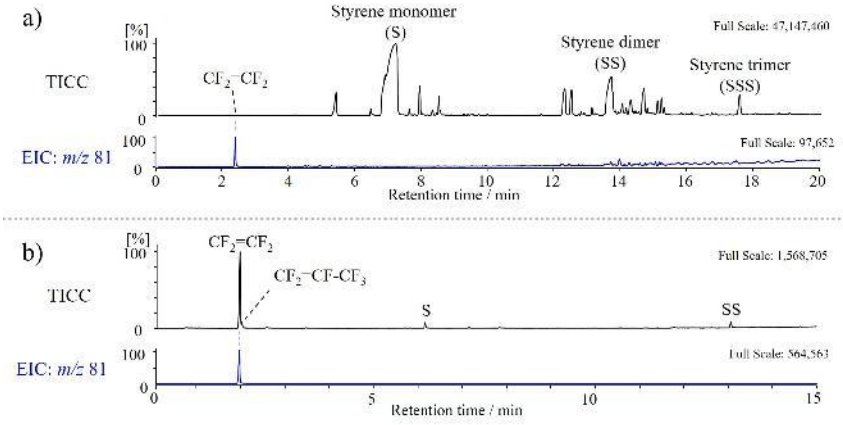


Figure 1. Pyrograms of PS-0.17 % PTFE measured by a) PY and b) DS.

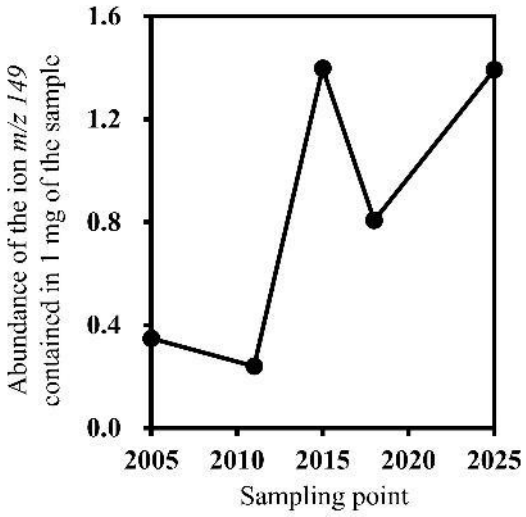
Chronological Characterization of Airborne Microplastics in Kanagawa, Japan by Pyrolysis-Gas Chromatography/Mass Spectrometry

Hibiki Shirata (Meiji University, Japan) Satoshi Inose (Meiji University, Japan) Takayuki Honda (Meiji University, Japan) Yuya Koike (Meiji University, Japan)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis
Location: First Floor

ABSTRACT

1. Introduction Since the early 2000s, microplastic pollution in the ocean has been recognized as a global environmental issue. In 2016, microplastics were found to exist not only in the ocean but also in the atmosphere1). Analysis of airborne microplastics (AMP) has been advanced by numerous research groups following this report. However, several challenges remain, including the lack of standardized analytical methods and the limited number of samples. In this study, airborne particles collected at our laboratory since 2000 for environmental behavior of radionuclides. AMP were qualitatively and quantitatively analyzed using evolved gas analysis-mass spectrometry (EGA-MS) and pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS). Various analytical conditions were determined based on the study by Mizuguchi et al.2). AMP samples were continuously collected in Kanagawa Prefecture, located in the urban area of Japan. Therefore, we aimed to investigate the long-term variations in AMP within urban areas. 2. Experiment The airborne particles samples were collected at the Meiji University in Kanagawa Prefecture (35°35’52” N, 139°32'59" E), using a high-volume air sampler (Sibata Scientific Technology Ltd., Japan, HV-500R). The air was vacuumed at a flow rate of 500 dm3 min-1 for 24 hours. The AMP collected on glass fiber filters (Advantech Co., Ltd., Japan, GB-100R). Airborne particles samples collected in 2005, 2011, 2015, 2018, and 2025 were analyzed to investigate chronological variations. Each filter was punched out in 4 mm diameter disks, and the three disks were put into a sample cup (Frontier Laboratories Ltd., Japan, Eco-Cup LF) for measurement of EGA-MS and Py-GC/MS. 3. Results and discussion The evolution of CO2 (m/z 44), hydrocarbons (m/z 57), and phthalate esters (m/z 149) were detected by EGA-MS in all measured samples. Comparison of the extracted ion chromatograms (EIC) at m/z 149 revealed intensity differences between samples. The abundance of the ion (m/z 149) contained in 1 mg of the sample (compound amount 149) was calculated for each sample. The investigation of the chronological variations in the compound amount 149 showed a steady upward trend. The EIC of m/z 149 is a typical indicator for phthalates2). Therefore, an increase in the amount of microplastics contained in the airborne particles has been suggested. 1) R. Dris, et. al.: Marine Pollution Bulletin, 104, 290 (2016). 2) H. Mizuguchi, et. al.: Journal of Analytical and Applied Pyrolysis, 171, 1 (2023).



The chronological variations of the abundance of the ion *m/z 149* contained in 1 mg of the sample.

Unravelling the impact of microwave-assisted pre-treatment on tire wear particles by Py-GC-MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

This study developed a microwave (MW)-based pre-treatment of tire wear particles (TWPs) to remove inorganics and investigated the effect of such pretreatment on their pyrolytic behavior. Tire and road wear particles (TRWPs) are among the major sources of plastic pollution in the environment. Their detection and characterization remain challenging due to their high carbon black content, which strongly interferes with commonly used spectroscopic techniques for microplastic (MP) analysis, such as infrared and Raman spectroscopy. As a result, alternative analytical approaches are required. Thermo-analytical techniques, including pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS), have therefore gained increasing interest for the detection and analysis of TRWPs through their characteristic thermal degradation products. However, the complex and heterogeneous composition of tire materials complicates both the detection and accurate quantification of these particles. Matrix interferences and variability in pyrolysis products can significantly affect analytical results. Consequently, the development and optimization of appropriate sample pre-treatment strategies are essential to reduce matrix effects and improve the reliability and accuracy of TRWP quantification in environmental samples. MW-assisted extraction and digestion is a promising tool for MP analysis in environmental samples, as it provides high efficiency while requiring shorter times compared to other methods. However, no application of MW to TWPs has been presented in the literature. In this study, MW digestion was used to remove zinc from TWPs. Zinc is a characteristic constituent of tire materials and is known to impact polymer pyrolysis behavior. Experimental conditions were optimized based on the zinc concentration extracted into the filtrate following digestion and filtration. Calibration curves obtained by Py-GC-MS using cryo-milled tire tread as standard revealed significant discrepancies between treated and untreated particles, indicating an impact of the pre-treatment on the pyrolytic response of the investigated polymers. Additionally, this study investigated the importance of the use of internal standards. When deuterated standards, including deuterated styrene butadiene rubber and deuterated polyisoprene were added directly to the pyrolysis cups, the previously observed linear relationship between sample mass and pyrolysis product peak area was no longer observed. These results suggest potential interactions between the internal standards and the polymers within the tire matrix.

Optimization of Pre-treatment Protocols for Micro- and Nanoplastics Detection in Human Keratinous and Blood Tissue Samples Using Analytical Py-GC/MS

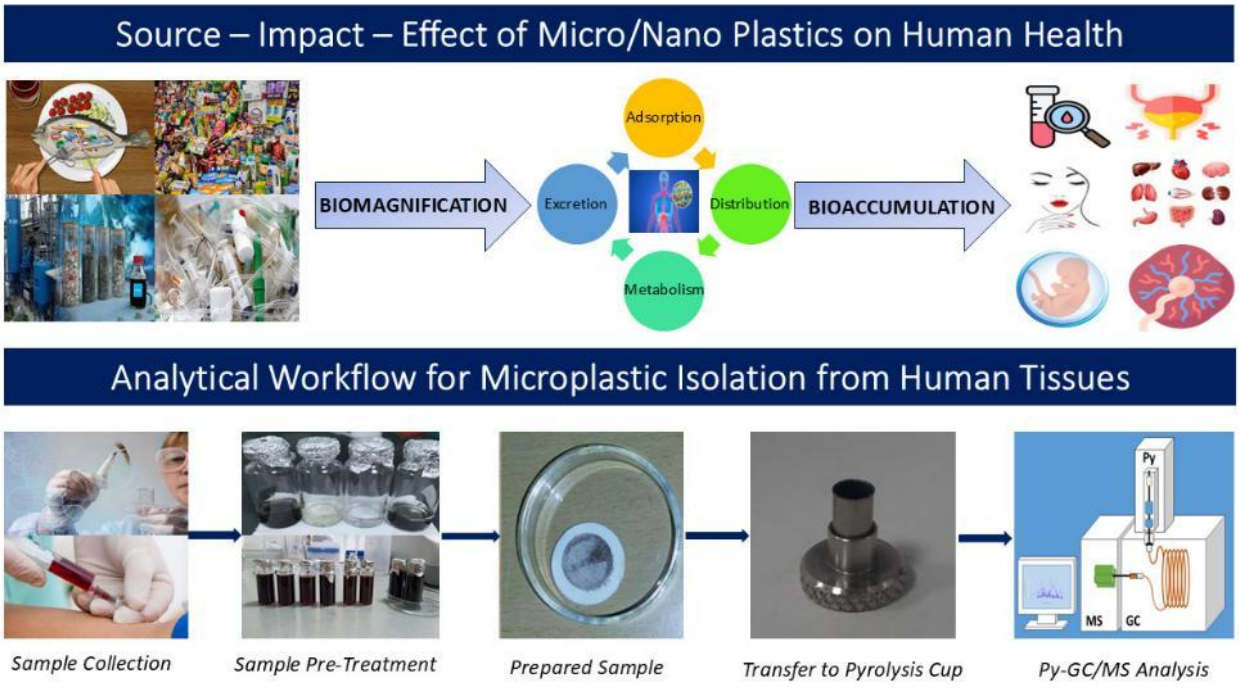
Sivakumar Charushree (Department of Chemical Engineering, Indian Institute of Technology Madras, India) Ravikrishnan Vinu (Department of Chemical Engineering, Indian Institute of Technology Madras, India)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

In the current era of plastic pollution, human exposure to micro- and nanoplastics (MNPs) has emerged as a critical global health concern. Emerging evidence indicates that MNPs are present across diverse biological systems. However, insufficiently developed, standardized, and sensitive analytical protocols continue to limit accurate exposure assessment and biomonitoring. Reliable detection strategies based on minimally invasive human biomarkers such as keratinous tissues (hair, nails) and blood are therefore essential for evaluating both long-term accumulation and recent exposure. This study focuses on the optimization of pre-treatment protocols for the isolation and detection of MNPs from human biological matrices using analytical pyrolysis–gas chromatography/mass spectrometry (Py-GC/MS). Keratinous tissues pose a major analytical challenge due to their highly cross-linked keratin structure and associated proteins. Alkaline digestion using potassium hydroxide (KOH) was systematically optimized to cleave keratin-associated proteins and disrupt disulfide crosslinks, enabling efficient matrix breakdown. A combined KOH–hexane treatment was further employed to enhance lipid removal, reduce matrix interference, and improve polymer recovery. For blood and clot samples, alkaline digestion effectively disintegrated fibrin networks and protein aggregates, facilitating the release of potentially entrapped MNPs. The optimized protocol is being refined to enable processing of larger sample quantities with reduced biological interference, with the aim of improving detection sensitivity. Py-GC/MS analysis demonstrated enhanced signal-to-noise ratios and improved reproducibility, enabling more reliable intensity-based relative quantification. While endogenous aromatic and aliphatic compounds posed challenges in differentiating polymer-specific ion markers, careful spectral interpretation enabled robust identification of characteristic pyrolysis products. Recurrent detection of styrene-derived peaks and associated additives across multiple trials indicated the presence of polystyrene-related residues, confirming the analytical applicability of the developed method. Comparison of MNP signatures in blood and hair matrices is expected to elucidate their complementary roles as biomarkers, where blood may reflect recent exposure and keratinous tissues may indicate long-term accumulation. The proposed workflow establishes a practical and scalable framework for human biomonitoring of MNP exposure and provides a foundation for future epidemiological studies and health risk assessment. The development of harmonized analytical protocols such as this is essential for advancing large-scale monitoring efforts and informing evidence-based policy measures aimed at mitigating plastic-related health risks.



Characterization and Quantification of Microplastics in Water in Mid-Atlantic Watersheds in the United States by Pyrolysis GC-MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Each year in the United States, more than 280,000 tons of plastic is dumped into rivers across the country. While there are many major waterways and bodies of water that have become contaminated with plastics contamination throughout the country, the mid-Atlantic region of the United States has uniquely defined positioning, being within the boundaries of both the Chesapeake Bay and Delaware Bay Watersheds, which is home to nearly 8% of the United States total population. The Chesapeake Bay Watershed is the country's largest estuary, with more than 150 rivers known to drain into the Chesapeake Bay. It is additionally well-known for its biodiversity and contribution to agricultural production. On the other hand, the Delaware Bay Watershed contains the major port city of Philadelphia, supplying water to other major metropolitan areas outside its geographic boundaries such as New York City. The Delaware Bay Watershed is considered to be a top contributor of microplastics pollution flowing into the Atlantic Ocean in North America. Due to the ecological and economical importance of both watersheds to the coastal mid-Atlantic regions of the US, the characterization of microplastics has already gathered interest in recent years. In each instance, the primary focus of such studies has been characterizing particle concentrations in either the bay or coastal areas via Raman spectroscopy. While other information, such as size and shape, is gained about the microplastics particles, it is not possible to quantify the concentrations of individual polymers. Consequently, the contributing polymers discussed have largely been limited to polyethylene (PE) and polypropylene (PP). This is to be expected, as they are the most widely used polymers in consumer plastic products. To this point, there is a lack of contributing datasets to microplastics contributions in the mid-Atlantic region of the US using pyrolysis-gas chromatography mass spectrometry (py-GC-MS). Both the headquarters of CDS Analytical and Lincoln University are located in Chester County, in southeast Pennsylvania, US, which is geographically influenced by rivers emptying into both the Chesapeake Bay and Delaware Bay Watersheds. The work presented here establishes a geographic layout for collecting water samples from various locations along selected rivers leading down to the mouth of the rivers emptying into the bay. After the collection of water samples, a sample preparation procedure of filtration onto a quartz filter followed by cryogenic milling is utilized. Final polymer identification and quantification is then done using py-GC-MS. The results are expanded to polymers other than PE and PP to include other known plastic contaminants in water such as polyethylene terephthalate, polystyrene, and nylon. Furthermore, the results are further described by the potential implications on ecology, the economy, and human health.

Exploring the potential of one-pot microwave-assisted pretreatments coupled with py-gc-ms for the quantification of mps and associated contaminants

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Microplastic (MP) pollution has been acknowledged as a global threat and presently one of the most pressing environmental issues. Different analytical techniques have been applied and optimized for the analysis of MP and of non-polymeric organic compounds associated with them, such as additives, persistent organic pollutants, and polymer degradation products. Nevertheless, there is still a major lack of understanding of the interaction mechanisms between these classes of pollutants and ecosystems. Analytical pyrolysis-based techniques have proven to be effective in the analysis of MP in environmental samples, providing mass-based quantification of different polymers, along with the quantification of MP-associated organic contaminants. However, depending on the environmental matrix, sample pretreatment before analysis can require numerous and time-intensive steps. In this work, we tested and optimized a new one-pot microwave sample pretreatment that allows for a comprehensive overview of the contaminants and microplastics present in the sample. The method was developed using mussels fed with microplastics (PP, PE, and N6), in order to work with a complex and challenging matrix rich in protein and lipids. We combined microwave-assisted extraction with thermal desorption and analytical pyrolysis coupled with gas chromatography and mass spectrometru (Py-GC-MS) to characterize and quantify different classes of pollutants frequently associated with MPs in biological samples [1,2], such as phthalate plasticizers, as well as contaminants including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and other contaminants of emerging concern (CECs). The same sample was subsequently processed through microwave digestion in order to characterize and quantify the MPs content. Different conditions were tested to obtain the most efficient digestion approach while limiting polymer degradation. This new rapid method paves the way for future applications to other biological samples, particularly human samples. Such an extension would enable direct assessment of human exposure to microplastics and related pollutants, offering valuable data for public health research and environmental risk assessment. Acknowledgement: This work was carried thanks to the financial support of NAMC (North Atlantic Microplastic Centre), the funding from the European Union - Next-GenerationEU - National Recovery and Resilience Plan (NRRP) – MISSION 4 COMPONENT 2, INVESTIMENT N. 1.1, CALL PRIN 2022 D.D. 104 02-02-2022 – DIORAMA (A deep dive into the study of microplastics in aqueous matrices), and the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 of MUR by the European Union's NextGenerationEU (Project CN 00000033, Decree No. 1034 of June 17, 2022 adopted by the MUR, CUP I33C22001300007, Project title "National Biodiversity Future Center-NBFC"). We acknowledge the NORCE Mass Spectrometry Lab for instrument access and expert support.

References:

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Analytical Pyrolysis for the Characterization of Hypercrosslinked Polymers

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Hypercrosslinked polymers (HCPs) are a versatile class of porous organic polymers characterised by their micro/mesoporous networks formed through extensive covalent crosslinking. Typically synthesised via Friedel–Crafts alkylation of aromatic precursors, HCPs can be constructed from a wide range of monomers and linking strategies, enabling the fine-tuning of chemical functionality, pore structure, and surface polarity. Application of such materials is in the capture of (very) volatile organic compounds for analytical purposes, water harvesting from air, or efficient removal of various cations from wastewater [1]. Due to their highly crosslinked nature, structural characterization possibilities of the material are very limited. Using analytical pyrolysis, we have developed a means of not only identifying different monomers incorporated into the HCPs, but also providing a quality control to monitor remaining crosslinking agents and impurities.

[1] Paul Schweng, Elias Rippatha, Clemens Schwarzinger, Robert T. Woodward, Hypercrosslinked Polymers for Volatile and Very Volatile Organic Compound Capture Beyond Commercial Benchmarks, Angew. Chem. Int. Ed. (2025), https://doi.org/10.1002/anie.202513362

Preliminary application of pyrolysis and TD-GC-MS/MS to study additive leaching from plastics induced by sediment abrasion and fragmentation

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Plastic debris is now ubiquitous in natural environments and progressively accumulates within sedimentary systems such as rivers, beaches, and the deep seafloor. During transport with natural sediments, plastics are exposed to repeated mechanical stresses that promote abrasion and fragmentation through sediment-plastic interactions. This results in the formation of micro and nanoplastics and increases the exposed surface area, thereby enhancing the release of plastic associated chemicals. To date, more than 16,000 chemicals have been identified in plastics, including functional additives, processing aids, starting substances, and non-intentionally added substances. As most of these compounds are not covalently bound to the polymer matrix, they can leach into the environment. However, the mechanisms governing plastic fragmentation in sedimentary systems and its interaction with chemical leaching processes are still poorly understood, due to analytical challenges and therefore limiting robust assessments of the related ecological risk. In this scenario, the PLASTICAL project (Fragmentation and Abrasion of Plastics by Sediments and Chemical Additive Leaching) aims to address these knowledge gaps by investigating plastic fragmentation and abrasion during sediment transport and its relationship with additive release. For this purpose, we investigated two conventional polymers (polyethylene terephthalate and polyamide 6.6) and two biodegradable ones (polylactic acid and polybutylene adipate terephthalate) selected for their different mechanical properties. Plastic samples were produced in-house by injection moulding in two formulations: (i) neat polymers and (ii) polymers compounded with the additives Irgafos 168 and Irganox 1010. Samples were analysed using a combination of large-volume pyrolysis adsorption with thermal desorption-gas chromatography-tandem mass spectrometry (TD-GC-MS/MS). Pyrolysis was performed in a stand-alone tube furnace with programmable temperature with the resulting pyrolyzates trapped on a non-polar sorbent tube and subsequently desorbed in a TD unit coupled to a GC-MS/MS system. Analytical methods were optimised to identify characteristic pyrolysis markers for each polymer and for both additives, with emphasis on reproducibility, selectivity, and sensitivity. These markers will be applied in laboratory experiments simulating sediment induced abrasion and fragmentation to trace plastic particles and additive leaching under varying sediment grain characteristics.

Assessing airborne microplastics concentrations in indoor working environments using Py-GC-MS

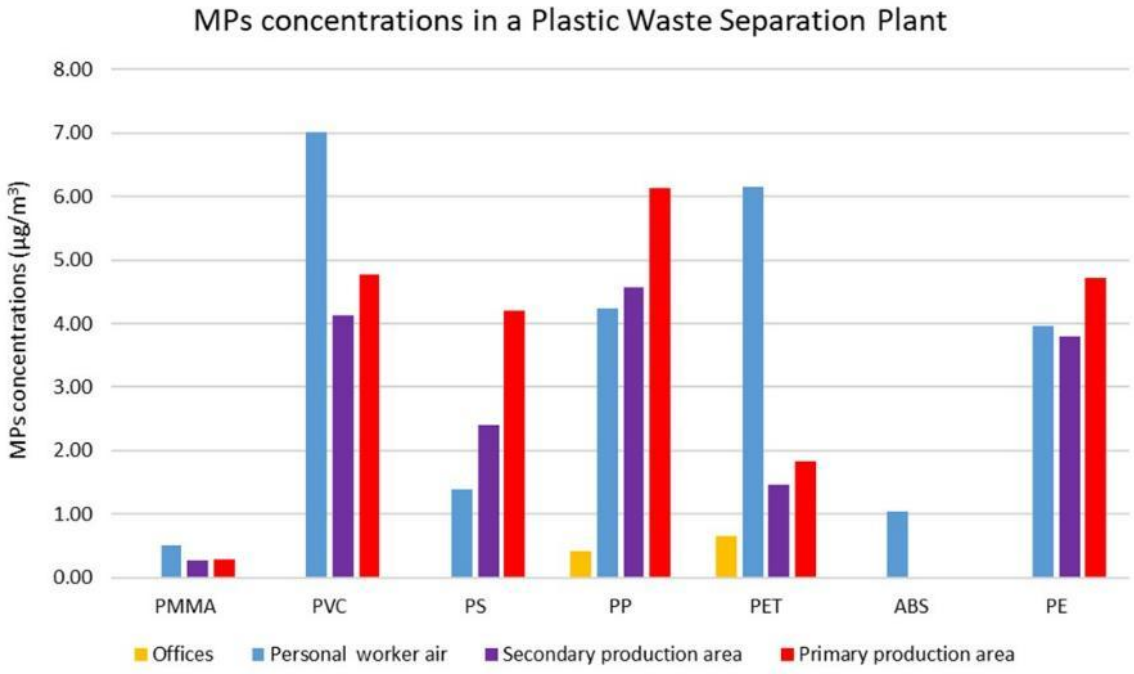
Leonardo Barlucchi (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Jacopo La Nasa (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Claudia Campanale (Department of Environment and Health, National Institute of Health (ISS), Rome, Italy) Augusta Piccardi (Department of Environment and Health, National Institute of Health (ISS), Rome, Italy) Marcello De Rossi (Laboratory of Industrial Hygiene, ASL Viterbo, Viterbo, Italy) Francesca Modugno (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy) Lorenzo Palumbo (Department of Environment and Health, National Institute of Health (ISS), Rome, Italy)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Microplastics (MPs) are generally described as small plastic particles, with dimensions between 1 mm and 1 µm, classified as primary and secondary MPs. While the presence of microplastics (MPs) in marine and terrestrial environments is well documented [1], the impact of airborne MPs remains a topic of ongoing research, especially in indoor environments, making them relevant for assessing long-term exposure risks [2]. In this study, we quantified the mass concentrations of airborne microplastics in indoor working environments using pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS). Air sampling was conducted in different factories and treatment plants in central Italy, where various plastic materials are mechanically processed. For each factory, sampling was performed in three working areas: (i) primary production areas, where plastic materials undergo intensive handling and are expected to generate the highest MPs concentration; (ii) secondary production areas, characterized by lower plastic manipulation; and (iii) offices, where minimal plastic processing occurs, and airborne MPs concentrations are expected to be lower. Air samples were collected through active sampling using quartz filters for Py-GC-MS, which were subsequently punched and directly analyzed by Py-GC-MS. By using this approach, we accurately quantified the concentrations of airborne MPs in different areas of the working environment. Py-GC-MS analysis enabled the determination of eleven different polymers: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polymethyl methacrylate (PMMA), acrylonitrile butadiene-styrene (ABS), styrene-butadiene rubber (SBR), polyethylene terephthalate (PET), polycarbonate (PC), nylon 6 (N6), and nylon 66 (N66). The results for a plastic waste separation plant showed a spatial trend in airborne MPs concentrations, with higher levels detected in primary production areas and in the workers' personal air samples, followed by secondary production areas, and the lowest concentrations observed in offices (Figure 1). Figure 1: MPs concentrations (µg/m3) in different working areas in a plastic waste recycling plant.



References

[1]: X. Zhai et al., "Characterization and quantification of microplastics in indoor environments," Heliyon, vol. 9, no. 5, p. e15901, May 2023. [2]: D. Pomata et al., "Plastic breath: Quantification of microplastics and polymer additives in airborne particles," Science of The Total Environment, vol. 932, p. 173031, Jul. 2024.

Quantification of nano/microplastic in urban atmospheric deposition using pyrolysis-GC-MS

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Micro- and nanoplastics (MPs and NPs) are among the most debated emerging contaminants of the last decade. Despite the substantial expansion of scientific research on this topic, their comprehensive assessment remains challenging. N/MPs are known to be globally distributed, as they can be resuspended and transported over long distances by wind and atmospheric processes. Therefore, atmospheric deposition (dry and wet) acts both as a dispersal pathway and as a sink, transferring plastic particles from the atmosphere to terrestrial and aquatic environments, with potential implications for ecosystems and human exposure. Identification methods for MPs have been optimized across various analytical approaches, mainly spectroscopic and thermal techniques; however, accurate quantification remains challenging. This difficulty largely stems from the heterogeneity of the polymers, as well as from the heterogeneity and complexity of environmental matrices, which complicate the isolation of plastic particles. In addition, the smallest size fractions (sub-micrometric particles, NPs) frequently remain undetected, despite their potential relevance due to possible interactions at cellular and subcellular levels. This study proposes a methodological framework for the identification and quantification of N/MPs in the size range from 0.3 µm to 0.3 mm in total atmospheric deposition (dry and wet). Samples were collected over a four-month period using a Bulk® deposition sampler in the urban area of Rimini (Italy). The workflow included a pre-concentration step in which deposition samples were sieved at 0.3 mm to remove visible macrofragments and coarse biogenic material, followed by chemical pretreatment with an optimized sono-Fenton oxidation to reduce the organic load. The treated samples were then filtered onto quartz membranes (pore size: 0.3 µm). The loaded filters were subsequently analyzed qualitatively and quantitatively by pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS), enabling direct measurement of polymer components associated with airborne particulates collected on quartz filters. Reactive Py-GC-MS was employed using tetramethylammonium hydroxide to minimize interactions between polymer pyrolysis products and those originating from the residual matrix. An internal standard calibration protocol was developed to ensure repeatability and reproducibility. Method validation was performed on commercial plastic particles, both unaged and after UV aging, without matrix inclusion in recovery tests. Preliminary results indicated the presence of the most common polymers and mean atmospheric deposition over the sampling period was approximately 40 µg m^{-2} day^{-1}. The method showed good precision, and recovery tests were satisfactory. However, the presence of refractory organic compounds, particularly humic substances and lignin, was highlighted. Consequently, Py-GC-MS quantification must account for matrix-specific interferents, underscoring the need for site-specific method validation prior to routine application.

Chemical markers for tyre wear particles using pyrolysis-GC-MS

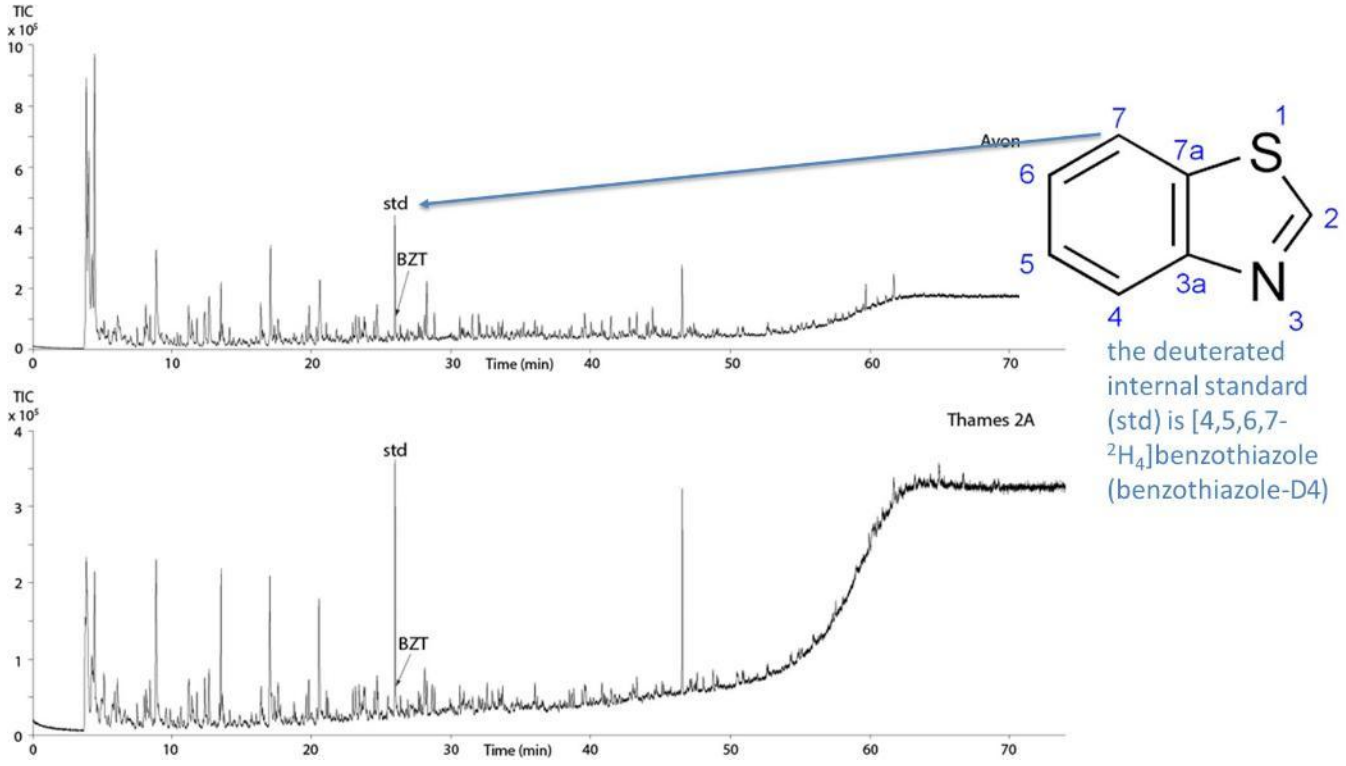
Geoffrey D. Abbott (School of Natural and Environmental Sciences, Newcastle University, UK, UK) Cijo Xavier (School of Natural and Environmental Sciences, Newcastle University, UK, UK) Florence Parker-Jurd (International Marine Litter Research Unit, University of Plymouth, UK, UK) Richard C. Thompson (International Marine Litter Research Unit, University of Plymouth, UK, UK)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

A novel approach based on pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) using Benzothiazole as a marker that is tightly bound to the tyre matrix will be described (1 -3). Benzothiazole is a pyrolysis product from benzothiazole sulfenamides which act as crosslinking agents for vulcanization. They act as cure accelerators and control the vulcanization rate and crosslink density. Benzothiazole moieties are bound into the polymeric structure and released by cleavage of weaker C-S bonds during pyrolysis. Chromatograms from the Py-GC/MS of riverine sediments from the Thames, Avon and Medway will be presented (Fig. 1) and a calibration curve based on a deuterated internal standard will be discussed giving a Limit of Quantification (LOQ) of ~ 1 ng/ mg of sediment. Other markers will also be described for some synthetic car tyre rubbers including Styrene-Butadiene Rubber (SBR) and Butadiene Rubber (BR). Figure 1. Fig. 1 Total ion chromatograms from the Py-GC/MS of riverine sediments from the rivers Thames, Medway and Avon



Biodegradable Bioplastics in Soil: Multi-Analytical Evidence of Fragmentation and Soil Organic Matter Changes

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14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Environmental contamination by plastic debris is a major global challenge, driving rapid growth in the development and use of bioplastics (BPs) as alternatives to conventional polymers. Although BPs are often perceived as less harmful because they can degrade, their chemical safety and environmental fate remain poorly understood. Many BP products contain additives similar to those used in petroleum-based plastics, and their leachates may exhibit comparable toxicity to ecosystems and humans. Moreover, under soil conditions, bio-based polymers are frequently not readily decomposed by microorganisms, and complete mineralization typically requires specific conditions (e.g., elevated temperature, sufficient moisture, oxygen availability, and active microbial communities) that are uncommon in natural ecosystems and more representative of industrial composting [1,2]. Consequently, materials marketed as biodegradable may persist and fragment rather than fully mineralize, generating micro- and nanobioplastics (BMPs/BNPs) with potential impacts similar to conventional micro- and nanoplastics. Emerging evidence also suggests that BPs can alter soil microbial community structure and influence plant growth [3], yet data on BP occurrence in soils and effects on soil processes remain limited. This study assessed the effects of biodegradable bioplastics on soil organic matter (SOM) and dissolved organic matter (DOM) and investigated the formation and persistence of residual fragments and BMPs/BNPs in soil under controlled laboratory conditions at two application rates. An analytical characterization was performed on soils amended with commercial biodegradable polymers and incubated for 100 days. Soil samples were analyzed before amendment and after incubation with polylactic acid and starch-based bioplastics using pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS), evolved gas analysis-mass spectrometry (EGA-MS), thermogravimetric analysis (TGA), headspace solid-phase microextraction coupled with gas chromatography-mass spectrometry (HS-SPME/GC-MS) and particle size analyzers (PSA) to elucidate changes in SOM/DOM composition and the polymer/additive signatures associated with soil exposure. Overall, the thermoanalytical results were consistent across Py-GC-MS, EGA-MS, and TGA, indicating no detectable compositional changes in the bioplastics attributable to the applied aging treatment over the timescales investigated. However, EGA-MS and TGA allowed differentiation between aged and unaged commercial bioplastics, indicating that incorporation into soil for 100 days can modify their thermal behavior and related properties. In addition, Py-GC-MS analyses of incubated soils, complemented by PSA, suggested the possible presence of in situ micro-bioplastic formation, supporting the view that fragmentation can occur even for materials marketed as biodegradable under typical soil conditions. Furthermore, combined evidence from Py-GC-MS and HS-SPME/GC-MS suggested that bioplastic residues can affect the soil DOM pool, implying shifts in DOM quality and turnover dynamics. Collectively, these findings improve our understanding of the environmental fate of biodegradable plastics in soil and underscore the need to evaluate both particle generation and SOM responses when judging the sustainability of bioplastic alternatives.

References [1]

Withana, P. A., Yuan, X., Im, D., Choi, Y., Bank, M. S., Lin, C. S. K., Hwang, S. Y., Ok, Y. S. (2025). Environ. Sci.: Process. Impacts, 27, 3321–3343. [2] Fan, P., Yu, H., Xi, B., Tan, W. (2022). Environ. Int., 163, 107244. [3] Liu, X., Wen, Z., Zhou, W., Dong, W., Ren, H., Liang, G., Gong, W. (2025). Microorganisms, 13(2), 259.

Decoding subsurface biomarkers in a Mars-analogue lava tube through analytical pyrolysis and isotope fingerprints

Ana Z. Miller (IRNAS-CSIC, Spain) Layla M. San-Emeterio (Swedish University of Agricultural Sciences, Sweden) José M. De la Rosa (IRNAS-CSIC, Spain) José A. González-Pérez (IRNAS-CSIC, Spain) Francesco Sauro (University of Padova, Italy) Nicasio T. Jiménez-Morillo (IRNAS-CSIC, Spain)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Basaltic lava tubes are considered excellent natural testbeds to evaluate how biosignatures are introduced, altered, and ultimately preserved under low-light, mineral-rich, and microbially active conditions. In this contribution, we integrate bulk and molecular approaches, such as elemental analysis coupled to isotope ratio mass spectrometry (EA/IRMS), traditional analytical pyrolysis (Py-GC/MS), and the novel pyrolysis compound-specific isotope analysis (Py-CSIA) for carbon and hydrogen ($\delta^{13}C$ and $\delta^{2}H$, respectively), to decipher the molecular composition and isotope systematics of organic matter (OM) preserved in speleothems from the Corona Lava Tube (Lanzarote, Canary Islands, Spain), a Mars analogue subsurface environments. During the ESA PANGAEA-X astronaut training program, we investigated four different matrices representing potential OM sources and sinks along a surface-to-cave gradient: a dark microbial mat enriched in organics, a whitish cave deposit dominated by mineral phases, the soil layer directly above the cave, and nearby Euphorbia balsamifera vegetation. The Py-GC/MS fingerprints showed clear differences between surface-derived inputs and cave-associated organics, while the Py-CSIA added a decisive layer of information by tracking $\delta^{13}C$ and $\delta^{2}H$ at the compound level. The cave matrix exhibited isotope patterns that are distinctive from the surface endmembers, consistent with different transformation pathways and substantial microbial overprinting. In particular, ^{13}C compound-specific value changes in sterol- and lignin-related pyrolysates suggest intensive recycling and/or selective stabilization within the mineral framework, whereas hydrogen isotopes ($\delta^{2}H$) point to meteoric water signals combined with diagenetic modification during subsurface residence. Taken together, these results demonstrate that Py-CSIA can resolve subtle biosignature-relevant information even when total OM is low and strongly altered. The combined molecular and isotope workflow presented here offers a transferable strategy to assess the detectability and interpretation of organic traces in volcanic subsurface environments, and supports the development of life-detection concepts for Martian lava tubes. Acknowledgments: This work was supported by the Spanish Ministry of Science and Innovation (MCIN/AEI/ 10.13039/501100011033) under the research project TUBOLAN PID2019-108672RJ-I00 and by the Spanish National Research Council (CSIC) through the intramural project PIE_20214AT021. We acknowledge the financial support from the Portuguese Foundation for Science and Technology (FCT) under the MICROCENO project (10.54499/PTDC/CTA-AMB/0608/2020), and from the MICROLAVA project (PROYEXCEL_00185) funded by the Andalusia Regional Government. N.T.J.M. thanks the support from the Ramón y Cajal contract (RyC2021-031253-I) funded by MCIN/AEI/10.13039/501100011033 and the European Union "NextGenerationEU"/PRTR. We thank the Cabildo de Lanzarote and the Lanzarote and Chinijo Archipelago Geopark for granting permission to access the La Corona Lava Tube system and collect samples. Field activities and sample collection were partially supported by the ESA PANGAEA-X training program. We are grateful to ESA astronaut Matthias Maurer for his dedicated involvement in collecting the samples analyzed in this study during the field training. We also thank Loredana Bessone, director of ESA's PANGAEA program, for her leadership and support in facilitating this multidisciplinary campaign.

Enhanced Processing Ability with a Newly Designed Underwater Microparticle Collection Device for Pyrolysis-GC/MS of Microplastics

Atsushi Watanabe (Frontier Laboratories; Tohoku University, Japan) Mai Matsueda (Frontier Laboratories, Japan) Koji Adachi (Frontier Laboratories, Japan) Takahisa Ishimura (Frontier Laboratories, Japan) Norio Teramae (Frontier Laboratories; Tohoku University, Japan) Chuichi Watanabe (Frontier Laboratories, Japan) Young-Min Kim (Daegu University, North Korea) Yasuyuki Ishida (Chubu University; Frontier Laboratories, Japan)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

For the analysis of microplastics (MPs) in water by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS), MPs are usually collected by filtration after appropriate sample pretreatment and subsequently introduced into a pyrolyzer. A commonly used approach involves filtering MPs onto a fiber filter, folding the filter, and placing it into a pyrolysis sample cup. However, microplastic particles are known to adsorb onto glassware surfaces, making thorough rinsing essential to achieve acceptable recovery. Previously, we developed a filtration device to address the issue1). Nevertheless, the effective filtration area remained limited, requiring several hours to process water samples on the order of tens of liters, and the filter section was prone to clogging, resulting in a significant decrease in filtration efficiency. In this study, we developed an improved device, which achieves a substantially higher processing speed while simplifying sample handling. This paper reports on the performance evaluation of the device and its application to the collection and pyrolysis of MPs in clean water. The device consists of a 300 mL funnel, a filtration/collection unit, a 1000 mL receiving flask, and a vacuum pump. A 1 μm opening-size metal filter was placed in a deactivated stainless-steel sample cup (4 mm i.d., 8 mm height) with a 1 mm through-hole at the bottom, referred to as the collection cup. This collection cup covered by a metal filter enables both filtration of MPs from water and direct Py-GC/MS measurements using the same cup. To improve processing speed, the filtration unit was newly designed to tightly seal the collection cup, minimizing the inflow of ambient air during filtration. Py-GC/MS measurements were carried out using a micro-furnace pyrolyzer (EGA/PY-3030D, Frontier Laboratories) directly coupled to a GC/MS system. To improve the sensitivity for trace-level MPs, F-splitless Py-GC/MS measurements were carried out using a Multi-Functional Splitless Sampler (MFS-2015E, same as above)2). Processing speed was evaluated using 300 mL of ultrapure water. For recovery tests, 0.150 mg of polyethylene (PE) microparticles (average diameter 10 μm) was dispersed in a water/ethanol (3:2) mixture and filtered using the device. Recovery was determined gravimetrically. For application to clean water analysis, ultrapure water stored in a PE container (10 L) was filtered, and the collected particles were pyrolyzed at 600 °C. The processing speed of the device was approximately 180 mL/min, representing 3.2 times faster than the previously reported device. Recovery tests using PE microparticles yielded recoveries exceeding 80% in all measurements with the RSD value of 3.8 % (n=5). As shown in Figure 1, the pyrogram obtained from particles collected from the ultrapure water stored in the PE container showed clear peaks attributable to pyrolyzates of PE, such as 1,20-heneicosadiene. Quantitative results indicated a PE concentration of 11.8 ppb in the stored ultrapure water. These results demonstrate that the combination of the new collection device and Py-GC/MS enables rapid and reliable collection and quantification of trace MPs in water.

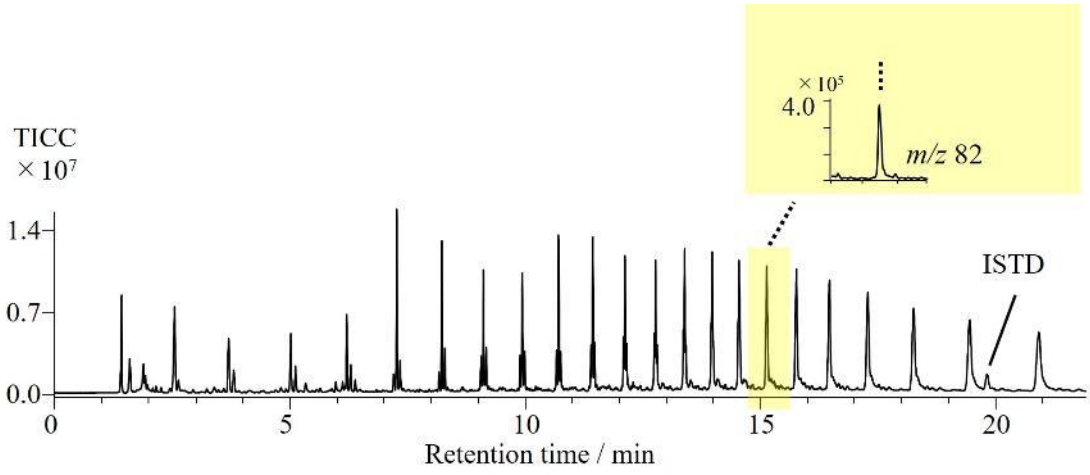


Figure 1. Pyrograms of ultrapure water stored in a PE container after filtration

References: 1) Y-M. Kim et al., Anal. Methods, 39 (2024) 6751. 2) K. Tei et al., J. Anal. Appl. Pyrolysis, 168 (2022) 105707.

Addressing Matrix Effects in Micro- and Nanoplastic Quantification Using Pyrolysis-GC-cIMS-HRMS

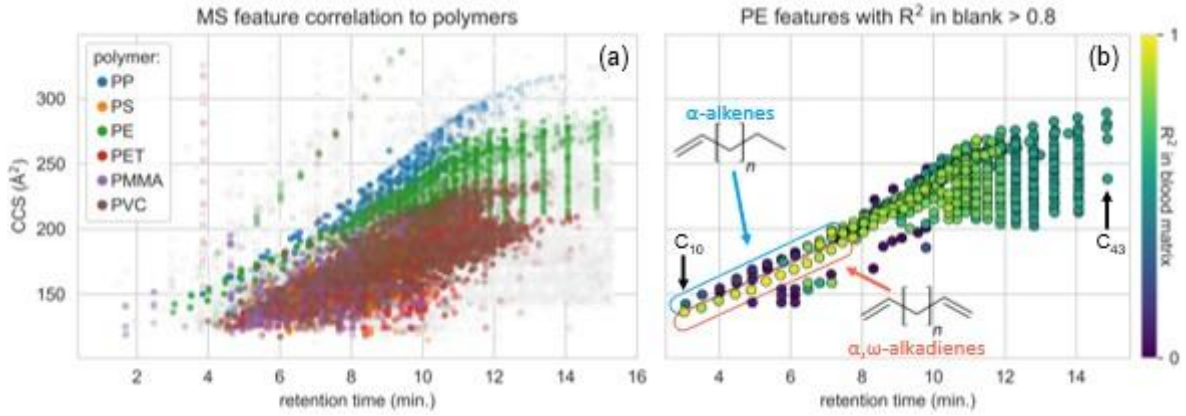
Kas Houthuijs (Vrije Universiteit Amsterdam, Netherlands) Justine Bissonnette (Memorial University of Newfoundland, Canada) Nikita Harvey (Memorial University of Newfoundland, Canada) Federica Nardella (Vrije Universiteit Amsterdam, Netherlands) Marja Lamoree (Vrije Universiteit Amsterdam, Netherlands) Karl Jobst (Memorial University of Newfoundland, Canada) Frederic Béen (Vrije Universiteit Amsterdam, Netherlands)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

With the increasing detection of micro- and nanoplastics (MNPs) in human biological samples, addressing concerns regarding exposure and health risks has become a priority. Exposure assessments currently rely on pyrolysis coupled to gas chromatography–mass spectrometry (Py-GC-MS), which quantifies plastics based on polymer-specific markers. A major challenge in Py-GC-MS is the risk of overestimating polymer concentrations when non-plastic matrix components generate identical markers during the pyrolysis process. Such interferences can distort toxicological findings and heighten public concern, yet consistent quality control measures to prevent these misidentifications are often lacking, leaving the reliability of much exposure data in question. To address these limitations, we utilized cyclic ion mobility spectrometry (cIMS) combined with high-resolution mass spectrometry (HRMS) for MNP quantification. The enhanced resolving power and background reduction of Py-GC-cIMS-HRMS provide greater analytical specificity, helping to eliminate false-positive results. We implemented a non-target screening approach to detect MS features that uniquely correspond to PE, PP, PS, PET, PVC, and PMMA. In our analysis, peak picking identified 35,365 MS features, which were then evaluated using linear calibration models. Based on the resulting coefficients of determination (R2) and matrix effects, we identified optimal markers for each polymer that remained stable even within complex sample matrices. Preliminary results show that PE is particularly prone to overestimation when using standard short-chain α-alkene markers; however, long-chain α-alkenes and α,ω-alkadienes proved to be more robust against matrix effects. For PET, we observed potential underestimation, likely due to co-pyrolysis with residual matrix. These matrix interferences appear more significant than previously reported, which we attribute to the use of single-shot pyrolysis, the common standard in MNP analysis. By contrast, double-shot pyrolysis allows for the removal of volatiles before polymer degradation, reducing the production of nonspecific fragments like α-alkenes and minimizing co-pyrolysis for reactive polymers like PET. These findings highlight the efficacy of Py-GC-cIMS-HRMS in refining marker selection and improving the overall accuracy of MNP exposure data.



Overcoming matrix and oligomer interferences in pyrolysis GC-MS analysis of microplastics in animal tissue

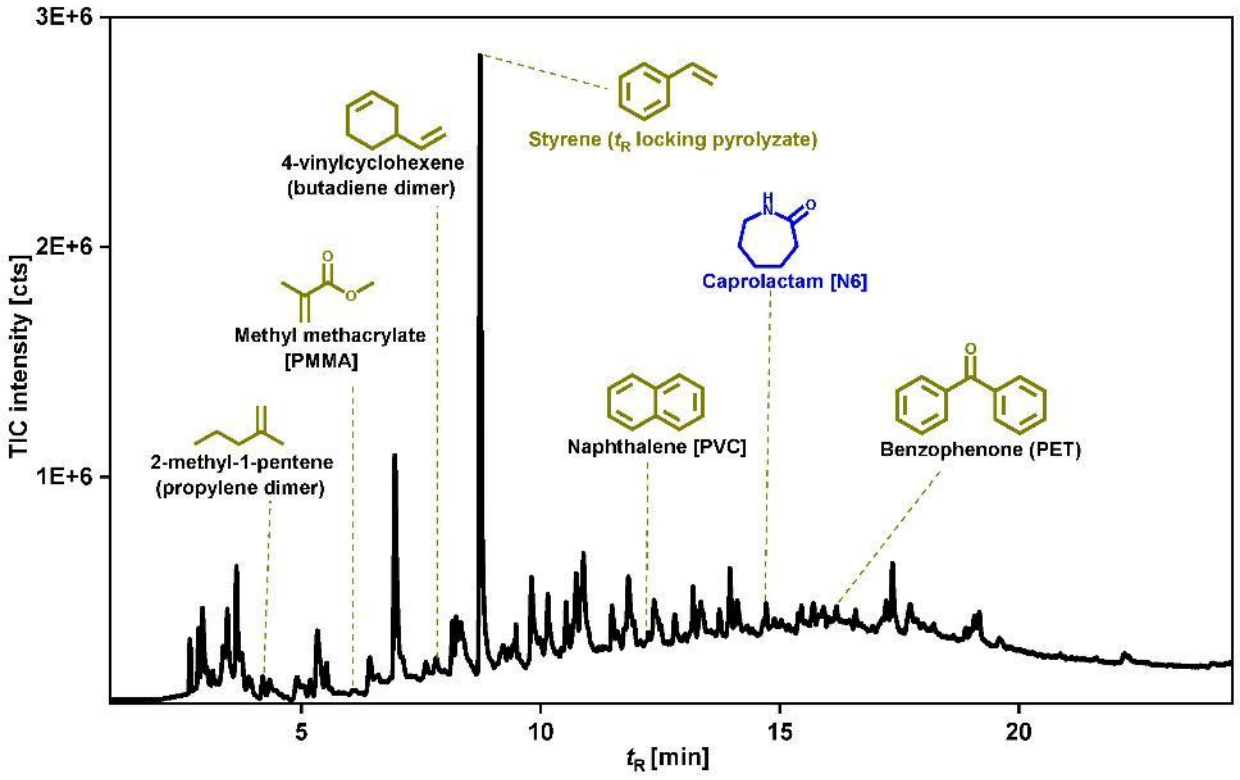
Timothy Omara (BOKU University, Institute of Chemistry of Renewable Resources, Austria) Barbora Benetková (BOKU University, Institute of Chemistry of Renewable Resources, Austria) Ivan Sumerskii (BOKU University, Core Facility Analysis of Lignocellulosics, Austria) Patrick Ssebugere (Makerere University, Department of Chemistry, Uganda) Christine Kyarimpa (Kyambogo University, Department of Chemistry, Uganda) Solomon Omwoma Lugasi (Jaramogi Oginga Odinga University of Science and Technology, Department of Physical Sciences, Kenya) Thomas Rosenau (BOKU University, Institute of Chemistry of Renewable Resources, Austria) Christine Betty Nagawa (Makerere University, Department of Forestry, Biodiversity and Nature Conservation, Uganda) Stefan Böhmdorfer (BOKU University, Institute of Chemistry of Renewable Resources, Austria)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Pyrolysis coupled with gas chromatography-mass spectrometry (Pyr-GC-MS) is a rapidly evolving technique for microplastic analysis. However, its application to biological matrices is analytically challenging due to their high organic matter contents, co-pyrolyzing biomacromolecules and the formation of overlapping pyrolysates that can complicate polymer quantification. In this study, we discuss how we addressed these challenges by optimizing Pyr-GC-MS conditions: the retention time was locked to styrene monomer and a post-column backflush was installed, which together minimised matrix-induced challenges related to instrument instability, retention time shifts and ion source fouling. The C21-α,ω-alkene (1,20-heneicosadiene) proved to be a reliable marker that prevented false positive detection of polyethylene. Nylon 6, styrene-butadiene rubber and poly(vinyl chloride) were reliably quantified at concentrations of 0.24–10.60 µg/g in edible crab tissues. Polystyrene, polypropylene, poly(ethylene terephthalate) and nylon 66 were detected below their limits of quantification. Interference from several discrete propylene oligomers led to false negative detection of polypropylene by suppressing the relative yield of its target quantification marker (2,4-dimethyl-1-heptene). By monitoring more pyrolysates per polymer and qualitative inspection of pyrograms, it was possible to identify samples that contained polypropylene and poly(methyl methacrylate), complementing results obtained by micro-Fourier transform infrared imaging.



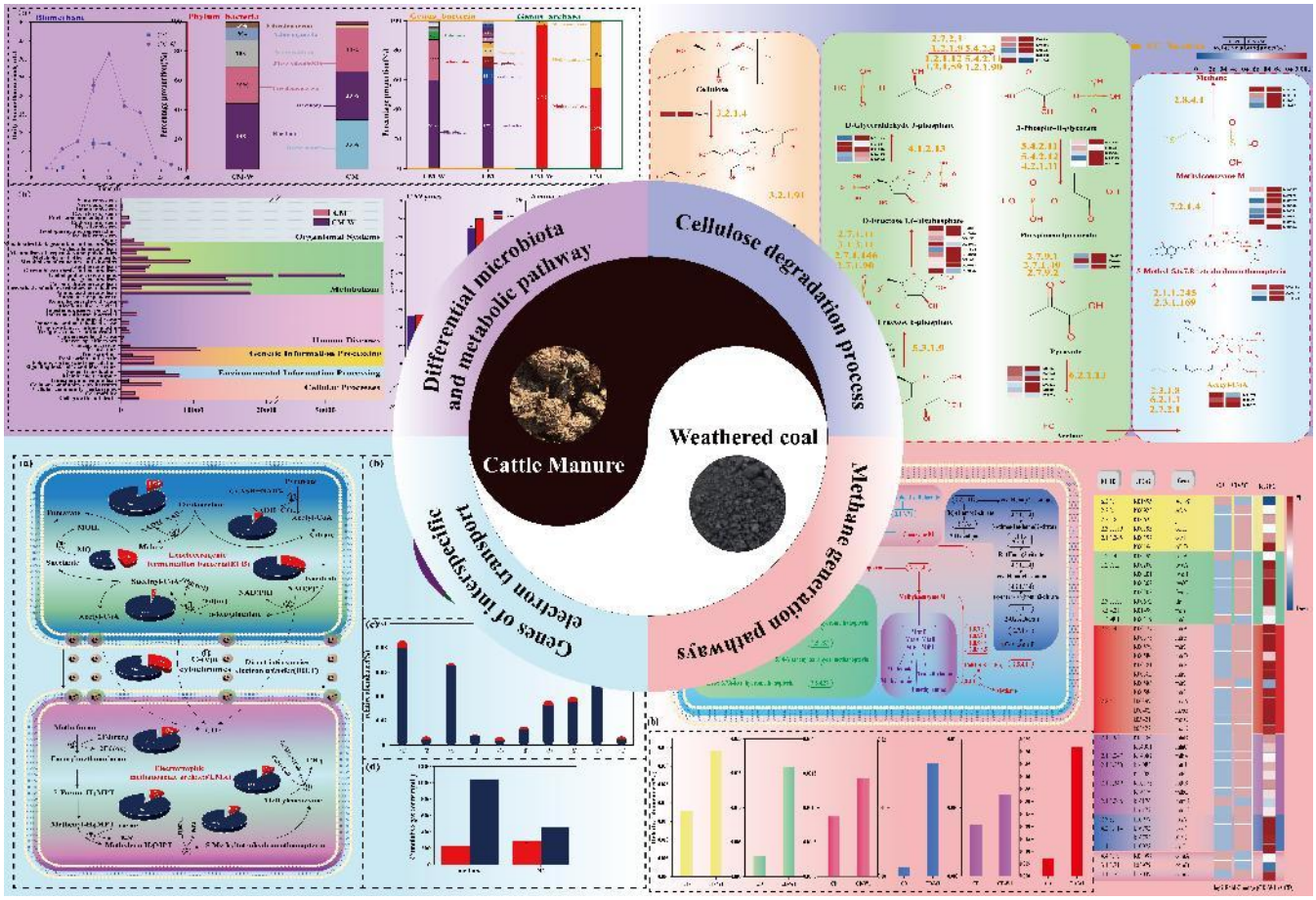
Metagenomic Analysis of Key Methanogenic Pathways in Solid-State Co-anaerobic Fermentation of Weathered Coal and Cattle Manure

Bo Song (Xian Jiaotong University, China) Cui Quan (Xian Jiaotong University, China) Hongyuuo Guo (Henan Polytechnic University, China) Ningbo Gao (Xian Jiaotong University, China)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis
Location: First Floor

ABSTRACT

This research leveraged metagenomic sequencing to assess microbial diversity and functional activity structures during solid-state co-anaerobic fermentation of cattle manure with weathered coal, aiming to evaluate key metabolic pathways. Results demonstrated that co-anaerobic fermentation significantly enhanced biomethane production, concomitant with substantial upregulation of carbohydrate-active enzymes including cellobiose phosphorylase (GH94), glycosyltransferase (GT4), and glycoside hydrolase (GH18). The process reinforced microbial interspecies electron transfer through enrichment of 2-oxoglutarate/2-oxoacid ferredoxin oxidoreductase subunit α, pyruvate ferredoxin oxidoreductase α subunit, and methyl-coenzyme M reductase β subunit, while glucose-6-phosphate isomerase and fructose-1,6-bisphosphatase II played pivotal roles in cellulose degradation within mixed substrates. Combined Solid-state co-anaerobic fermentation was dominated by methane production from the acetyl fragmentation pathway, and that the two synergistically promoted the CO_2 reduction pathway. This study provides a mechanistic study for the treatment of weathered coal and cattle manure, which provides new ideas for solid waste treatment and clean energy.



Improving the determination of atomic mass balances of biochars produced from biomass pyrolysis

Marilyne Farhat (CNRS Nancy, University of Lorraine, France) Mohamed Hechmi Aissaoui (CNRS Nancy, University of Lorraine, France) Marine Guilmont (CNRS Mulhouse, University of Haute Alsace, France) Roger Gadiou (CNRS Mulhouse, University of Haute Alsace, France) Anthony Dufour (CNRS Nancy, University of Lorraine, France) Yann Le Brech (CNRS Nancy, University of Lorraine, France)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Biochar is considered as an interesting alternative to remediate some environmental issues, especially by storing carbon to mitigate global warming, in addition to the wide range of applications it offers in different sectors, including soil management, air/gas cleaning, water purification, buildings and catalysis.[1] Its potential for these applications depends on its properties (high carbon content, porous and stable structure, high surface area, etc.), which are determined by the raw starting biomass and the pyrolysis conditions (temperature, pyrolytic regime, etc.).[2] Thus, an accurate characterization of biochar composition is essential to provide the desired properties for a given application [3] and contribute to the understanding of pyrolysis chemical mechanisms. Nevertheless, some analytical techniques used to study the elemental composition of biochars present uncertainties (i.e oxygen and inorganic characterization and quantification). For this reason, this study aims to gather and compare the different methods in order to provide more accurate atomic mass balances. Biochars were produced in tubular reactor by slow (10 K/min) and intermediate (1 K/s) pyrolysis at 550°C and 700°C final temperatures from several types of biomasses (oak, douglas, corn cobs, digestate, poultry droppings and cattle manure). Complementary analyses were carried out: elemental analysis (C, H, O, N, S), thermogravimetric analysis (TGA), muffle furnace, inductively coupled plasma (ICP), X-ray fluorescence spectroscopy (XRF) and X-ray diffraction (XRD). For biochars containing low mineral content, the quantification methods of ash have low effect on atomic mass balances determination. Then, direct oxygen quantification appears to be a reliable method as it reaches approximately 100% (between 98 and 102%). Concerning biochars with high mineral content (above 3%wt. db), the atomic mass balances accuracy is function of the method used for inorganics' quantification. Direct quantification by elemental analysis (C, H, N, S, O) combined with TGA (proximate analysis) shown the best results (between 100 - 106%wt. db), whereas, muffle furnace method for ashes quantification gave overestimated atomic mass balances (up to 120%). Then, more specific methods (XRF or ICP) were combined with elemental analysis (C, H, N, S, O). Both combinations provided accurate atomic mass balances (between 99 - 106%wt. db) with similar results (less than 2% difference).

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2. Weber, K. & Quicker, P. Properties of biochar. Fuel 217, 240–261 (2018).

3. Lebrun Thauront, J., Soja, G., Schmidt, H. & Abiven, S. A critical re-analysis of biochar properties prediction from production parameters and elemental analysis. GCB Bioenergy 16, e13170 (2024).

Which pyrolysers should you choose based on your samples, your analytical methods and your instrumentation (GC, GC-MS)? How can you reduce the maintenance costs of a pyrolyser?

Yann Simon (Gaz Analytique, France)

14:00-15:00 Session Posters P-S1F1: Analytical Pyrolysis

Location: First Floor

ABSTRACT

Which pyrolysers should you choose based on your samples, your analytical methods and your instrumentation (GC, GC-MS)? How can you reduce the maintenance costs of a pyrolyser?

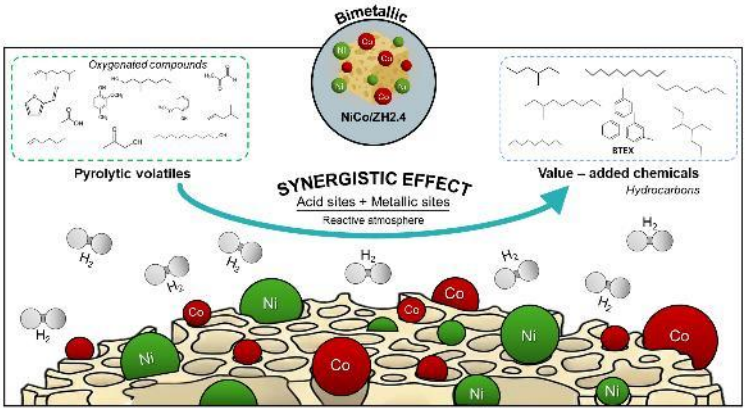
Catalytic co-hydropyrolysis of biomass/plastic over Chilean natural zeolite modified with acid and impregnated with mono- and bimetallic nickel - cobalt

Bastián Puentes-Navarro (Universidad del Bío-Bío, Chile) Serguei Alejandro-Martín (Universidad del Bío-Bío, Chile) Laura Azócar-Ulloa (Centro de Energía UCSC, Chile)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

The catalytic co-hydropyrolysis of biomass and plastic residues represents a promising pathway for producing value-added hydrocarbons suitable as precursors for sustainable aviation fuels. In this study, a Chilean natural zeolite was modified by acid treatment with HCl (2.4 M) and subsequently impregnated with Ni, Co, and Ni–Co to develop acid–metal catalysts tailored for upgrading volatile pyrolysis streams. The objective was to assess how acid modification and metal incorporation influence the structural, acidic, and textural properties of the catalysts and their impact on the chemical distribution of volatile products from the co-hydropyrolysis of Chilean oak (biomass) and HDPE-LDPE(plastics). To evaluate the catalytic influence on product distribution, all co-hydropyrolysis experiments were carried out using an analytical pyrolysis system coupled to gas chromatography–mass spectrometry (Py-GC/MS). This technique enabled rapid screening of catalytic effects by providing detailed identification of the volatile compounds generated, including hydrocarbons, oxygenates, aromatics, and fuel-range fractions. The Py-GC/MS setup allowed consistent comparison between catalysts while minimizing mass-transfer limitations and secondary reactions, making it a suitable tool for mechanistic interpretation of catalytic behavior. Acid treatment of the natural zeolite (ZN) generated a substantial increase in surface area (from 213 to 439 m^2/g), enhanced mesoporosity, and a higher Si/Al ratio (~33% increase), as confirmed by N_2 physisorption and XRF. This modification removed extra-framework and framework aluminum and decreased the concentration of inorganic impurities (Na, Ca, Fe, Mg, K), improving acid site accessibility. SEM-EDX analysis revealed increased surface roughness, enlarged pores, and homogeneous distribution of the impregnated metals on the modified zeolite (ZH2.4). XRD analysis showed that the zeolite crystalline structure was preserved after acid treatment and metal impregnation. Monometallic catalysts displayed NiO and Co_3O_4 reflections, while the bimetallic NiCo/ZH2.4 catalyst additionally exhibited characteristic peaks of the mixed spinel phase $NiCo_2O_4$, suggesting structural integration of both metals. H_2-TPR profiles indicated that NiCo/ZH2.4 had the most intense and easily accessible reduction features, likely due to hydrogen spillover and the formation of mixed metal phases. NH_3-TPD experiments showed that metal incorporation modulated surface acidity: Ni promoted medium-strength acidity, Co preserved strong acid sites, and NiCo/ZH2.4 presented a balanced acid distribution favorable for bifunctional acid–metal reactions. Py-GC/MS analysis of the co-hydropyrolysis products at 550 °C demonstrated that the NiCo/ZH2.4 catalyst significantly enhanced hydrocarbon formation, especially alkanes, while markedly reducing oxygenated compound families. This catalyst showed the highest selectivity toward Jet Fuel–type hydrocarbon fractions, evidencing a strong acid–metal synergy in volatile upgrading. Overall, the results indicate that combining acid modification with bimetallic impregnation effectively boosts catalytic performance in biomass/plastic co-hydropyrolysis. The NiCo/ZH2.4 catalyst exhibited superior physicochemical properties and product selectivity, highlighting its potential for sustainable aviation fuel precursor production from mixed waste feedstocks.



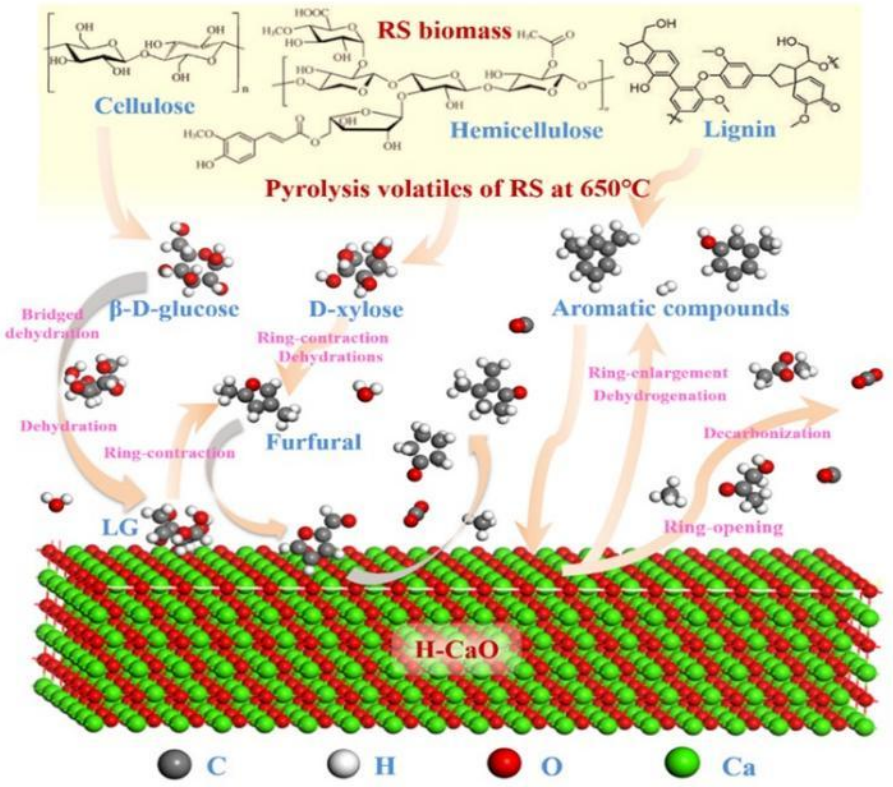
The mechanism of biomass pyrolysis quality improvement catalyzed by calcium oxide-based catalysts

Guangsuo Yu (East China University of Science and Technology, China) Xudong Song (Ningxia University, China) Linmin Zhang (Ningxia University, China) Jiaofei Wang (Ningxia University, China)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

Pyrolysis is a key technical means for the clean and efficient utilization of biomass. However, the high oxygen content of biomass leads to a large amount of water and CO_2 in its pyrolysis products. How to in-situ utilize these water and CO_2 to improve bio-oil quality and reduce CO_2 emissions during biomass utilization is crucial, with the core lying in matching the reforming reaction temperature with the CO_2/steam release temperature. In this study, the catalytic adsorption performance of CaO was enhanced by regulating its physicochemical properties and constructing a bimetallic sequential catalytic system, realizing the simultaneous adsorption and conversion of water and CO_2 to improve bio-oil quality. Furthermore, DFT calculations, isotope tracing, and other techniques were employed to reveal the mechanism of CaO's dynamic participation in the pyrolysis process and the catalytic pyrolysis upgrading mechanism of the CaO-based catalytic system.



Comprehensive utilization of corn cob (Zea Mays) for the production of biofuels and platform molecules through a hybrid bio-thermocatalytic conversion route

Evelyn Guadalupe Vargas Alvarez (UANL, Mexico) Eileen Susana Carrillo-Pedraza (UANL, Mexico) Diana Bustos-Martinez (UANL, Mexico)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

Sugar measurements during fermentation showed a maximum ethanol concentration of 0.46 ± 0.05 g/L after 72 h. The physicochemical characterization of corn cob biomass and its fermented residue revealed overall consistency, with differences attributed to compositional changes induced by biochemical conversion. Thermogravimetric analysis identified 500 °C as the optimal temperature for pyrolysis, yielding the highest liquid fractions (63% for raw corn cob and 54% for fermented residue). At this temperature, bio-oil from raw corn cob showed a higher abundance of value-added compounds, such as furfuryl alcohol and acetic acid, compared to the fermented residue. Catalytic pyrolysis of the fermented residue reduced liquid yield (36%) due to deoxygenation reactions, increasing gas production (40%) and CO/CO_2 concentrations, while enhancing phenolic compounds and reducing ketones and acids. Biochar obtained may be further evaluated for advanced materials or bioremediation. Overall, the hybrid bio–thermocatalytic conversion route demonstrates strong potential for sustainable waste valorization aligned with the United Nations Sustainable Development Goals.

Valorization of Non-Edible Vegetable Oil through Zeolite-Catalyzed Pyrolysis: A Model Study on Oleic Acid for Aromatics and SAF Precursors Production

Weiling Piao (Dalian Institute of Chemical Physics, CAS, China) Ziwei Liu (Dalian Institute of Chemical Physics, CAS, China) Jinmei Liu (Nanjing Tech University; Dalian Institute of Chemical Physics, CAS, China) Jinping Guo (Nanjing Tech University;Dalian Institute of Chemical Physics, CAS, China) Songbo He (Dalian Institute of Chemical Physics, CAS, China)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The catalytic pyrolysis of lipid-based biomass, such as non-edible vegetable oils, offers a promising route for producing sustainable aviation fuel (SAF) and high-value chemicals such as benzene, toluene, and xylene (BTX) However, achieving precise selectivity toward targeted hydrocarbons remains a fundamental challenge in catalyst design. Through a systematic evaluation of zeolite catalysts, the ex-situ pyrolysis of oleic acid was studied in a continuous fixed-bed reactor at 550 °C to achieve precise control over product selectivity. Non-catalytic pyrolysis of oleic acid afforded a high bio-oil yield (>80 wt%) with a broad, non-selective product spectrum. In contrast, zeolites enabled targeted transformations. H-ZSM-5, leveraging its strong acid sites and shape selectivity, exhibited exceptional performance for BTX production, achieving 81% selectivity and a stable yield of 37.3 wt.% over 8 h without significant deactivation. This catalyst also demonstrated robustness with real feedstocks, affording a 28 wt.% BTX yield from castor oil. Meanwhile, MCM-41, MCM-41 favored milder cracking, preserving a higher liquid yield of 57.1 wt.% with inherent selectivity toward C8–C16 alkanes/alkenes. Strategic modification of MCM-41 with Ni and Mo further enhanced SAF-precursor selectivity, increasing the C8–C16 fraction from 12% to 28%. This improvement is attributed to optimized metal-support interactions and tailored acid sites that promote deoxygenation and mild cracking while suppressing excessive aromatization. These results underscore the critical role of zeolite design in directing lipid pyrolysis toward distinct product streams. Ongoing work expands this study to diverse fatty acid profiles and employs advanced characterization techniques (e.g., structure/acidity/coke analysis) to elucidate deactivation mechanisms and refine catalyst stability. This integrated approach establishes a versatile pathway for converting renewable lipids into bio-aromatics and SAF components, advancing the circular bio-economy.

Performance of Ni/Al_2O_3, Ni/SiO_2, and Ni/ZrO_2 in the biomass pyrolysis and in-line oxidative steam reforming process for hydrogen production

Farid Atashi (University of the Basque country, Spain) Stephanie Arias (University of the Basque Country, Spain) Leire Olazar (Universirt of the Basque Country, Spain) Dani Goma (Uiniversity of the Basque Country, Spain) Laura Santamaria (University of the Basque Country, Spain) Maite Artetxe (University of the Basque Country, Spain) Maider Amutio (University of the Basque Country, Spain)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Environmental concerns related to global warming are accelerating the transition from fossil fuels toward renewable energy sources, with hydrogen expected to play a key role in future energy systems. Despite this, H2 is still mainly produced from fossil fuels, which has motivated the development of sustainable alternatives such as biomass thermochemical conversion [1]. In this context, the integration of biomass fast pyrolysis with in-line oxidative steam reforming (P-OSR) represents an efficient route for H2 production, enabling autothermal operation while improving catalyst stability [2]. Ni-based catalysts are particularly attractive due to their high activity, although their susceptibility to coke deposition remains a challenge [3]. Therefore, this work investigates the performance of Ni-based catalysts in the P-OSR with the aim of maximizing H2 production under autothermal conditions. Pine sawdust serves as the biomass feed in a laboratory-scale plant comprising two in-line reactors: a conical spouted bed reactor (CSBR) for pyrolysis (500 °C) and a fluidized bed reactor for OSR of the resulting volatiles (600 °C). Ni/Al_2O_3, Ni/ZrO_2, and Ni/SiO_2 catalysts are employed to convert the biomass pyrolysis volatiles into H2. The runs were conducted with continuous biomass feeding (1 $g \cdot min^{-1}$), a steam-to-biomass (S/B) ratio of 3, and a space-time of 15 $gcat \cdot min \cdot gvolatiles^{-1}$. The results obtained in this process at zero time on stream give evidence of the high influence of catalyst support on process performance. For Ni/Al2O3 catalyst, almost full conversion as well as a H2 yield over 90% was attained, which is related to the suitable properties of this support as are high surface area and proper Ni dispersion. However, Ni/SiO2 and Ni/ZrO2 evidenced lower initial activity (conversion of 88.5 and 84.5%, respectively). Thus, H2 production decreased as follows: Ni/Al2O3 (9.5 wt%) > Ni/ZrO2 (6.1 wt%) > Ni/SiO2 (5.3 wt%). The carbon conversion and H2 yield decreased with time on stream for all three catalysts due to coke deposition on the catalytic surface. Ni/Al_2O_3 demonstrated the highest stability, maintaining higher H2 yield throughout the reaction. Ni/ZrO_2 exhibited the fastest decline in volatile conversion (it decreased from 84.5 to 58.8% for 18 min on stream), leading to higher yields of by-products compared to Ni/Al2O3 and Ni/SiO_2 catalysts. As regards Ni/SiO2 catalyst, it presents a suitable stability, maintaining a stable conversion during 60 min on stream and then decreasing to 55.7% for 81 min on stream. This fact can be ascribed to the basic nature of SiO2 support, which hinders coke formation. In view of these results, it can be concluded that the Ni/Al2O3 catalyst is the best one in terms of initial activity and stability, leading to a high H2 production (9.5 wt%). Moreover, the process proposed is a promising alternative for sustainable hydrogen production from biomass.

Preparation of carbon nanosheet from molten salts assisted pyrolysis of biomass towards to carbon-negative technology

Sunwen Xia (Shandong University, China) Defu Shi (Shandong University, China) Haiping Yang (Huazhong University of Science and Technology, China)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Preparation of two-dimensional carbon materials through biomass pyrolysis is of great significance for the high value utilization of biomass. But, biomass-derived 2D carbon materials are prone to agglomeration at elevated temperatures. Herein, we propose a method for coproducing carbon nanosheets and methanol-rich oil in a potassium chloride-lithium chloride (KCl-LiCl) liquid phase environment. Results showed that carbon nanosheets featuring a low layer thickness of 21.3 nm were produced through pyrolysis at 800 ◦C with the assistance of KCl-LiCl, which is lower than that of commercial carbon nanosheets (100 nm). In addition, methanol-rich oils with a selectivity of 98 % were prepared under the same conditions. The temperature and molten salt ratio can change the thickness of carbon nanosheets and the selectivity of methanol. Moreover, we propose a Molten salt catalytic mechanism for intercalation stripping. The KCl-LiCl etched the carbon surface and intercalated into the carbon layers, while molten salt ions covalently bonded with carbonyl and aldehyde groups on the carbon surface. These interactions facilitated cross-linking between the carbon layers, leading to the exfoliation and formation of carbon nanosheets.

Enhanced hydrocarbons generation of cyclic catalytic pyrolysis of acid-washed sweet sorghum stalk through Mo/HZSM-5

Zhifeng Li (Shenyang agricultural university, China) Yusi Hao (Shenyang agricultural university, China) Yuanyuan Zhao (Shenyang agricultural university, China) Xinwen Wang (Shenyang agricultural university, China) Jing Wang (Shenyang agricultural university, China) Wenxian Yu (Shenyang agricultural university, China) Weisheng Niu (Shenyang agricultural university, China) Yueyang Liu (Shenyang agricultural university, China) Huanhuan Wei (Shenyang agricultural university, China) Dongyu Chen (Shenyang agricultural university, China)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Improving the efficiency and stability of biomass cyclic catalytic pyrolysis has become a recent research focus. This study details the effects of hydrochloric acid and acetic acid washing pretreatments and Mo-modified HZSM-5 on hydrocarbon production during five cyclic catalytic pyrolysis cycles of sweet sorghum stalk (SSS). The results showed that acid-washing pretreatments significantly increased hydrocarbon yields. Hydrochloric and acetic acid washing raised the volatile matter content to 78.89% and 77.86%, and the higher heating value (HHV) increased by 45.00% and 37.27%, respectively. Mo/HZSM-5 also enhanced hydrocarbon selectivity and stability. Nevertheless, the combination of acetic acid washing and Mo/HZSM-5 exhibited superior performance after five pyrolysis cycles, with hydrocarbon selectivity remaining as high as 14.22% compared with only 4.31% for raw SSS. This study proposes an integrated strategy combining acid-washing pretreatment and metal-modified HZSM-5 as a sustainable and feasible method to enhance hydrocarbon production from biomass pyrolysis.

Thermal and Catalytic Pyrolysis of Olive Stone to produce Phenol-rich Bio-oils

Antonio Capasso (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy) Renata Migliaccio (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy) Anna Basco (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy) Biagio Ciccone (Dipartimento di Scienze Chimiche, Federico II di Napoli, Italy) Giovanna Ruoppolo (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy) Massimo Urciuolo (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy) Paola Brachi (Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili-CNR, Italy)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

The present study reports the results of an extensive experimental campaign carried out within the framework of the European "BioPhenom" project (Grant Agreement No: 101135107), aimed at developing sustainable pathways to produce bio-based phenolic compounds. Phenols are among the most important classes of aromatic compounds in the chemical industry, serving as key intermediates for the manufacture of a wide range of value-added products. Since phenol production relies on fossil resources (e.g., the energy- intensive cumene process [1]), the development of renewable and low-carbon routes for phenol production is of great environmental and industrial relevance. Fast pyrolysis of lignocellulosic biomass represents a promising technology for the sustainable production of phenolic compounds. This process is feedstock-flexible, using lignin-rich agricultural residues and industrial by-products, and directly produces phenolic intermediates within pyrolysis bio-oils. These bio-oils contain both monomeric phenols and polyphenolic oligomers derived from lignin depolymerization. While monomeric phenols are of high industrial interest due to their direct applicability, their concentration in conventional pyrolysis oils is typically low, whereas the dominant phenolic fraction consists of high-molecular-weight, oxygen-rich oligomers commonly referred to as pyrolytic lignin, which limits their direct valorization. In this work, thermal and catalytic pyrolysis experiments were performed using lignin-rich Olive Stone residues as feedstock in a laboratory-scale fluidized bed reactor. The tests were carried out at 400, 500, and 600 °C with a gas residence time of approximately 1 s, to assess the influence of operating conditions on product yields and composition. To enhance the yield and selectivity towards monomeric phenols while suppressing the formation of heavy oxygenated by-products, a calcined dolomite catalyst was employed as bed material. Dolomite was selected due to its low cost, non-toxicity and minimal environmental impact, and its basic properties, which are favorable for selective phenolic production [2]. The effect of the weight hourly space velocity on product distribution and quality was also investigated. The pyrolysis products were characterized by continuous online gas analysis and chemical analysis of the condensed bio-liquid. GC-MS was used to identify and estimate the relative abundance of volatile and semi-volatile compounds, while Karl Fischer titration, Folin-Ciocâlteu assay, and total acid number (TAN) analysis were applied to quantify water content, total (poly)phenols, and acidity, respectively. In addition, bio-char samples were characterized in terms of textural, morphological, and chemical properties to evaluate their potential for further valorization. Results demonstrate that the use of calcined dolomite significantly improves the selectivity of pyrolysis towards phenol-rich bio-oils. Under optimized conditions, the resulting bio-oils exhibit a simplified chemical composition mainly consisting of phenols and ketones, along with reduced oxygen content and acidity. Overall, these findings highlight the potential of catalytic fast pyrolysis of OS as a viable and sustainable route for the production of bio-based phenolic compounds.

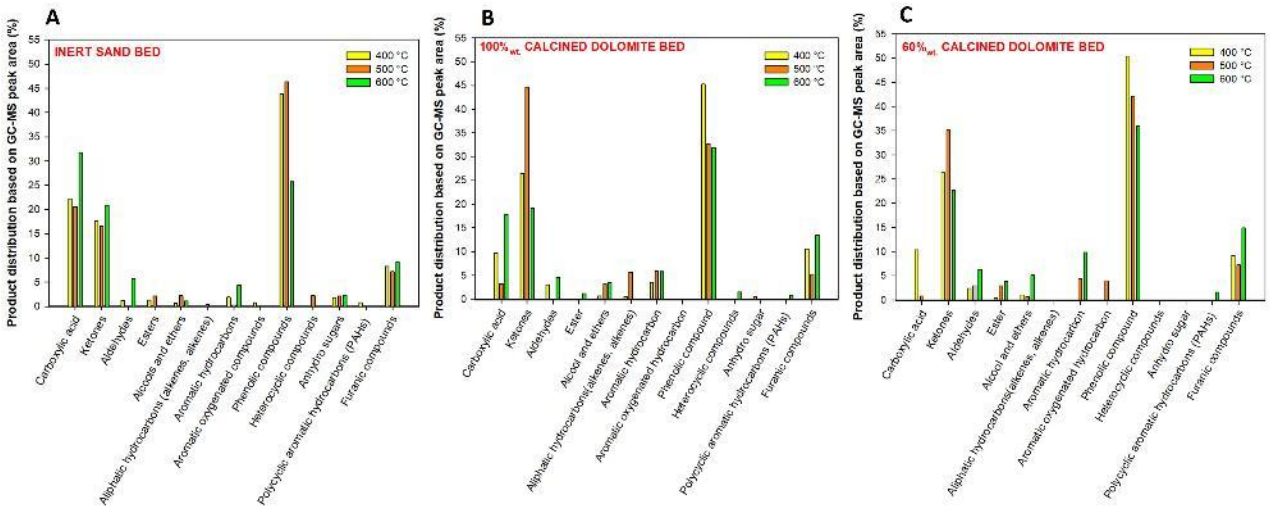


Figure 1. GC-MS peak area (%) for vapors produced over: (a) sand, (b) 100 wt.% and (c) 60wt.% calcinated dolomite, at 400, 500 and 600 °C. [1] L.M.J. Sprakel and B. Schuur, Journal of Chemical Thermodynamics 162 (2021) 106577. [2] M. Tawalbeh, et al., Journal of Environmental Management 299 (2021) 113597.

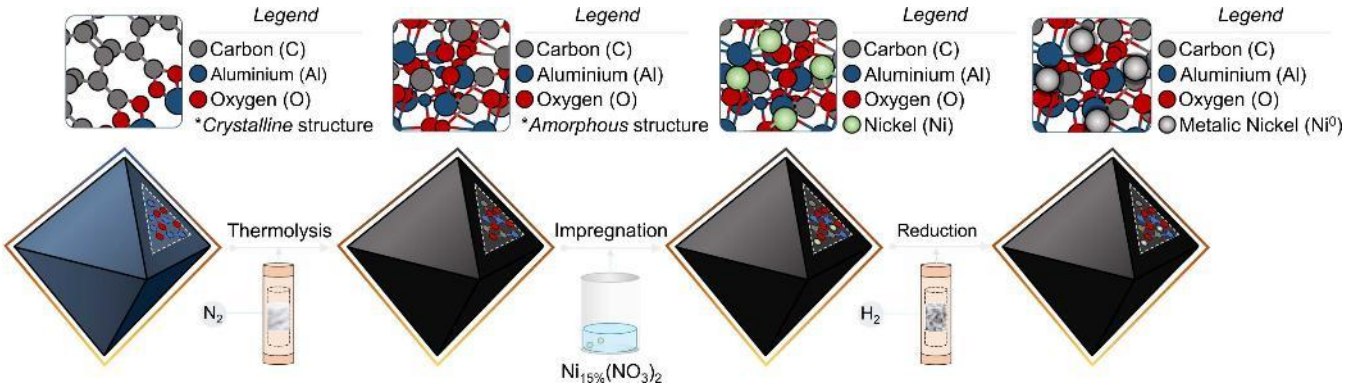
Thermo-metallic engineering of MOF-derived catalysts: Influence on selectivity during biomass-plastic co-hydropyrolysis

Carlos Romero-Unda (Universidad del Bio-Bio, Chile) Serguei Alejandro-Martín (Universidad del Bío-Bío, Chile) Konstanza Ortiz-Araya (Universidad del Bio-Bio, Chile)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

Mitigating atmospheric CO2 accumulation justifies the development of sustainable processes focused on key molecular building blocks that do not rely on high-emission fossil feedstocks. In this context, catalytic co-hydropyrolysis (CCo-HyPy) of biomass and plastics offers an attractive route for converting waste resources into monoaromatic hydrocarbons (MAHs); however, its efficiency remains tightly constrained by the need for a carefully tailored, exigent catalyst design. Commonly, such processes use synthetic zeolites such as ZSM-5, which incorporate Brønsted and Lewis acid sites within strictly microporous frameworks, thereby enabling efficient coupling between furanic intermediates derived from biomass and olefinic fragments originating from plastics to obtain monoaromatics. Nevertheless, their high acidity and restricted porosity promote polycyclic aromatic hydrocarbon (PAH) formation and rapid coke deposition, ultimately reducing MAH selectivity. Herein, a metal-organic framework was employed as a sacrificial precursor to generate thermo-metallically transformed Ni0/Al2O3-C catalysts integrating accessible acid sites, oxophilic domains and well-dispersed Ni0 hydrogenation centres. This thermo-metallic restructuring enhances mesoporosity and surface chemistry, enabling a systematic assessment of how structural evolution governs catalytic performance and product distribution in CCo-HyPy. The pristine support (MIL-53(Al)) was impregnated by incipient wetness with 5, 10 and 15 wt% Ni and subsequently subjected to controlled thermolysis at 650 °C and 800 °C under flowing N2 for 2 h, after which the resulting structures were reduced in H2 at 500 °C for 2 h and characterised by XRD, NH3-TPD and N2 physisorption. CCo-HyPy experiments were conducted at 600 °C and 100 psi H2 in a Py-GC/MS system, with product selectivity semi-quantified using relative abundance (RA), and synthetic ZSM-5 used as a benchmark. XRD confirms the formation of metallic Ni, with reflection intensities increasing as Ni loading increases, while the support remains predominantly amorphous. Progressive Ni incorporation suppresses strong acid sites, whereas weak acidity is maximised at 10 wt% Ni and medium-strength acidity peaks at 15 wt%, consistent with partial masking or neutralisation of high-energy acid centres by dispersed Ni0 species. The bare support exhibits nearly constant BTEX selectivity across thermolysis temperatures, whereas the introduction of 5 wt% Ni approximately doubles selectivity and renders it insensitive primarily to thermolysis conditions. In contrast, higher Ni loadings result in a pronounced decrease in BTEX selectivity at 650 °C, followed by partial recovery at 800 °C, reflecting enhanced hydrogenolysis and hydrogenation activity that diverts unsaturated intermediates towards saturated aliphatics. Consequently, the 5 wt% Ni catalyst achieves BTEX selectivity comparable to that of ZSM-5, with only a marginal reduction (-6.5%), while simultaneously suppressing PAH formation by approximately 11%. Overall, optimal monoaromatic production is achieved at low Ni loadings, where thermo-metallic modification of the MOF-derived framework establishes a favourable metal-acid balance. In contrast, higher loadings disrupt this balance and compromise MAH selectivity during biomass-plastic CCo-HyPy.



Catalytic upgrading of pyrolysis vapors from residual Acacia longifolia biomass: comparative performance of commercial Fe-, Ni-, and Mo-based catalysts

Catarina Marques (Department of Environment and Planning, Center of Environment and Marine Studies, University of Aveiro, Portugal) Klas Engvall (Department of Chemical Engineering, KTH Royal Institute of Technology, Sweden) Luis Tarelho (Department of Environment and Planning, Center of Environment and Marine Studies, University of Aveiro, Portugal) Isabel Nunes (Department of Environment and Planning, Center of Environment and Marine Studies, University of Aveiro, Portugal) Giorgio Bruno Braghin (Department of Chemical Engineering, KTH Royal Institute of Technology, Sweden) Pedro Souza (Department of Chemical Engineering, KTH Royal Institute of Technology, Sweden)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Bio-oils from pyrolysis of residual forest biomass offer a promising route to partially replace liquid fossil fuels, but their direct utilization is constrained by undesirable properties such as a high-water content, elevated concentrations of oxygenated compounds, and low heating values. Catalytic pyrolysis has emerged as an effective upstream strategy to enhance bio-oil quality. Although this approach does not typically yield a ready-to-use fuel, it can significantly improve the operating constraints associated with downstream hydrotreatment processes. In this context, three commercially available Ni-, Fe-, and Mo-based catalysts, selected for their high technological readiness and industrial relevance, were evaluated in an ex-situ configuration for the upgrading of pyrolysis vapors from Acacia longifolia, an invasive species widely available as residual biomass in Southern Europe. Fast pyrolysis experiments were conducted in a bubbling fluidized bed reactor operating at 550 °C, followed by catalytic upgrading in a fixed-bed reactor at 450 °C. The influence of each catalyst was assessed for product yields, permanent gas composition, and bio-oil water content (Karl Fischer titration) and chemical composition (GC–MS). Catalyst type proved decisive on governing product distribution and deoxygenation pathways. The Fe-based catalyst exhibited the highest activity, promoting extensive deoxygenation through dehydration and secondary cracking reactions, as reflected by increased water formation and a significant shift toward aromatics, hydrocarbons, and phenolic compounds. Hydrogen production was also enhanced, suggesting a contribution from water-gas shift reactions occurring in parallel. These improvements in bio-oil quality, however, came at the cost of liquid yield, with marked increase in permanent gas production. The Ni-based catalyst showed a milder catalytic effect, largely preserving overall product yields while promoting the accumulation of oxygenated species, particularly acetic acid. This selectivity suggests potential applicability beyond fuel production, namely for the generation of renewable chemical intermediates. The Mo-based catalyst exhibited the lowest activity under the tested conditions, resulting in only minor changes in product distribution and bio-oil composition. These results demonstrate that catalyst fundamentally shapes upgrading pathways and the trade-offs between deoxygenation efficiency and liquid yield. Fe-based catalysts show strongest potential for bio-oil quality improvement but require strategies to mitigate carbon losses to the gas phase, pointing to catalyst formulation and process optimization as priority directions. Ni- and Mo-based catalysts, with their milder activity profiles, may better suited for selective valorization of oxygenated fractions toward chemical applications. These differences point to distinct upgrading routes and open opportunities for tailoring catalytic systems toward a range of fuel and chemical applications.

Polymer to fuel-range hydrocarbons: An investigation of thermal and β-zeolite-catalyzed pyrolysis of polypropylene (PP) using Py-GC-MS and Py-FT-IR techniques

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The increasing accumulation of plastic waste, particularly polyolefins such as polypropylene (PP), represents a growing environmental and technological challenge. Polyolefins account for more than 50% of the global plastic waste stream [1]. Among available waste management strategies, chemical recycling has attracted considerable attention as a route for recovering valuable products from waste plastics. In this context, pyrolysis enables the conversion of polymer waste into hydrocarbon mixtures that may be used as petrochemical feedstocks or components of transportation fuels. However, further development of this approach requires a better understanding of polymer degradation mechanisms and the role of catalysts in directing product distribution toward desirable fuel-range fractions. The present study investigates the thermal and catalytic pyrolysis of polypropylene using β-zeolite as a catalyst. Particular attention was paid to degradation pathways leading to hydrocarbons within typical fuel fractions. Experiments were carried out using complementary analytical techniques: pyrolysis–gas chromatography–mass spectrometry (Py-GC-MS) and pyrolysis combined with Fourier transform infrared spectroscopy (Py-FT-IR). These methods enabled identification of compounds formed during PP decomposition, evaluation of the chemical character of the resulting mixtures, and interpretation of possible reaction mechanisms involved in polymer degradation. β-Zeolite was selected due to its developed pore structure and the presence of acidic active sites known to promote cracking reactions and facilitate the transformation of polymer chains into lighter hydrocarbons. The obtained pyrolysis products were grouped according to carbon number into four fractions corresponding to conventional fuel ranges: C1–C4 (refinery gases), C5–C10 (gasoline range), C11–C15 (kerosene and light diesel range), and C15+ (heavier hydrocarbons). Additionally, the chemical character of the compounds was analyzed, with emphasis on aromatic, olefinic, and paraffinic hydrocarbons. This enables a preliminary assessment of the potential applicability of the resulting mixtures as blending components for conventional fuels. The results show that thermal degradation of polypropylene produces a wide range of hydrocarbons, with olefins representing a significant fraction of the products. Their formation is mainly associated with random chain scission followed by β-scission reactions during polymer decomposition. The presence of β-zeolite significantly influences the process by enhancing cracking reactions and promoting secondary transformations on acidic catalyst sites, including isomerization and hydrogen transfer reactions. Consequently, the product distribution shifts toward lighter hydrocarbon fractions with noticeable changes in the relative proportions of olefins and paraffins. Overall, the results provide insight into the relationship between polypropylene degradation pathways and the formation of hydrocarbons within fuel-range fractions, contributing to a better understanding of the potential use of polyolefin pyrolysis products in refinery processes or fuel blending. Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101086071, project name "CUPOLA — Carbon-neutral pathways of recycling marine plastic waste". Support was also provided by the Ministry of Science and Higher Education in Poland through the program "PMW grant no. 5863/HE/2024/2 (no. W52/HE/2024).

Tailoring Hierarchical Nanocrystalline Zeolite NaY: A Template-Free Hydrothermal Strategy for Advanced Catalytic Pyrolysis Applications

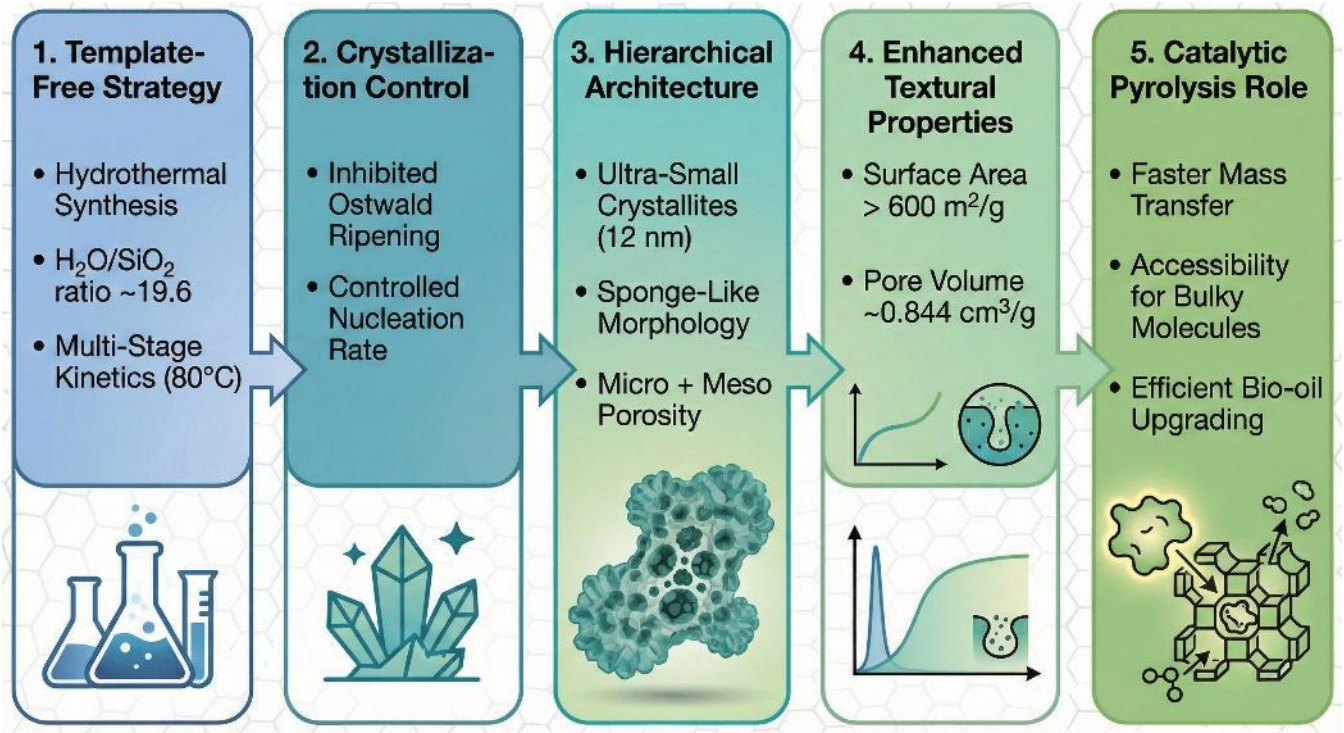
Chenicheni Ayoub (National Gendarmerie Research and Development Center (CRD-GN), Algeria) Samir Belkhiri (Ecole Military Polytechnic (EMP), Algeria) Ahmed Fouzi Tarchoun (Ecole Military Polytechnic (EMP), Algeria)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Catalytic pyrolysis represents a cornerstone technology for the valorization of complex feedstocks, where the structural efficiency of the zeolite catalyst is paramount. To enhance catalytic performance while simplifying synthesis, this research establishes a robust template-free hydrothermal route for the production of hierarchical NaY nanozeolites. By systematically unraveling the synergistic interplay between gel composition and kinetic parameters, we successfully tailored the crystallization pathways to maximize textural properties suitable for industrial applications. The results reveal a distinct correlation between system dilution and crystal size, where an optimized H_2O/SiO_2 ratio of ~19.6 yielded ultra-small primary crystallites of 12 nm. Furthermore, the implementation of a multi-stage thermal protocol (incorporating a nucleation step at 80 °C) inhibited Ostwald ripening, resulting in a highly uniform morphology of interconnected nanocrystalline aggregates. Comprehensive characterization via XRD, FTIR, SEM, and advanced N_2 physisorption confirms the development of a superior hierarchical architecture. The optimized nanozeolites exhibit high specific surface areas (> 600 m^2/g) and exceptional total pore volumes up to 0.844 cm^3/g, merging intrinsic FAU microporosity with extensive interparticular mesoporosity. This specific architecture ensures optimal accessibility to active sites, making these materials highly effective candidates for demanding catalytic pyrolysis and upgrading reactions.



Thermal Decomposition and Energetic Behavior of Ammonuim Nitrate modified with Nitrocellulose-Coated AlMg–NGO@nFe_2O_3 Nanothermite

Feriel Gahfif (Ecole Militaire Polytechnique, Algiers, Algeria., Algeria) Moulai Karim Boulkadid (Ecole Militaire Polytechnique, Algiers, Algeria., Algeria) Sabri Touidjine (Ecole Militaire Polytechnique, Algiers, Algeria., Algeria) Samir Belkhiri (Ecole Militaire Polytechnique, Algiers, Algeria., Algeria)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The pyrolytic decomposition behavior of ammonium nitrate (AN) and AN–nanothermite composites was investigated. A nanothermite composed of a fuel mixture (Al and Mg) and iron oxide nanoparticles supported on nitrogen-reduced graphene oxide (NGO@nFe_2O_3) ,synthesized via a one-step hydrothermal process and subsequently coated with nitrocellulose (NC). This mixture was used as a catalyst for AN, in proportions ranging of 7%. The resulting energetic formulations (AlMg-NGO@nFe_2O_3-NC/AN) were characterized using Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), thermogravimetric analysis (TG), and oxygen bomb calorimetry. The kinetic parameters of AN decomposition were determined from thermogravimetric data using integral isoconversional methods, including the Kissinger–Akahira–Sunose (it-KAS) and Flynn–Wall–Ozawa (it-FWO) models.FTIR analysis confirmed that the chemical structure of the nitrocellulose-coated nanothermite corresponds to a physical mixture, indicating the successful synthesis of the composite. The combined kinetic and calorimetric results demonstrate the strong catalytic effectiveness of the AlMg/NGO@nFe_2O_3/NC system in promoting the thermal decomposition of ammonium nitrate (AN) and enhancing its energetic performance.

Spray pyrolysis synthesis of Cu-CeO2-ZrO2 catalysts with enhanced oxygen storage capacity for reverse water-gas shift reaction

I-Jeong Jeon (Wonkwang University, South Korea) Chang-Hyeon Kim (Wonkwang University, South Korea) Chae-Min Yoon (Wonkwang University, South Korea) Kyung-Won Jeon (Kunsan National University, South Korea) Jae-Oh Shim (Wonkwang University, South Korea)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Spray pyrolysis is a simple and cost-effective process that has been widely applied to the synthesis of carbon-based composite microspheres with diverse compositions. In addition, spray pyrolysis enables the generation of micron-sized droplets with controlled precursor ratios, allowing the synthesis of catalysts with uniformly distributed components at specific molar ratios. In this study, Cu catalysts supported on CeO2-ZrO2 were synthesized using spray pyrolysis and applied to the reverse water–gas shift (RWGS) reaction. An enhancement in oxygen storage capacity (OSC) was found to positively influence catalytic activity, and Cu-CeO2-ZrO2 catalysts prepared at different calcination temperatures exhibited similar trends in both OSC and catalytic performance. Consequently, these results demonstrate that superior OSC properties of the catalyst can be translated into enhanced activity in the RWGS reaction.

Structurally stable methanation-resistant catalysts for the reverse water-gas shift reaction

Chae-Min Yoon (Wonkwang University, South Korea) I-Jeong Jeon (Wonkwang University, South Korea) Chang-Hyeon Kim (Wonkwang University, South Korea) Kyung-Won Jeon (Kunsan National University, South Korea) Jae-Oh Shim (Wonkwang University, South Korea)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The reverse water-gas shift (RWGS) reaction is a promising route for syngas production via CO2 valorization. However, the endothermic RWGS reaction faces strong competition with the methanation at low temperatures, limiting the simultaneous achievement of high activity and selectivity. To address these challenges, high entropy oxide (HEO) was applied as a catalyst for the RWGS reaction, leveraging its excellent thermal stability and tunable redox properties. Spray pyrolysis method allows precise compositional control, leading to the formation of structurally stable oxide catalysts. All catalysts were synthesized via spray pyrolysis, and among the three prepared catalysts, the CoNiCuZn catalyst exhibited the highest catalytic activity and stability, which can be attributed to its unique structural characteristics.

Catalytic fast pyrolysis of biomass over hierarchical zeolites: comparison of mordenite, beta and ZSM-5

Ludovic Pinard (ENSICaen, CNRS, France) Liangyuan Jia (Hefei University of Technology, China) Anthony Dufour (CNRS, France)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Biomass catalytic fast pyrolysis (CFP) is a promising process but its development is still hampered by the formation of coke which reduces the carbon selectivity of the process to the targeted aromatic hydrocarbons. It is important to better understand the effect of zeolite structure on the mechanisms of coke deposit and how this coke deposit poison the active sites (Bronsted sites, BAS). In our article [1] and in this poster, we provide a systematic comparison of various zeolites: mordenite (MOR), beta (*BEA) and ZSM-5 (MFI) with different hierarchization methods (NaOH, HF, NH4F). The effect of crystal size has been also studied for *BEA. These zeolites were tested with a constant biomass to catalyst ratio of 0.8 in a double fixed bed reactor which enables to decouple biomass pyrolysis and ex-situ volatiles conversion. The formation of volatiles species was monitored on-line by photoionization mass spectrometry. Aromatic hydrocarbons were also quantified by GC/MS-FID. The spent catalysts were analysed by pyridine probe (for acidity), FTIR (for coke composition) and N2 sorption (for porous structure). The structure of mordenite with a two dimensional network of channels and weak connections between the channels leads to a fast deactivation by pores blocking even after different hierarchization methods. The hierarchical MFI (obtained by mild desilication with NaOH) was the best selective zeolite towards aromatic hydrocarbons. The selectivity towards aromatics and coke formation depends on the shape of canals but not on the H+ cage environment. *BEA promotes the diffusion of species to BAS in larger pores than MFI but it leads to a lower shape-selectivity than MFI, especially after partial deactivation by coke. [1] Pinard et al., Energy & Fuels 38 (15), 14351-14364, 2024

Catalytic Pyrolysis of Organic Waste over Nanosponge Zeolite for Enhanced Aromatic Hydrocarbon Production

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The thermochemical conversion of organic waste into value-added chemicals is a promising strategy for achieving resource circularity and reducing environmental burdens associated with waste disposal. Among various conversion routes, catalytic pyrolysis has attracted significant attention due to its ability to selectively upgrade complex organic feedstocks into high-value hydrocarbons. Conventional microporous zeolites, such as ZSM-5, are widely used in catalytic pyrolysis due to their strong Brønsted acidity and shape-selective pore structures, which are effective for promoting cracking, deoxygenation, and aromatization reactions. However, their strictly microporous channels impose significant diffusion limitations when processing bulky oxygenated intermediates derived from organic waste. These limitations often result in incomplete vapor upgrading, rapid coke formation, and catalyst deactivation, ultimately restricting aromatic yields and long-term catalytic stability. Nanosponge zeolites offer a promising alternative by incorporating a hierarchical pore architecture that combines intrinsic micropores with interconnected meso- and macroporous networks. This structural modification enhances molecular accessibility to active acid sites and facilitates the transport of large pyrolysis-derived molecules within the catalyst framework. As a result, nanosponge zeolites can alleviate diffusion resistance, suppress secondary condensation reactions, and mitigate coke deposition while maintaining the intrinsic catalytic functionality of the zeolite framework. These features make nanosponge zeolites particularly suitable for upgrading complex and oxygen-rich pyrolysis vapors generated from organic waste. During catalytic pyrolysis, the nanosponge zeolite facilitates cracking, deoxygenation, and aromatization reactions, promoting the conversion of oxygen-rich pyrolysis vapors into mono-aromatic hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes. Overall, this work highlights the potential of nanosponge zeolite catalysts for the efficient catalytic pyrolysis of organic waste and demonstrates their applicability for producing aromatic-rich hydrocarbon streams. The findings provide insight into catalyst design strategies for waste-to-chemicals technologies and contribute to the development of sustainable thermochemical conversion processes.

Catalytic co-pyrolysis of woody biomass and waste plastics: mechanistic insights into selective BTX production

Hoesuk Yim (Seoul National University, South Korea) Sejin Hwang (University of Korea, South Korea) Jong Hun Kang (Seoul National University, South Korea) Eilhann E. Kwon (Hanyang University, South Korea) Hocheol Song (Hanyang University, South Korea) Jong-Ki Jeon (Kongju National University, South Korea) Joonjae Ryu (University of Seoul, South Korea) Young-Kwon Park (University of Seoul, South Korea)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The continuous demand for fossil resources has resulted in greenhouse gas emissions, environmental degradation, and depletion of non-renewable feedstocks. As a sustainable alternative, catalytic co-pyrolysis of biomass and waste plastics has emerged as a promising approach for producing carbon-circulated aromatic hydrocarbons (BTX: benzene, toluene, xylene). This study aims to elucidate and optimise the catalytic reaction pathways that maximise BTX yields from the simultaneous conversion of woody biomass and plastic wastes. Particular attention is given to the interactions between biomass-derived furans and plastic-derived olefins, which are central to two key mechanisms: the furan–olefin Diels–Alder pathway and the hydrocarbon pool mechanism. The former enhances BTX selectivity through effective deoxygenation via dehydration reactions, while the latter promotes aromatic hydrocarbon formation by utilising olefins as hydrogen donors. These synergistic pathways reduce coke formation, improve catalyst stability, and enhance the overall efficiency of BTX production. ZSM-5 based catalysts were further tailored through metal incorporation and acidity modulation, enabling improved control over product selectivity and resistance to deactivation. The results demonstrate that catalytic co-pyrolysis can overcome the limitations of processing biomass or plastics alone, offering a viable strategy for upgrading heterogeneous waste streams into high-value aromatics. This work highlights the scientific basis for catalytic co-pyrolysis as a pathway to resource circulation and carbon neutrality within the chemical industry. Acknowledgements: This study was supported by National Research Foundation of Korea (RS-2024-00341143, RS-2024-00416414) and also supported by the Ministry of the Environment's waste resource energy recycling professional training project (YL-WE-22-001).

Catalytic co-conversion of biodegradalbe polymer and plastics over hierarchical zeolite catalyst

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Polylactic acid (PLA) is often regarded as a biodegradable plastic, but it decomposes poorly under normal conditions and is mostly disposed of together with conventional plastic waste. To address this limitation, catalytic co-pyrolysis of polylactic acid (PLA) and high-density polyethylene (HDPE) was investigated to enhance deoxygenation and aromatic hydrocarbon formation. Non-catalytic co-pyrolysis showed strong synergistic suppression of oxygenates due to hydrogen transfer from HDPE-derived intermediates. Zeolite catalysts further promoted aromatization, with HZSM-5 (HZ) exhibiting high BTEX selectivity owing to its strong acidity and shape-selective micropores. To overcome diffusion limitations of bulky PLA-derived intermediates, hierarchical HZ catalysts were prepared by alkaline desilication using NaOH (N-HZ) or NaOH combined with TEAOH (TE-HZ) or TPAOH (TP-HZ). Compared with the parent HZ, which produced a BTEX area of 377.3 × 106, alkali-treated catalysts exhibited enhanced mesoporosity and increased acidity, leading to improved oxygenate removal and aromatic hydrocarbon formation. During catalytic co-pyrolysis, hierarchical catalysts significantly promoted decarbonylation, as evidenced by increased CO formation in the gas phase, due to facilitated transport of bulky PLA-derived oxygenates to accessible acid sites of catalysts. While N-HZ showed a slightly reduced BTEX signal (354.0 × 106) due to weakened shape selectivity and enhanced secondary alkylation, TE-HZ and TP-HZ exhibited higher BTEX production, reaching 396.8 × 106 and 430.1 × 106, respectively, owing to their well-regulated micro–mesoporous structures combined with increased surface area, pore volume, and acidity. Acknowledgement: This work was supported by National Research Foundation of Korea (RS-2024-00341143, RS-2024-00416414).

Effect of Nano structuring on the Decomposition Kinetics of Cellulose Nitrate

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Nano-cellulose nitrate has attracted increasing interest due to its unique physicochemical properties and potential energetic applications. In this study, the thermal decomposition kinetics of nano-cellulose nitrate were systematically investigated and compared with those of conventional (macro-scale) cellulose nitrate. Nano-cellulose was synthesized via a bacterial route, ensuring high purity and controlled nanoscale morphology. Thermogravimetric analysis (TGA) was employed to study the decomposition behavior under non-isothermal conditions. Kinetic parameters were determined using two model-free isoconversional methods, namely the iterative Kissinger–Akahira–Sunose (IT-KAS) and the iterative Flynn–Wall–Ozawa (IT-FWO) approaches. The results reveal a noticeable decrease of approximately 5% in the apparent activation energy for nano-cellulose nitrate compared to its macro-scale counterpart, indicating enhanced thermal reactivity associated with nanoscale effects. Furthermore, the decomposition process of nano-cellulose nitrate follows a different reaction model, g(α), highlighting a change in the dominant decomposition mechanism induced by nanostructuring. These findings demonstrate that size reduction at the nanoscale significantly influences the thermal decomposition kinetics and mechanisms of cellulose nitrate, providing valuable insights for its safe handling and potential energetic applications.

Zn-Fe Co-modified HZSM-5/MCM-41 Catalytic Co-pyrolysis of Miscanthus and Polystyrene to Produce Aromatic-Rich Oil

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

This study investigates the catalytic co-pyrolysis of Miscanthus (MT) and polystyrene (PS) over Zn-Fe co-modified HZSM-5/MCM-41 molecular sieves to produce aromatics. Various characterization techniques, including transmission electron microscopy, X-ray diffraction, Brunauer-mmett-Teller analysis, and ammonia temperature-programmed desorption, were used to analyze the catalysts. Py-GC/MS was employed to study the pyrolysis of MT and PS separately, together, catalytically, and non-catalytically, and to evaluate the catalysts. The experimental results show that all catalysts significantly increase the proportion of aromatics in the pyrolysis products. Under the action of 2wt% Zn-2wt% Fe-HZSM-5/MCM-41, Zn and Fe exhibit a notable synergistic effect, with the proportion (93.47%) and yield (1.01×109) of aromatics (AHs) reaching the maximum values. Oxygenated compounds, except for furan, drop to 0%. The synergy between Zn and Fe enhances the proportion of polycyclic aromatic hydrocarbons (PAHs) while suppressing the content of monoaromatic hydrocarbons (MAHs). Furthermore, after nine cycles of using 2wt% Zn-2wt% Fe-HZSM-5/MCM-41, the proportion of AHs decreases to 84.1%, which is lower than that in the non-catalytic pyrolysis of MTPS, indicating deactivation has occurred. This study provides a new approach for the recycling of MT and waste PS.

Structural tailoring of pyrolysis-derived carbon from thermo-catalytic methane decomposition

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Abstract Thermo-catalytic methane pyrolysis has introduced a promising route for the simultaneous production of hydrogen and solid carbon without direct CO2 emissions. In this work, pyrolysis-derived carbon produced in a stainless-steel-based catalytic reactor is systematically characterized to assess its structural diversity and application potential. Scanning electron microscopy (SEM) analyses reveal the coexistence of multiple carbon morphologies, including agglomerated amorphous sub-micron particles, spheroidal carbon, and filamentous nanotube-like structures, indicating heterogeneous growth mechanisms driven by local catalytic conditions. Energy dispersive X-ray spectroscopy (EDS) confirms high carbon purity (typically >90 wt.%), with minor Fe- and Ni-based residues originating from the catalytic stainless steel, which may be advantageous for metallurgical integration. X-ray diffraction patterns show predominantly amorphous carbon with distinct graphitic (002) reflections near 26°, whose intensity and sharpness depend strongly on post-collection physical separation. Fine carbon powders exhibit sharper (002) peaks and reduced background noise compared to mixed flake-powder fractions, indicating locally enhanced structural order and partial graphitization. These results demonstrate that carbon quality can be significantly refined through morphology-based separation without altering synthesis conditions. The combined structural and compositional analysis highlights the versatility of methane pyrolysis-derived carbon and its tunability for targeted applications, including ironmaking reductants, carburizing agents, catalysis, and energy-related materials, supporting the role of methane pyrolysis as a circular and sustainable industrial process.

Microwave-Assisted Catalytic Pyrolysis of Mixed Medical Plastic Waste: Sustainable Hydrocarbon, Fuel gas, and Carbon Material Recovery

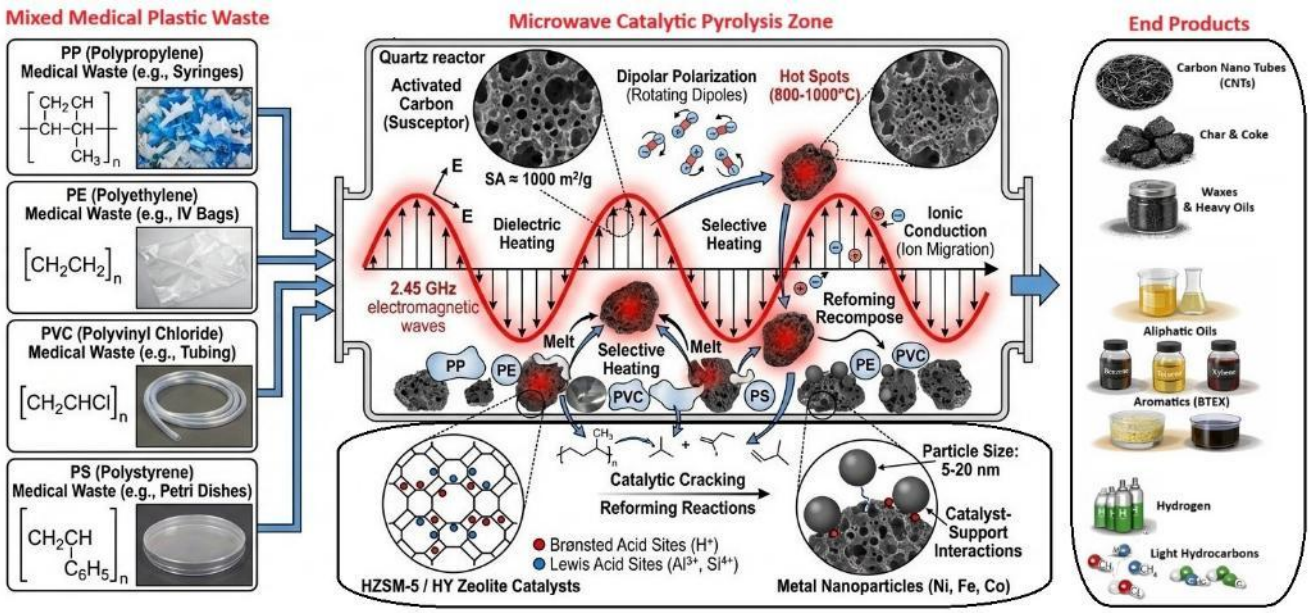
Kanak Kumar (IIT ISM DHANBAD, India) Dr. B. Rajasekhar Reddy (IIT ISM DHANBAD, India)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

The surge in generation of medical waste, particularly plastic based waste needs immediate and sustainable eradication sustainable techniques due to its environmental and community health risk. The findings of this experimental study provide a strong basis for advancing microwave assisted catalytic pyrolysis into practical waste to resources solutions. These technologies are designed to be compliant, energy efficient, and resilient, supporting the needs of modern health care system while addressing regulatory, environmental, and operational challenges. They align with emerging frameworks for circular bioenergy and materials recovery, offering scalable approaches to global medical waste management infrastructure. Microwave assisted pyrolysis is gaining attention as a viable method for converting complex plastic waste into valuable products. In this study, the medical feedstock comprising PP, PE, PS and PVC, from syringes, IV bags, tubing, and packaging was rigorously pretreated, decontaminated and homogenized. Microwave-assisted pyrolysis of mixed medical waste plastics was carried out employing activated carbon as the microwave susceptor, alongside four different catalytic materials as activated alumina, iron powder, natural zeolite, and regenerated zinc oxide at fixed microwave power input of 450 W, reaching final temperature up to 600 °C. End products yield distribution confirms catalyst selection fundamentally determines cracking severity, secondary reforming, and product selectivity. With activated alumina, extensive β-scission and deoxygenated occurred, delivering lighter hydrocarbon fractions while limiting wax. Iron powder catalyzed in situ reforming and aromatization, markedly increasing H_2 and CO yields via dehydrogenation and cracking. Natural zeolite achieved shape selective monoaromatics production, though pore clogging and acid catalyzed condensation led to higher coke deposition. ZnO demonstrated intermediate acidic properties coupled with redox-active characteristics, facilitating balanced liquid production with suppressed coke formation while minimizing undesired carbon deposition and enhancing catalyst durability across repeating microwave assisted treatment cycles. Gas phase composition characterization confirms the enrich presence of hydrogen, methane, and light olefins when iron and ZnO were employed as catalytic additives, highlighting their effectiveness in generating syngas-type, energy-dense mixtures from medical plastic residues. The condensed liquid primarily consists aliphatic and aromatic hydrocarbons, exhibiting a lower proportion of heteroatom-containing compounds relative to uncatalyzed microwave pyrolysis underscoring the upgrading potential of the applied catalysts. The solid carbonaceous char residue exhibited increased fixed carbon content with improved chemical and physical properties for cyclical application as an auxiliary heating medium. This research establishes a novel approach combining affordable, regenerable catalytic materials with microwave-assisted processing for therapeutic polymer valorization, confirming operational viability, ecological compatibility, and commercial promise for distributed resource recovery networks within medical facility frameworks. Findings provide a scalable blueprint for circular economy implementation in high-risk waste streams, aligning with UN SDGs 3, 7, 12, and 13.



Thermal conversion of heterogeneous marine polymer waste via catalytic pyrolysis using waste-derived catalysts: assessment of conversion efficiency and product quality for future applications

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14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Marine plastic pollution constitutes a global environmental crisis, with an estimated concentration of at least 268,940 Mg of plastic particles in the oceans, primarily originating from riverine flows reaching 1.15–2.41 million Mg annually. In particular, polymer waste containing polyesters (PET) and polyolefins (PP, PE) does not undergo biodegradation and poses a permanent threat to aquatic ecosystems. Simultaneously, modern chemical recycling technologies can convert heterogeneous polymer mixtures into aromatic and aliphatic hydrocarbons with significant market potential. However, the application of conventional catalysts at the industrial scale may encounter economic and logistical barriers related to their sourcing and regeneration. The study conducted within the CUPOLA project focused on catalytic pyrolysis of marine polymer waste, utilising catalysts derived from waste processing, which represent a fundamental paradigm shift in resource thinking. The catalysts used in this study were waste-derived materials, namely the solid residue from the gasification of sunflower husks (SH) and tomato processing waste (TW), as well as the commercial catalyst. SH and TW ashes were characterised by a composition dominated by alkali and alkaline earth metal oxides, primarily CaO and K_2O, accompanied by significant amounts of phosphates and sulphates (P_2O_5, SO_3). This chemical composition indicates a predominance of basic/neutralising properties and suggests a strong potential to bind acidic and halogen-containing species during pyrolysis. These catalysts demonstrate potential for converting heterogeneous polymer mixtures without their preliminary sorting, maintaining the principles of circular economy by avoiding the challenges associated with sourcing pure materials. The application of such catalysts can additionally minimise multi-stage separation processes, which traditionally generate substantial operational costs and additional process waste streams. The experimental section of the study encompassed catalytic pyrolysis of heterogeneous marine polymer waste at temperatures ranging from 400 to 600°C using analytical pyrolysis with chromatographic separation and mass detection (Py-GC-MS) with various waste-derived catalysts, followed by detailed product analysis and determination of possible directions for their subsequent utilisation. The results were compared with commercially available catalysts such as unmodified ZSM-5 and catalytically active forms of ZSM-5 in various modification variants (NH_4/ZSM-5, Ni-ZSM-5). The conversion yields obtained from the waste-derived catalysts reached 70–78% total conversion, with selectivity toward aromatic compounds (benzene, toluene, and xylenes) of approximately 52%, representing 10–20% higher compared to the commercially unmodified ZSM-5 catalyst, which achieved merely up to 30–40% BTEX compounds for PP and PET, respectively. Such products constitute a precursor to a further purification process enabling subsequent steps to obtain products applicable in polymer synthesis, aircraft fuels with reduced sulphur content, and speciality chemicals. The study thus aligns with the broader vision of the European Green Deal, transforming the economy toward more sustainable and circular models, supported equally by European Union directives such as the Circular Economy Action Plan. Acknowledgement This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101086071, project name "CUPOLA — Carbon-neutral pathways of recycling marine plastic waste". This research was funded in part by the National Science Centre, Poland [Grant no. 2023/51/B/ST8/01531].

Zeolite Catalysed Upgrading of CFRP Pyrolysis Vapours for Enhanced Hydrogen Production

Haritz Gomez Llona (University of the Basque Country, EHU, Spain) Alex Lopez Urionabarrenechea (University of the Basque Country, EHU, Spain) Esther Acha Peña (University of the Basque Country, EHU, Spain) Blanca Maria Caballero Iglesias (University of the Basque Country, EHU, Spain)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis

Location: Ground floor

ABSTRACT

Carbon fibre reinforced plastics (CFRP) are extensively employed in the transport and energy sectors owing to their outstanding mechanical performance and high strength-to-weight ratio, which contribute to reduced fuel consumption and lower CO_2 emissions during service life. As their use expands across aircraft structures, automotive components, and recreational boats, the amount of CFRP waste expected in the coming decades is rapidly increasing. Despite their strategic importance, end-of-life management of CFRP remains challenging, as consolidated and economically viable recycling routes are still scarce. Among the different CFRP recycling technologies proposed, pyrolysis has emerged as a particularly promising option. This thermochemical route allows the decomposition of the polymeric matrix in an oxygen-free environment, enabling the recovery of high-value carbon fibres with minimal structural damage. At the same time, the resin is converted into a mixture of permanent gases and condensable vapours. While considerable research efforts have been devoted to optimising fibre recovery and preserving fibre properties, the effective valorisation of the volatile products generated during CFRP pyrolysis has received considerably limited attention, especially with regard to their conversion into hydrogen rich gas streams. In this work, the influence of different cracking catalysts, concretely zeolites, on hydrogen production during the pyrolysis of CFRP waste is investigated. Experiments were conducted using a two-stage reactor configuration, consisting of a primary pyrolysis reactor followed by a second fixed-bed catalytic reactor. The volatile products released during CFRP pyrolysis were directed to the catalytic stage, where they were subjected to further cracking and reforming reactions over the selected zeolites. A range of zeolite frameworks with different pore architectures, textural properties and Si/Al ratios was examined in order to establish correlations between catalyst characteristics, gas composition, hydrogen yield and overall performance. The experimental results demonstrate that the incorporation of a zeolitic catalytic stage substantially modifies the product distribution compared to non-catalytic pyrolysis. In particular, the presence of zeolites enhances gas formation and increases hydrogen production. This behaviour is mainly associated with the intensification of secondary cracking reactions of the pyrolysis vapours within the catalytic bed, which promotes the breakdown of heavier species into lighter gaseous compounds. As a result, hydrogen concentration in the product gas increases, while the formation of heavy hydrocarbons and high boiling condensable fraction is significantly suppressed. To sum up, this study demostrates the strong potential of zeolite-based catalytic upgrading for transforming CFRP-derived pyrolysis vapours into hydrogen-rich gas streams. These findings support the development of integrated recycling approaches that combine high-quality carbon fibre recovery with energy and chemical valorisation of the polymeric fraction, contributing to more sustainable end-of-life management of composite materials.

Enhancing Syngas Production from Plastic Waste via Catalytic Steam Gasification

Antzela Fivga (CPERI/CERTH, Greece) Stylianos Stefanidis (CPERI/CERTH, Greece) Georgios Marnellos (Aristotle University of Thessaloniki & CPERI/CERTH, Greece) Angelos Lappas (CPERI/CERTH, Greece)

14:00-15:00 Session Posters P-S2F0: Catalytic pyrolysis
Location: Ground floor

ABSTRACT

The management and disposal of plastic waste is an escalating challenge, with the EU alone producing over 29 million tons of post-consumer plastics annually [1]. Gasification presents a promising thermochemical pathway for converting plastic waste into synthesis gas (syngas), allowing for the processing of mixed plastics alongside energy recovery. Syngas primarily contains H_2, CO, CO_2, CH_4, and light hydrocarbons (C_2–C_5) [2], with its composition influenced by factors such as the oxidizing agent, temperature, and oxidant to plastic ratio. However, syngas can also carry contaminants, including halogenated and sulfur compounds, nitrogen species, tars, and trace organics like dioxins and furans, which can impede its downstream utilization [3]. Within the EU-funded SURPLAS project (Marie Skłodowska-Curie Actions), this work investigates plastic waste gasification, focusing on the impact of steam and catalysts on product yields, contaminant mitigation, and syngas optimization for applications such as Fischer–Tropsch (FT) synthesis. This study specifically examines the steam gasification of plastic waste under both catalytic and non-catalytic conditions, focusing on syngas composition, product yields, and tar reduction. Experiments were conducted at 850 °C in a continuous-flow fluidized-bed reactor, using either inert bed material or a commercial nickel based catalyst, with and without steam. Gas products were collected and analyzed offline via gas chromatography. Feed and carrier gas flow rates were optimized (0.8 g/min PE, 2.7 L/min N_2) to maximize gaseous product yields while minimizing condensable organics. Steam addition significantly increased H_2 and CO concentrations while decreasing CH_4, adjusting the H_2/CO ratio from 21.2 to 3.4, approaching the ideal range for FT synthesis. The incorporation of the catalyst dramatically reduced tar formation from 17.12 wt.% to 0.3 wt.% and increased total gas yield from 60.2 wt.% to 84.0 wt.%, attributed to enhanced reforming, water–gas shift reactions, and catalytic tar cracking. These findings demonstrate that catalytic steam gasification of PE waste can produce high-quality syngas suitable for synthetic fuels and other downstream applications, supporting energy recovery and circular economy strategies. Future work will investigate water–gas shift catalysts under varied conditions to further optimize syngas composition and minimize contaminants, as well as, assess the effects of incorporating other types of plastic waste.

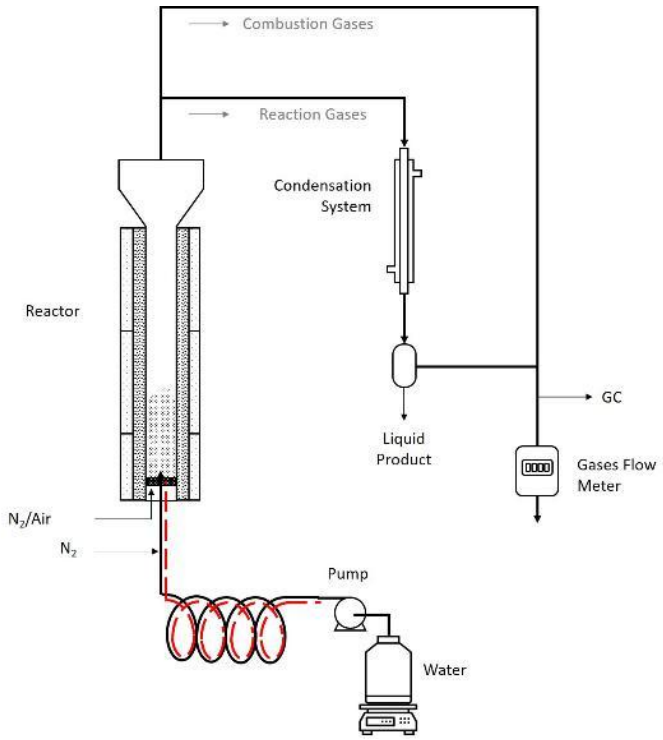


Figure 1. Schematic representation of the experimental set-up

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Optimizing Activated Carbon Properties: The Role of Precursor Source, Carbonization and Activation Parameters

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Various types of biomass as a renewable and sustainable feedstock have attracted increased attention as precursors for activated carbons synthesis lately. Activated carbons can be synthesized from numerous precursors such as wood and its components and residues, e.g. industrial lignins or black liquor, nut shells, straw, peat, etc. Use of biomass in the production of carbon materials has several advantages, including low cost, abundance, and environmental friendliness. Chemical activation is a widespread approach to obtain activated carbons with the highly developed porosity, and it is possible to synthesize activated carbons with a specific surface close to theoretical limits for this type of materials. The main factors influencing total porosity, pore size distribution, surface groups functionality and nature of internal pore structure of the activated carbons can be summarized as follows: precursor nature, type of pretreatment (carbonization or hydrothermal treatment), activation temperature, nature of activation agent, activation agent impregnation ratio, taking into account that their combination can work in synergy and used for the fine tuning of desired properties. This work is dedicated to the study of the influence of the above mentioned parameters on the properties of activated carbons. Various biomass-based precursors, including number of wood species, such as alder, birch, eucalyptus, oak, and pine, were tested to demonstrate how the choice raw materials can influence porosity. Two types of pretreatment, conventional slow pyrolysis and hydrothermal treatment, were tested to show the influence and the importance of carbonization methodology. Activation temperatures in the range 600-800 C and three common activation agents (NaOH, KOH and H3PO4) at various addition rates has been studied as well. The resulting activated carbons were characterized using nitrogen sorption at 77K, ultimate analysis, SEM, etc. It is worth noting here that in some cases, biomass-based precursors have a certain hierarchical structure, which can contribute to the formation of the necessary porous material during the activation process, and thus tailored for the further application of the synthesized carbons as electrodes in supercapacitors, for oxygen reduction reactions in fuel cells, hydrogen evolution reactions, or as catalysts or catalyst substrates for other processes. Another possibility for further development of necessary properties is doping of activated carbons with various heteroatoms or transitional metals. This study was funded by Horizon Europe Framework Programme, ARMS project, under grant agreement No 101120677, as part of Graphene Flagship initiative which works to advance technologies that rely on graphene and other 2D materials.

Bromination mechanism of typical metallic radionuclides on defective graphite surface by HBr：Insight from first principles

Meiqian Chen (Beijing Jiaotong University, China) Ruitao Niu (Beijing Jiaotong University, China) Zhiheng Ma (Beijing Jiaotong University, China)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

A substantial amount of spent nuclear graphite generates after the decommissioning of high-temperature gas-cooled reactors and molten salt reactors. The bromination mechanisms were estimated by density functional theory for the trace metallic radionuclides triggered by HBr on a nuclear graphite surface in an enhanced thermal treatment. The existence of defects affected both the adsorption and the diffusion of metallic nuclides on surfaces. Ni, Cs and Eu adatoms were adsorbed preferably at the defective surface, and the defective sites enhanced the adsorption of metallic nuclides. The presence of HBr could promote the diffusion properties of 59Ni, 134Cs and 152Eu on defective surfaces. The absorption energies of 59Ni and 152Eu on the single vacancy (SV) were -698.8 and -202.9 kJ/mol, respectively, which were substantially larger than those on the double vacancy (DV) and the pristine surface. Moreover, the absorption energy of 134Cs on the DV was -341.2 kJ/mol, which was far greater than that on the pristine and SV surfaces. Based on the energy barrier of the rate-determining step, the recovery of Ni and Eu by bromination was more difficult than that of Cs. The bromination of Ni, Cs and Eu on the surface of defective graphite was all described by the second order reaction model. The most stable adsorption site in single vacancy existed for Ni and Eu atoms, while that emerged in double vacancy for Cs atom. The bromination roasting approach was feasible for recovery of 59Ni, 134Cs and 152Eu from nuclear graphite. Bromination reaction pathways of 59Ni, 152Eu and 134Cs followed the sequence: Ni → NiBr → NiBr2, Eu → EuBr → EuBr2, Cs → CsBr. The bromination of three metallic nuclides on the defective surfaces all obeyed the Eley-Rideal mechanism. The study would contribute to fundamental data for the design of enhanced thermal treatment systems for decommissioned nuclear graphite.

Hydrothermal Carbonization of Sewage Sludge for Thermal Plasma Treatment: Influence of Process Parameters on Energy and Mineral Recovery in Hydrochars

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

This study investigates the hydrothermal carbonization (HTC) of wet sewage sludge as a thermochemical pretreatment prior to plasma gasification. The impact of reaction temperature and residence time on hydrochar yield and properties are examined, with particular emphasis on their suitability for syngas production and nutrients recovery during subsequent treatment in a plasma torch. The combined application of HTC and plasma gasification advances the current state of the art on the treatment of organic waste streams from wastewater treatment plants, aiming to maximize the value creation from this challenging biomass. Hydrothermal carbonization of centrifuged, digested sewage sludge is performed at reaction temperatures of 180, 210, and 240 °C and residence times of 2 and 4 h, using a constant water to biomass ratio of 7. Initial experiments are performed in small 30-mL autoclave reactors heated in an electric oven and subsequently scaled up to a 450-mL stainless-steel mechanically stirred autoclave reactor under identical process conditions. The resulting hydrochars are analyzed through elemental and proximate analyses to determine their composition and higher heating value (HHV), while hydrochar yields are calculated through mass balance techniques. Metal and mineral contents are quantified by inductively coupled plasma optical emission spectroscopy (ICP-OES), with a specific focus on phosphorus (P) to calculate P recovery yields. Previous studies on HTC of non-thickened digested sewage sludge with a total solids content of 4.1 % were carried out in 30 mL autoclave reactors at temperatures between 180 and 220 °C and residence times of 2 and 4 h, resulting in promising average char yields (57.6 – 72.2 %) and phosphorus recovery efficiencies (79.9 – 89.3 %), with HHV values ranging between 8.5 and 9.0 MJ/kg. The present study builds on this work by exploring a broader temperature range, increased reactor scale, and higher solid content in the biomass, enabling a more comprehensive assessment of hydrochar properties. Based on the experimental outcomes, an optimization criterion for further conversion in plasma torches will be determined, based on the following features: carbon enrichment, energy yield, hydrochar production, and mineral recovery yields. In addition, this approach may be extended to the treatment of industrial sewage sludge containing persistent xenobiotics such as PFAS, offering potential pathways for contaminant stabilization within the char followed by high-temperature destruction during plasma gasification.

Oxidative Slow Pyrolysis in an Auger Reactor: Autothermal Operation and Process Intensification

Giacomo Lombardi (RE-CORD, Italy) Andrea Maria Rizzo (RE-CORD, Italy) David Chiaramonti (Polytechnic of Turin, RE-CORD, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The main aim of the present study is to assess the feasibility of a self-sustained process within an innovative auger pyrolyzer (SPYRO), targeting biochar production, and to increase plant throughput through autothermal operation. To the author's knowledge, autothermal operation has been achieved and validated in various reactors, such as fluidized and fixed bed reactors. However, it has not yet been investigated in auger reactors. Despite auger reactors present a simple design, the heat transfer is a limiting factor for scaling up. Therefore, this work deals with the experimental investigation of poplar oxidative slow pyrolysis (OSP) within an innovative patented auger reactor, which was designed to facilitate the introduction of air into the cylinder. In this work autothermal pyrolysis is proposed as a solution to overcome the heat exchange limitation of allothermal reactors. Firstly, OSP trials were performed at a poplar flow rate of 1.5 kg/h, temperature of 500 °C and solid residence time of 30 min, at distinct amount of air injected into the reactor. An increase in the air flow rate led to an increase in gas and reaction water yields and a decrease in organics yield, whereas char yield was almost preserved at 25 wt%. Autothermal operation was experimentally achieved at an equivalence ratio (ER) of 0.05 ± 0.03. In this condition, partial oxidation of products provided the enthalpy for pyrolysis while reactor heaters were only used to overcome thermal losses. Without countering thermal losses in this manner, pilot pyrolyzers would require operation at very high equivalence ratios to overcome thermal losses. These would result in excessive consumptions of pyrolysis products and inaccurate performance predictions for industrial-scale reactors. Autothermal operation led to a decrease of 7 wt% in organics yield compared to conventional pyrolysis. On the other hand, yields of reaction water and gas increased by 4 wt% and 8.6 wt%, respectively, while char yield was almost preserved at 24.7 wt%. These outcomes suggested that during autothermal operation the heat for the process was mainly provided by volatiles oxidation rather than char oxidation. In addition, it led to a decrease of 3.4% and 3.9% in the energies retained in the oily and aqueous phases, respectively, compared to conventional pyrolysis. On the other hand, gas energy increased by 3.5%, while the energy retained in the char was almost preserved and equal to 42 wt%. The total energy content of the pyrolysis products decreased by 2%, since volatiles were partially oxidized to provide heat for the process. Finally, the intensification of OSP was performed by increasing both biomass and air flow rates while keeping constant the ER slightly above 0.05. Autothermal operation made possible a three-fold increase in feedstock throughput for this reactor, resulting in a 3.1-fold increase in biochar, a 2.0-fold increase in oil phase, a 3.6-fold increase in aqueous phase, and an 8.8-fold increase in gas compared to allothermal operation, while maintaining constant electric consumptions and yield of products. Therefore, autothermal operation enabled smaller reactors to handle much higher throughputs compared to heat transfer-dependent reactors of similar size.

Evaluation on the migration and occurrence mechanism of impurities in decommissioned nuclear graphite by multi-halogen synergistic roasting

Zhiheng Ma (Beijing Jiaotong University, China) Meiqian Chen (Beijing Jiaotong University, China)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Nuclear graphite serves as an indispensable core material for the fourth-generation advanced nuclear energy systems such as high-temperature gas-cooled reactors (HTGRs) and molten salt reactors (MSRs). During the irradiation service period, nuclear graphite will adsorb and accumulate various radionuclides, which would encounter severe challenges to its subsequent treatment and disposal after decommissioning. At present, the technology is still immature for efficient and thorough decontamination of decommissioned nuclear graphite. The synchronous deep removal of multiple impurities embedded in the graphite matrix has become a key bottleneck restricting the safe treatment and resource utilization of nuclear graphite. Therefore, in this study a multi-halogen synergistic roasting technology was proposed for removing radionuclides from decommissioned nuclear graphite, aiming to systematically evaluate the removal mechanism and regulation effect of this technology on all impurities in decommissioned nuclear graphite. The effect of single additive (NH_4Cl) and the composite additive (NH_4F-NH_4Cl) was compared on the overall volatilization rate of main impurities such as Ca, Mg, Sr, V and U. The composite additive was able to significantly enhance the overall volatilization efficiency of target elements in decommissioned nuclear graphite by virtue of the fluorine-chlorine synergistic complementary effect. In addition, a Back Propagation (BP) neural network model optimized by the Particle Swarm Optimization (PSO) algorithm was developed constructed, establishing a nonlinear mapping relationship between process parameters (three composite additives: NH_4F-NH_4Cl, NH_4F-NH_4Br and NH_4Cl-NH_4Br and their dosage, as well as roasting temperature) and volatilization rate. On this basis, the Non-dominated Sorting Genetic Algorithm Ⅱ (NSGA-Ⅱ) was introduced for multi-objective optimization to screen out the optimal process scheme that could balance the maximization of volatilization rate and the minimization of energy consumption. The overall volatilization rate of elements in nuclear graphite ramped up with the rise of temperature and additive dosage. when the temperature was over the critical threshold (1427 ℃), it became the core driving factor dominating element volatilization, while the regulatory effect of composite additive ratio on the volatilization process greatly weakened. When the mass ratio of additive to graphite was close to 2:1, the supply of halide ions in the system was sufficient to fully remove the impurities in graphite. NH_4F-NH_4Cl additive was identified as the optimal halogenating additive combination. The findings could provide important theoretical basis and direction for the harmless and effective disposal of decommissioned nuclear graphite.

Biochar from intermediate pyrolysis for enhanced cementitious grouts

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

This study centres biochar as the key pyrolysis product, evaluating pinewood biochar as a partial Portland cement replacement in cementitious grouts and examining how curing environment governs performance when biochar is combined with supplementary cementitious materials (SCMs) to reduce clinker demand. Although biochar is often discussed mainly as an environmental amendment, its porous, carbonaceous structure and surface chemistry can also influence hydration kinetics, moisture transport and cracking behaviour in cement-based materials. If these interactions are managed through mix design and curing, biochar offers a route to lower-carbon binders while introducing a stable carbon phase into long-life infrastructure. Here, we focus on practical formulation space for pumpable grouts and on curing conditions that are realistic for field placement, linking fresh-state workability and setting to longer-term mechanical and durability indicators. Our proof-of-concept work showed that adding biochar consistently reduced initial flow and increased flow loss over 30 minutes. This behaviour is consistent with water uptake into the biochar pore network and higher particle friction and it was more pronounced when slag and biochar were combined due to their higher overall surface-area demand. Moderate biochar incorporation (≤15% wt.%) maintained workable mixes (typically <25 wt.% loss of spread) while enabling meaningful clinker reduction. In hardened grouts, curing environment was decisive: sealed air curing increased compressive strength by from 25 to 80 wt.% relative to unsealed curing by limiting moisture loss and carbonation-related decalcification, particularly in SCM-rich systems. Under sealed air curing, many mixes with ≥60 wt.% Portland cement achieved at least 75% wt.% of the reference strength, whereas high biochar contents (25 wt.%) depressed compressive strength under unsealed curing (typically 20–40% lower), consistent with dilution and increased matrix porosity. In contrast, flexural behaviour was more composition-sensitive; slag–biochar combinations frequently improved modulus of rupture (up to ~15%), consistent with crack-bridging and toughening from carbonaceous inclusions. Biochar-containing mixes tended to show slightly lower sorptivity (pore connectivity) but higher absorption at high dosages (total open porosity). Carbonation depth increased as clinker content decreased, but remained limited (<5 mm) when Portland cement content was ≥55 wt.%. The results also showed that pyrolysis-derived biochar can function simultaneously as a carbon-sequestering filler and a microstructural modifier in grout systems, provided dosage and curing are designed together. Because the pinewood biochar was highly carbonaceous (85.1 wt.% C) and retained a porous surface area after grinding (8.3 $m^2 g^{-1}$), it represents a stable, functional carbon phase rather than an inert filler, with clear potential for incorporation into long-life construction materials. This provides a credible, higher-value utilisation route for pyrolysis chars beyond land application, while supporting clinker reduction when biochar is combined with SCMs. Practical formulations were achieved at ≤10 wt.% biochar with balanced SCM contents, while higher biochar levels require sealed curing (or equivalent moisture management) to retain strength and durability.

Upgrading fast-pyrolysis chars through thermal stabilization: analytical insights and implications for their use

Andrea Maria Rizzo (RE-CORD - Renewable Energy Consortium for R&D, Italy) Ann-Christine Jahansson (Ri.SE - Research Institutes of Sweden, Sweden) David Casini (RE-CORD - Renewable Energy Consortium for R&D, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Fast pyrolysis of lignocellulosic residues produces a solid char fraction whose high volatile content and limited structural stability restrict its valorization beyond energy use. Within the Horizon Europe project ABATE, we investigated a thermal stabilization pathway to upgrade fast-pyrolysis char (FP-char) derived from sawdust (SD) and forest residues (FR). FP-chars were pelletized and subjected to slow-pyrolysis at 500 °C in a pilot plant, generating pilot-scale stabilized chars (PSS-chars). A comprehensive analytical dataset was collected to characterize the structural, compositional, and microstructural evolution induced by stabilization. Proximate and ultimate analyses quantified significant chemical shifts, with H/Corg molar ratios decreasing from 0.82 (SD) and 0.53 (FR) to 0.33 and 0.37, respectively. Thermogravimetric analysis (TGA) revealed substantial depletion of thermolabile fractions, and reflectance microscopy provided direct evidence of carbon structural reorganization, with inertinite content increasing from 7.9 % to 44.6 % (SD) and 5.1 % to 47.7 % (FR), indicating a transition toward highly condensed aromatic domains. Microstructural characterization by N_2 physisorption showed moderate increases in BET surface area, while water-holding capacity measurements revealed slight reductions, consistent with pelletization-induced densification. Organic contaminant analysis (PAH16, PCDD/F, PCB) confirmed concentrations well below EU limits, with PAH16 at 0.97–2.06 mg/kg. Overall, thermal stabilization at 500 °C significantly enhances FP-char permanence, transforming a labile co-product into a structurally robust carbonaceous material. The high degree of recalcitrance already achieved (H/Corg < 0.4; inertinite > 40 %) suggests that increasing the maximum process temperature, e.g. toward 600 °C, may unlock additional improvements in carbon stability, increasing further the inertinite content. This treatment broadens potential applications, including carbon removal certification pathways and soil-related deployment where long-term carbon persistence supports both agronomic value and carbon accounting functions.

Rapid biochar quality screening using Hyperspectral Imaging (HI) and Machine Learning (ML)

Pham Thi Hong (Thuyloi University, Viet Nam) Adam El-Aradi (Aston University, Energy and Bioproducts Research Institute (EBRI), UK) Raghavan Chinnambedu-Murugesan (Aston University, Aston Institute of Photonic Technologies, UK) Hoang Thi Thu Huong (Hanoi University of Science and Technology, Viet Nam) Daniel Nowakowski (Aston University, Energy and Bioproducts Research Institute (EBRI), UK)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Biochar as a value-added pyrolysis product converts lignocellulosic residues into a stable, carbon-rich material that can be traded and used across agriculture, remediation and materials markets. Its quality can vary widely because pyrolysis is carried out using different feedstocks and operating conditions. As a result, biochar from different biomass batches, sites or harvesting seasons may show clear differences in properties that matter for use and sale, including carbon content, ash and nutrient levels, pH and surface chemistry. This variability is a growing challenge for biochar quality assurance and certification. Current certification routes typically rely on representative sampling, laboratory analysis and audit-based checks, which can be expensive and slow and may miss variation within biochar batches. To scale certification with market growth, producers need faster ways to check product quality during production and before shipping. Hyperspectral imaging (HSI) can support biochar certification by providing a quick, non-destructive check of product consistency. When paired with machine learning (ML) and artificial intelligence (AI), HSI data can screen key quality indicators and identify batches that may need confirmatory laboratory testing, strengthening routine quality control. We present a UK-Viet Nam study where wood-based feedstocks from Viet Nam were converted to biochar by pyrolysis and then assessed in the UK to support biochar quality control and certification. Biochar samples produced across 300-600 °C were scanned using a near-infrared HSI system collecting 168 spectral bands over 884-1726 nm . This provided a fast, non-destructive way to capture chemistry-related signals and detect variation across the sample surface. After standardising the spectra, we trained predictive models for key elemental parameters (C, H, N and O). For single-wood biochar, strong performance was achieved even with a small dataset (<50 samples), reaching prediction scores up to R^2 = 0.998 for elemental composition. When multiple wood sources were combined, advanced models maintained good performance, supporting robust screening across mixed-feedstock biochar and reflecting real supply-chain conditions. Our preliminary results show that combining HSI with ML and AI provides a practical, fast screening method for pyrolysis biochar. The HSI signal can be converted into simple, numerical quality indicators that support routine checks, batch sorting and tighter process control without disrupting production. For certification, this approach can sit alongside standard laboratory testing by reducing repeat analyses, identifying batches that may not meet the required quality, and keeping a simple digital record for tracking and reporting as biochar is traded more widely. Next steps will expand the multi-feedstock training set (including additional UK–Viet Nam samples), improve model transfer between instruments and sites, and run Round Robin inter-laboratory comparisons to benchmark HSI systems and modelling pipelines and move towards harmonised, reproducible rapid-assessment methods.

Study on CO2 activation on properties of biochar

Liang Wang (SINTEF Energy Research, Norway) Jørn Bakken (SINTEF Energy Research, Norway) Nicholas Islongo Canabarro (SINTEF Industry, Norway) Rukshan Madhawa Jayathilake (SINTEF Industry, Norway)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

CO2 activation is a thermochemical process used to transform raw biochar into a high-performance material, often referred to as activated biochar. In this work, the biochar produced from spruce wood was activated using CO2 as activated agent at 700 and 900 °C. The untreated biochar and CO2 activated biochar were characterized using a combination of analytical techniques. The mass yield from activation experiments indicated CO2 activation removes residual tars and volatile organic compounds trapped in the biochar pores during initial pyrolysis. As the activation were conducted at 900 °C, CO release was more intensive where CO2 starts etching the carbon. The concentration of CO in the effluent gas rises as the Boudouard reaction becomes more favorable, leading to more significant burn-off of material. As the activation temperature increases, the carbon matrix is consumed by the CO2 gasification reaction. This leads to a relative enrichment of most inorganic elements. The FTIR analyses indicate that more oxygen-containing functional groups formed on the surface of biochar after CO2 activation. It can enhance the biochar's affinity for specific reactants or pollutants. The SEM-EDS analysis results showed, CO2 activation etches away the carbon matrix, exposing inorganic element (e.g., Ca and K) naturally present in the biochar. It leads Ca and K move from the internal bulk to the surface of the pores created by CO2, making them more accessible for catalytic reactions. In addition, the temperature is the critical threshold that dictates the chemical state of these inorganic elements, particularly calcium, which is most abundant inorganic element in the studied biochar. The XRD analysis results revealed that, at low activation temperature 700°C, the carbonation effect is more evident as for example CaO or MgO produced during initial heating can react with the CO2 atmosphere to form carbonates. For the biochar after activation at 900 °C, both calcium carbonate and oxide were detected. The latter was formed due to decomposition of the calcium carbonate, which is highly significant for using the activated biochar as catalyst.

Modeling of residence time for screw conveyors and auger reactors

Eugen Aschenbrenner (KIT, Germany) Axel Funke (KIT, Germany) Nicolaus Dahmen (KIT, Germany)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Auger reactors represent an interesting alternative for the pyrolysis of biomass. Research focused mainly on the mass throughput and the power requirements of horizontal, inclined, or vertical screw conveyors. Knowledge of the residence time would be beneficial for simple modeling of auger reactors, especially with heat-carriers and could be used for the design and scale-up of these types of reactors [1]. Literature on residence time is rather sparse and therefore still not well understood, and often an ideal plug flow is assumed to predict the solid residence time. Nachenius et al. measured the residence time of four different materials for a single screw conveyor and created a model to predict the mean residence time that took not only the frequency but also the volumetric throughput into account [2]. This showed a good prediction for the tested geometry and materials. However, the current methods are not able predict the actual residence time of screws with larger pitches and underestimate them significantly. Also the influence of the ratio between the particle size and clearance on the residence time is often not taken into account. Therefore the aim of this was to create new methods to predict the mean residence time of a wider range of pitches that also take other parameters into account, such as e.g. the clearance. With the help of Discrete Element Method various pitches were investigated and two new models were developed, by combining the ideal plug flow and the work of Nachenius et. al. with the transport efficiency that was investigated in earlier work. [3, 4]. This showed good predictions the own simulations and experiments, as well as for various screw conveyors from literature and can be used to model the pyrolysis in an auger reactor.

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Evolution Mechanism of Mechanical Properties of Recycled Glass Fibers during Pyrolysis–Oxidation Treatment of Waste Wind Turbine Blades

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Wind turbine blades are typical thermosetting composites characterized by high chemical stability and a highly crosslinked three-dimensional network structure. The fiber reinforcement accounts for more than 60% of the total mass, making end-of-life blades a potential resource rich in high-value glass fibers. During pyrolysis of waste wind turbine blades, cracking products from the resin matrix exert an erosive effect on the glass fibers, damaging the structural integrity of the fiber surface, inducing microcracks and surface defects, and consequently reducing the mechanical strength of recycled fibers. This study systematically investigates the evolution of mechanical strength and the transformation behavior of the intrinsic surface structure of recycled glass fibers under high-temperature pyrolysis–oxidation conditions. Results show that at a pyrolysis temperature of 500 °C, the epoxy matrix undergoes complete depolymerization and volatilization, resulting in carbon deposition and axial microcracks on the fiber surface. Consequently, the tensile strength decreases from 2969.54 MPa to 2151.52 MPa, accompanied by a reduction in the Weibull modulus, indicating a defect-dominated failure mechanism. Subsequent oxidation treatment in the range of 300–500 °C reveals a distinct performance transition. Under moderate oxidation conditions (350–400 °C), the initially continuous and dense carbon layer gradually transforms into discrete carbon residues and is ultimately removed (weight loss increasing from 1.27% to 3.06%). Correspondingly, the tensile strength increases to 2724.92 MPa, achieving 91.7% of the original fiber strength. Between 400 and 450 °C, the fibers enter a transitional stage characterized by declining mechanical performance. When the oxidation temperature exceeds 450 °C, high-temperature oxidative cleavage of the Si–O–Si network occurs, and structural degradation features such as corrosion pits and cracks appear on the fiber surface, leading to a significant decrease in tensile strength to 1964.92 MPa. Overall, this work elucidates the synergistic mechanism of “pyrolytic depolymerization for resin removal – moderate oxidation for decarbonization and release of interfacial constraints – excessive oxidation inducing glass network degradation.” The evolutionary pathway of fiber performance—from damage initiation to strength recovery and finally structural deterioration—is clarified, and 350–400 °C is identified as the critical oxidation window for maximizing strength retention.

Comprehensive Characterization of Pyrolytic Aqueous Phases for Valorization via Aqueous Phase Reforming

Lioudmila Nossova (Natural Resources Canada, Canada) Gianni Caravaggio (Natural Resources Canada, Canada) Fanny Montreil-Rivera (National Research Council, Canada) Fabrice Tanguay-Rioux (National Research Council, Canada) Laurent Spreutels (National Research Council, Canada)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The sustainable valorization of biomass-derived waste streams is a critical challenge in advancing circular bioeconomy strategies while reducing environmental burdens. Fast pyrolysis of lignocellulosic feedstocks generates complex aqueous phases that can contain up to 30 % of the initial carbon as soluble oxygenated organics. These streams are often treated as wastewater, resulting in carbon loss and increased treatment costs. Integrating pyrolysis with downstream catalytic processes, particularly aqueous phase reforming (APR), offers a promising route to produce renewable hydrogen and light hydrocarbons. However, the efficiency and selectivity of APR is strongly dependent on the chemical composition of the feed, which is highly variable and poorly understood for real pyrolytic waters. A wide range of organics commonly present in pyrolytic process waters can poison catalysts, promote fouling, or trigger undesired side reactions, making comprehensive characterization of these streams a prerequisite for effective catalyst design and process optimization. In this study, five representative aqueous fractions derived from fast pyrolysis of agricultural and forestry residues were comprehensively analyzed using advanced analytical techniques. Chromatographic methods (GC-FID, HPLC-UV, HPLC-RI, headspace and direct injection GC-MS) were combined with elemental analysis, ICP-OES, and physicochemical measurements to quantify various organics, inorganic species, and bulk properties. Results revealed wide variability in water content (23.6–80.9 wt%), carbon content (9.2–48.4 wt%), and acidity (pH 2.1–3.2), strongly influenced by feedstock type, pyrolysis severity and separation method. High concentrations of reactive oxygenates such as glycolaldehyde (up to 67 g/L) and hydroxyacetone (up to 30 g/L) reinforced the potential of these aqueous streams for catalytic conversion via APR. The detection of thermally unstable or polymerization-prone species such as levoglucosan, furans, and phenolics indicated the need for stabilization strategies (e.g., mild hydrogenation) to suppress coke formation during APR. Inorganic analysis revealed significant levels of K, Mg and S, particularly in wheat straw-derived samples, which may poison reforming catalysts or accelerate sintering. These findings demonstrate that APR catalyst development for pyrolytic waters cannot rely on simplified model compounds or generic assumptions about feed quality. Instead, tailored valorization APR strategies must address the high oxygen content, acidity, and presence of reactive species in pyrolytic aqueous phases. The resulting compositional fingerprints provide essential input parameters for designing APR catalysts that achieve high conversion efficiency with minimal deactivation. Ultimately, coupling detailed characterization with targeted APR catalyst engineering will facilitate thermochemical–catalytic upgrading routes for sustainable fuel production.

Hydrogen evolution through ammonia borane hydrolysis over iron tailored pig manure biochar catalyst

Mattia Bartoli (Fondazione Istituto Italiano di Tecnologia, Italy) Fabrizio Pirri (Politecnico di Torino, Italy) Sergio Bocchini (Politecnico di Torino, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Hydrogen storage systems have become of great interest particularly especially for those that conjugate a high storage capacity together with high safety standards. Chemical storage using amino borane has attracted a great interest and ammonia borane is playing a major role in the field due to the hydrogen storage capacity up to 19 wt%. Nevertheless, the hydrogen evolution from ammonia borane is a matter of great complexity and hydrolytic methods represent the simpler way to approach it. Actually, the ammonia borane hydrolysis is carried out by using complex catalysts not containing critical raw materials and/or noble metals. In the present work, we report the production of iron based heterogeneous catalyst support onto biochar derived pig manure. The complexity of this waste stream was very helpfully to provide an active surface for the anchoring of iron nanoparticles and promoting the hydrogen evolution form hydrolysis of ammonia borane reaching a conversion of 98.3 % at 50 ◦C with an iron loading of 10 wt%. The catalytic system reduced the activation energy of the reaction up to 51 % increasing the kinetic constant of the reaction of one order of magnitude. Furthermore, the stability of the catalytic system was preserved after three cycles without appreciable changes.

Corn stalk pyrolysis: process characterization and properties of products

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Corn is one of the most widely produced raw materials globally. According to the literature, corn grain production in the EU alone exceeds 61 million tones in 2023 (Pacuar et l., 2025). This suggests a meaningful possibility that corn cob residues could serve as a viable feedstock for biochar production and future applications. Corn stalk waste has been analyzed in terms of three components: corn stalk wall, corn stalk spongy core, and leaves. Experiments were carried out for final carbonization temperatures of 450, 550 and 650ºC using laboratory scale batch reactor. First stage of experimental investigations showed that biochar from the corn stalk wall is characterized by its lower volatile (19.5%) content than biochar from leaves and the spongy core (27.5% and 27.2%) and higher fixed carbon content, which reached 65.6% and 52.2 and 49.7% for leaves and the spongy core respectively. The first stage of experimental investigation showed that carbonization of the mixture of corn stalk waste is characterized by a similar caloric value of the obtained gases (3.08-3.67 MJ/kg). However, the analysis of the calorific value of the entire volatile fraction (tar + gases) indicates that increasing the temperature of corn stalk carbonization t from 450 to 650 °C results in an increase in the total calorific value of the products from 2.5 MJ/kg to 7 MJ/kg. Characterization of the obtained biochars showed that low content of fixed carbon and high ash content, indicates that obtained biochar samples cannot be used to produce barbecue products. However, thermogravimetric analysis of the biochar samples suggested that the biochar produced at a carbonization temperature of 650 °C may exhibit a relatively high calorific value and combust in a manner similar to that of a commercial charcoal briquette. These results indicate that the obtained biochars may be used as additive for the formation of fuels intended for combustion. An important aspect of biochar application is its potential use in wastewater treatment, particularly for the removal of pharmaceutical contaminants. Adsorption experiments were conducted over a 24 h test. The evaluation of biochars derived from corn stalk waste indicated that biochar produced at a carbonization temperature of 450 °C adsorbed approximately 21% of ibuprofen from an aqueous solution with an initial concentration of 100 mg L^{-1}. In contrast, chemical modification of the biochar using a 1 M HCl solution enhanced the adsorption efficiency to 81%. These results suggest that biochars derived from corn stalk waste may be suitable for application in wastewater treatment processes. Financial support for this study was provided by National Science Centre. Poland. OPUS 25. Nr. 2023/49/B/ST8/02136/R – “Experimental research and modeling of contaminant transformation processes in biochar-sand filters”

Sustainable valorisation of almond residues to hard carbon cathodes for aqueous zinc hybrid supercapacitors

Densa Ann Shaj (Universidad de Zaragoza, Spain) Darío Alvira (Universidad de Zaragoza, Spain) Daniel Antorán (Universidad de Zaragoza, Spain) Joan J. Manyà (Universidad de Zaragoza, Spain)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Carbonaceous materials are highly promising for post-lithium energy-storage devices, particularly aqueous zinc hybrid supercapacitors (ZHSCs). However, conventional carbon-based cathodes suffer from limited capacity and sluggish ion transport, restricting the achievable energy density and efficiency of ZHSCs.1 Developing sustainable, high-performance alternatives is therefore critical. Here, we investigate biomass-derived hard carbons (BHCs) from almond tree pruning residues (AT) and almond shells (AS)—non-edible agricultural by-products abundantly generated during almond cultivation and processing—as low-cost cathode materials. Valorisation of these residues aligns with circular-economy principles while enabling the production of functional carbons with tuneable surface chemistry, structural diversity, and cost-effective synthesis.2 The study systematically examines the influence of precursor morphology, activation strategy, and electrochemical configuration on the resulting electrochemical performance. The precursors (AT and AS) were converted into hard carbons via hydrothermal pre-treatment followed by chemical activation using K2CO3 or KOH, generating hierarchical porous materials, as illustrated in Figure 1. HTC significantly enhanced surface area and porosity by opening the lignocellulosic matrix, facilitating deeper penetration of the activating agent and increasing ion-accessible sites. AT-derived carbons exhibited the highest surface areas (1461–1494 m2 g–1) and mesopore volumes (up to 0.068 cm3 g–1) surpassing AS-derived materials. This reflects how AT is more reactive, in contrast to the denser and lignified structure of AS, as confirmed by thermal and morphological analysis. Mild K2CO3 activation achieved high carbon recovery (ca. 19 wt. %), outperforming harsher KOH routes by limiting excessive burn-off. Figure 1. Schematic of hard carbon synthesis from almond residues Electrochemical testing confirmed the superior performance of AT-derived hard carbons. The best-performing K2CO3-treated sample delivered a specific capacity of 142 mAh g–1 at 0.1 A g–1 and maintained 92 % capacity retention over 2 000 cycles at 10 A g–1. Its enhanced performance is attributed to hierarchical porosity, higher mesopore volume, and oxygen-rich surface chemistry. This improves electrolyte wetting, reduces ion-diffusion resistance, and enables mixed electric double-layer and pseudo-capacitive charge storages. Overall, these findings establish a sustainable and scalable strategy for converting almond-based agricultural residues into high-performance hard carbons for next-generation aqueous ZHSCs. Precursor selection and pre-treatment are decisive: the morphology and chemical composition of AT favour pore development and activation efficiency, while hydrothermal pre-treatment promotes hierarchical porosity and introduces O-containing moieties on surface leading to improved rate capability and cycling stability.



References: (1) Ramavath, J. N.; et al. J. Electrochem. Soc. 2021, 168, 010538. (2) Yang, L.; et al. J. Mater. Chem. A 2022, 10, 24208–24215.

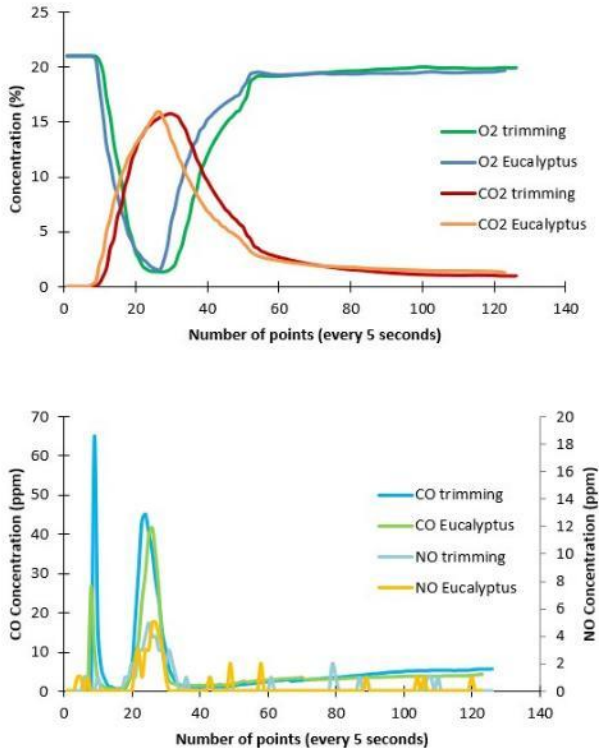
Gas Composition Dynamics in Biomass Gasification Processes

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The temporal evolution of gas composition during biomass gasification offers important insight into reaction mechanisms and process dynamics. Monitoring key gaseous species such as oxygen (O2) and carbon dioxide (CO2) makes it possible to identify distinct operational phases, including initial oxidation and subsequent gasification under sub-stoichiometric conditions. This study analyzes gas concentration profiles measured during a gasification run to clarify the transition between these stages and to evaluate the influence of biomass fuel properties on reaction behavior. At the beginning of the process, oxygen concentrations remain close to atmospheric levels (~21 vol.%), indicating that the reactor initially contains air. As gasification starts, a rapid decrease in O_2 concentration is observed, reflecting oxygen consumption through partial oxidation reactions. These reactions are essential for providing the heat required to sustain endothermic gasification processes. Although oxygen levels drop to very low values, they do not remain at zero, confirming operation under sub-stoichiometric conditions characteristic of gasification rather than complete combustion. Simultaneously, CO2 concentrations increased sharply, reaching peak values of 15-16 vol.% shortly after the O2 minimum (1.5 vol.%).



This peak corresponds to the initial oxidation stage, during which part of the biomass carbon is oxidized to CO2, contributing significantly to reactor temperature rise. The presence of two CO2 curves suggests differences related to fuel type, measurement location, or experimental conditions, resulting in variations in peak intensity and temporal behavior. Following this peak, CO2 concentrations gradually decline, signaling a transition from oxidation-dominated reactions to gasification reactions. As oxygen becomes scarce, CO2 is increasingly consumed through secondary reactions, particularly the Boudouard reaction, which converts CO2 into CO. This process explains the sustained decrease in CO_2 levels despite the continued presence of carbonaceous material. Differences in the decay rates of the CO2 curves indicate variations in fuel reactivity and composition. More heterogeneous biomass, such as trimming residues, tends to sustain CO2 production and consumption over a longer period, whereas more homogeneous fuels

like eucalyptus wood show sharper peaks and faster declines due to more uniform reaction kinetics. In the final stage of the process, oxygen concentrations increased and recovered to 19 vol.% slightly below their initial values, indicating depletion of reactive fuel and the end of active gasification. At this point, CO2 levels reach low, quasi-steady values, suggesting that most carbon has been converted or remains in a less reactive solid form. Overall, the gas profiles illustrate the typical two-stage behavior of biomass gasification: an initial partial oxidation phase followed by a reduction-dominated gasification phase. The observed differences between fuels highlight the significant influence of biomass properties on gasification dynamics and performance. Acknowledgements The authors acknowledge Fundação para a Ciência e a Tecnologia, I.P. (Portuguese Foundation for Science and Technology) under grant UID/05064/2025 (https://doi.org/10.54499/UID/05064/2025), and H2DRIVEN Green Agenda, reference C644923817-00000037.

Conceptual Pathways for the Valorisation of Gasification-Derived Biochars

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Biochar is a carbon-rich material obtained from thermochemical processes such as pyrolysis, torrefaction and gasification, conducted under sub-stoichiometric conditions. Its physicochemical characteristics—including carbon content, surface area, porosity, pH, nutrient composition and cation exchange capacity—are strongly dependent on feedstock type and processing parameters. These variations determine the potential performance of biochars in environmental and energy-related contexts. Biochars produced at elevated temperatures, particularly through thermal gasification processes above 700 °C, typically exhibit higher aromaticity, increased carbon content and enhanced surface area, largely due to the removal of volatile compounds and the development of porous structures. However, in gasification systems biochar is generated as a secondary product, resulting in comparatively lower yields. Thermal gasification involves partial oxidation using limited amounts of gasifying agents, producing gaseous, liquid and solid fractions. While extensive literature exists on the energetic aspects of biomass gasification using diverse feedstocks, the properties and potential valorisation pathways of gasification-derived biochars remain comparatively underexplored. Olive pomace is an abundant agro-industrial residue in Mediterranean regions and represents a relevant case study for examining the theoretical relationships between feedstock composition, gasification conditions and resulting biochar properties. From a conceptual standpoint, the porous structure of biochar—spanning micro- to nanopores—and the presence of surface functional groups underpin its interaction with organic and inorganic species. These characteristics are commonly associated with adsorption phenomena and are influenced by production temperature, residence time and post-processing strategies. From a theoretical perspective, biochars have been widely discussed in the literature in relation to carbon sequestration mechanisms, soil carbon stability and long-term persistence in terrestrial systems. Additionally, their structural and surface properties have been analysed in the context of gas purification, catalyst support materials and hydrogen-related technologies, where porosity and surface chemistry play a critical role. Biochars have also been described as carbonaceous adsorbents for aqueous systems, with hydrophobicity and surface functionality governing interactions with organic pollutants and emerging contaminants. This contribution provides a comprehensive theoretical discussion on the properties of biochars derived from the thermal gasification of olive pomace, emphasising structure–property relationships, compliance with international biochar quality frameworks and potential valorisation concepts. The work aims to consolidate existing knowledge and identify research gaps regarding gasification-derived biochars, supporting future studies focused on their role within circular bioeconomy and sustainable thermochemical conversion systems. Acknowledgements The authors acknowledge Fundação para a Ciência e a Tecnologia, I.P. (Portuguese Foundation for Science and Technology) under grant UID/05064/2025 (https://doi.org/10.54499/UID/05064/2025).

Effect of CaO Loading on In-Situ CO2 Capture during Pruning Biomass Gasification

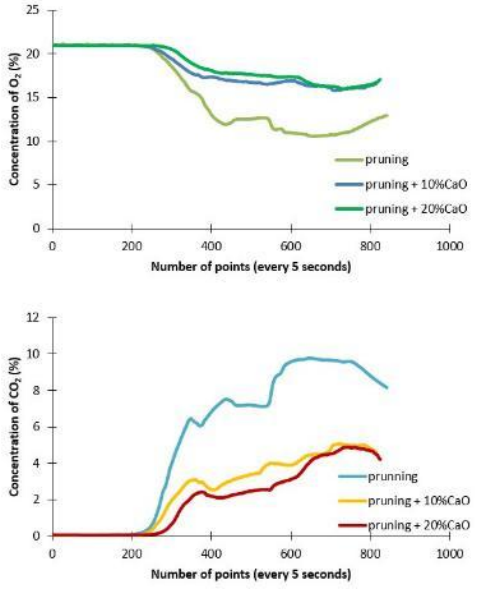
Bruna Rijo (VALORIZA – Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, Portugal, Portugal) José Rey (VALORIZA – Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, Portugal, Portugal) Paulo Brito (VALORIZA – Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, Portugal, Portugal) Roberta Panizio (VALORIZA – Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre, Portugal, Portugal)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

This study, developed within the framework of the Interreg AIHRE project (Analysis and Promotion of Renewable H_2 in the POCTEP region), investigates the integration of in-situ CO2 capture using CaO during biomass gasification is a promising route to reduce carbon emissions while maintaining process efficiency. However, the influence of CaO loading on sorbent utilisation efficiency remains insufficiently understood. In this study, the effect of CaO addition on gas composition and CO2 capture performance during pruning biomass gasification was investigated, with particular attention to oxygen (O2) and carbon dioxide (CO2) concentration profiles. Experiments were conducted using pruning alone and pruning mixed with 10 wt% and 20 wt% CaO. Gas concentrations were continuously monitored, and CO2 capture was quantified by mass balance, while char conversion was independently evaluated. Results show that char conversion was essentially identical for all cases, indicating that CaO addition did not affect the overall extent of char oxidation. However, significant differences were observed in the gas-phase composition. In the absence of CaO, CO2 concentration increased rapidly after ignition and reached peak values close to 10%, reflecting the full release of CO2 from biomass oxidation into the gas phase. Correspondingly, the O2 concentration exhibited the largest decrease, attributable to both oxygen consumption and dilution by accumulated CO2. When CaO was added, CO2 concentrations were markedly reduced throughout the reaction. The maximum CO2 concentration decreased to approximately 4–5% for both CaO loadings, confirming effective in-situ CO2 capture via carbonation. Quantitative analysis showed that the addition of 10 wt% CaO resulted in the highest CO2 capture, corresponding to 42% of the total CO2 produced on a mass basis, while 20 wt% CaO captured 39%. Despite the higher sorbent loading, the increase in CaO content did not lead to a proportional enhancement in CO2 capture. The O2 concentration profiles reflected these trends. In the presence of CaO, higher O2 concentrations were measured compared to pruning alone, despite identical char conversion. This behavior is attributed to the removal of CO2 from the gas phase, which increases the relative molar fraction of O2 rather than indicating a reduction in oxidation reactions. The similarity of the O2 profiles for 10 wt% and 20 wt% CaO is consistent with their comparable gas-phase CO2 concentrations. The lower CO2 capture efficiency observed at higher CaO loading suggests a limitation in sorbent utilization. Possible explanations include diffusion resistance through the CaCO3 product layer, reduced gas–solid contact efficiency, and partial deactivation or agglomeration of excess CaO. These factors limit the effective participation of additional CaO once carbonation becomes kinetically or mass-transfer controlled. Overall, this study demonstrates that CaO addition significantly alters gas composition during pruning biomass gasification by enabling in-situ CO2 capture without affecting char conversion. The authors acknowledge Fundação para a Ciência e a Tecnologia, I.P. (Portuguese Foundation for Science and Technology) under grant UID/05064/2025, the HYFUELUP project under grant agreement no. 101084148 and AIHRE project, reference 0093-AIHRE-6-E, co-financed by the European Regional Development Fund (ERDF) through the Interreg V-A Spain - Portugal Cooperation Programme (POCTEP) 2021- 2027.



Valorisation of intermediate pyrolysis oils from woody biomass towards marine residual fuels

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Using pyrolysis oils as blend components in marine residual fuels offers a practical route to introduce renewable carbon into shipping without requiring full chemical upgrading of the bio-liquid, as shipping faces tightening greenhouse-gas and pollutant requirements. Any candidate blend must still behave as a high-energy-density fuel compatible with existing engines, storage and bunkering. Woody-biomass intermediate pyrolysis oils can be produced from lignocellulosic residues, but their direct use is limited by high acidity, water content and chemical instability, which create handling, storage and engine-compatibility risks. This study therefore applies a certification-led framework in which fuel properties are benchmarked against ISO 8217:2024 bio-residual grades, treating the specification as an engineering 'acceptance gate' rather than reporting blend properties in isolation. Two pine-wood intermediate pyrolysis oils were produced in a continuous, oxygen-depleted Pyrotest™ system at 500 °C using different residence times (PO-500-20 and PO-500-40). The oils were characterised using ASTM methods for water, net heat of combustion, total acid number, viscosity, density, flash point, ash and elemental content, supported by GC–MS speciation. The neat oils contained about 8–10 vol% water and exhibited high acidity (total acid number 49-70 mg KOH g^{-1}), confirming they are not suitable as drop-in marine fuels. Four ternary blends were then prepared with a fixed 30 vol% pyrolysis oil fraction and variable waste-cooking-oil biodiesel and n-butanol fractions (10–20 vol% butanol), selected to balance ignition quality and cold-flow. All blends remained homogeneous after 48 h and (when benchmarked against ISO 8217) achieved RF20-relevant viscosity and density with acceptable ignition quality (CCAI). Acidity was reduced into the specification range (2 mg KOH g^{-1}, below the 2.5 limit), sulphur and key metals were below detection and energy content remained in the mid-30 MJ kg^{-1} range with a pour point around −15 °C. The results demonstrate that intermediate pyrolysis oils are valuable blendstocks for low-sulphur marine residual fuels when developed through a certification-relevant lens, and that low-severity blending with biodiesel and a higher alcohol can deliver broad ISO 8217:2024 alignment across most measured properties. Meeting the 60 °C minimum flash point needs close control of alcohol content and blend variability to keep storage and handling safe. Water content also depended strongly on n-butanol level: blends with 10 vol% butanol were 0.37-0.38 vol% (near the 0.5 vol% limit), while 20 vol% butanol increased water to 0.71-0.74 vol%. In some blends, accelerated aged sediment reached 0.30-0.50% m/m, exceeding the 0.10% m/m limit, which is consistent with carry-over of fine solids and ageing during storage. Next stages of our research will focus on practical mitigation measures, including upstream oil cleaning (hot filtration, centrifugation or electrostatic precipitation), drying and tighter blend control, followed by longer-term storage tests, materials compatibility checks and engine-scale validation under representative marine conditions.

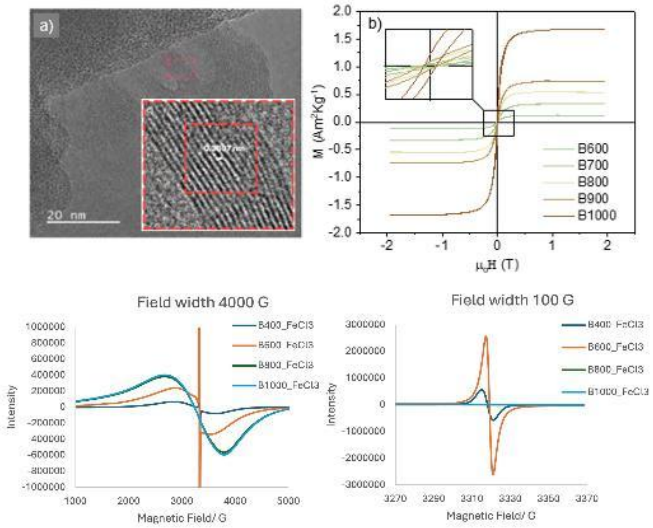
Evolution of Magnetic and Paramagnetic Behavior in Pyrolyzed Bamboo: Influence of Thermal Treatment and Iron Incorporation

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Bamboo is an abundant, renewable lignocellulosic material whose hierarchical porosity, anisotropic structure, and mechanical robustness make it an attractive template for bio based functional devices. In this study, we investigate the evolution of magnetic and paramagnetic properties in untreated and Fe impregnated bamboo subjected to slow pyrolysis across a wide heat treatment temperature range (300–1000 °C). Bamboo-derived biochar (BB) monoliths were produced from Dendrocalamus giganteus under nitrogen, with parallel series prepared with and without $FeCl_3$ impregnation to assess the synergistic effects of iron incorporation and thermal transformation. X ray diffraction analysis revealed progressive graphitization at high temperatures, leading to turbostratic, graphene like domains consistent with enhanced electrical conductivity, especially in biochars treated at 800 and 1000 °C. These findings align with previous demonstrations of bamboo-derived carbons as promising electrodes for microfluidic heaters, lithium ion batteries, and sodium ion batteries. Magnetic characterization via vibrating sample magnetometry (VSM) showed the onset of clear ferromagnetic like behavior beginning at 600 °C. The S shaped hysteresis loops suggest the presence of ferro or ferrimagnetic contributions arising either from trace iron naturally present in the pristine bamboo (~0.2 wt%, confirmed via ICP OES and XRF) or from defect induced magnetism associated with disordered graphitic domains. $FeCl_3$ impregnated bamboo pyrolyzed under the same conditions exhibited a small enhanced magnetic signatures. Raman analysis confirmed the coexistence of carbon D/G bands with characteristic peaks of magnetite (Fe_3O_4), indicating in situ formation of iron oxide nanophases. Electron paramagnetic resonance (EPR) spectroscopy further revealed two paramagnetic species: (i) persistent free radicals (PFRs) centered on aromatic carbon (g = 2.0037, ~8 × 10^{18} spins g^{-1}), and (ii) signals attributable to superparamagnetic iron nanoparticles (g ≈ 2.020). The coexistence of carbon based PFRs and iron based magnetic nanodomains suggests a hybrid mechanism for redox activity, magnetization, and potential catalytic behavior. The combined magnetic response, electrical conductivity, and radical stability highlight pyrolyzed bamboo as a multifunctional, sustainable carbon platform. These properties unlock new prospects for magnetically assisted water remediation, flow reactor oxidation processes, and smart carbon architectures where magnetic separation, radical reactivity, and conductivity are simultaneously desirable.



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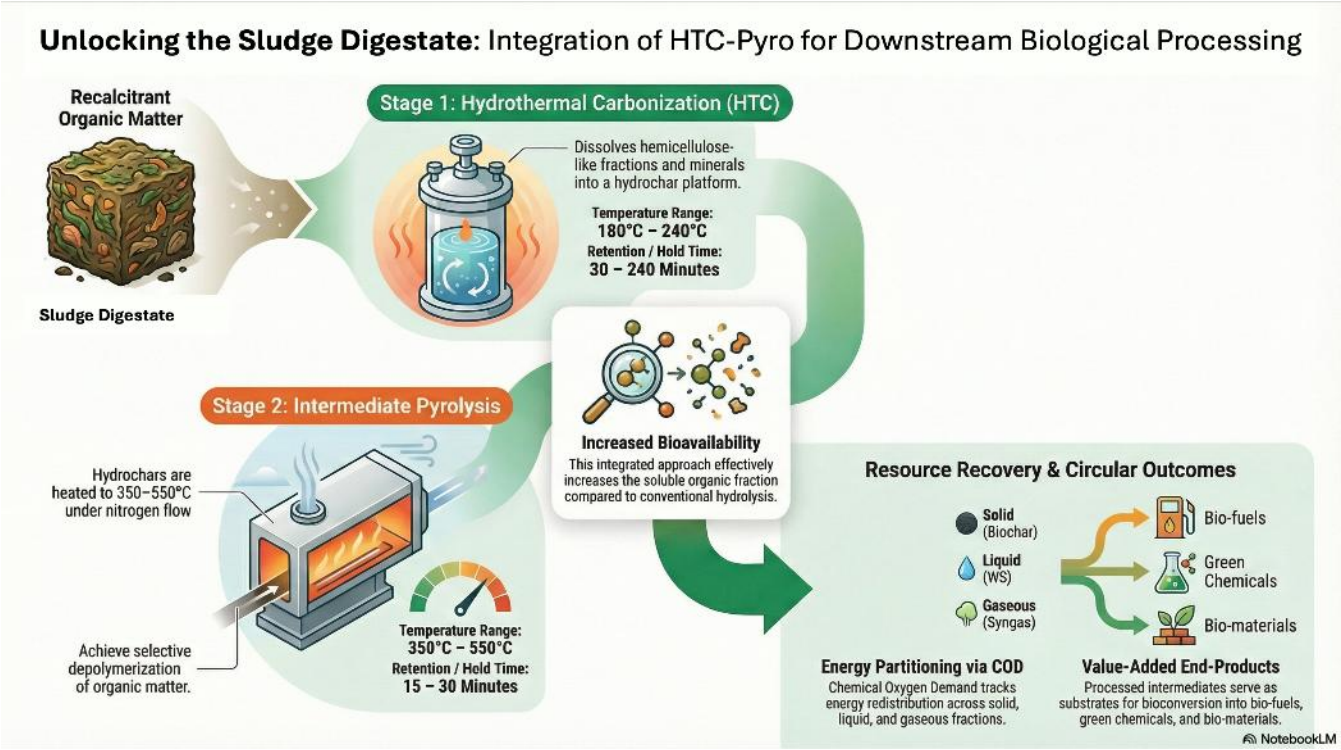
Integrating Hydrothermal Carbonization and Pyrolysis for the Revalorization of Sewage Sludge Digestate: A Hybrid Thermochemical-Biological Perspective

Yusuf Küçükağa (Gebze Technical University, Turkey) Görkem Dinç (Gebze Technical University, Turkey) Dilara Öztürk (Gebze Technical University, Turkey) Cristian Torri (University of Bologna, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Municipal wastewater treatment produces massive quantities of digestate, a highly recalcitrant residue that remains after anaerobic stabilization of sewage sludge. Current management practices, such as thermal drying for use in cement kilns or incineration, are energetically intensive and overlook the potential for circular valorisation. This study proposes an innovative revalorization pathway for biologically-stabilized sewage sludge digestate by integrating Hydrothermal Carbonization (HTC) and intermediate pyrolysis within a Hybrid Thermochemical-Biological (HTB) framework. The research evaluates the performance of the HTC-Py coupling to transform poorly bioavailable digestate into a platform of fermentable intermediates. The feedstock consists of thermally dried digestate (≈ 98% TS) and digestate slurry (≈7% TS) obtained from an advanced biological municipal wastewater treatment facility in Istanbul. HTC experiments are conducted in a 100 mL high-pressure reactor at temperatures ranging from 180 to 240 °C with retention times between 30 and 240 minutes under autonomous pressure. The resulting hydrochars and dried raw digestate are then subjected to intermediate pyrolysis in a sealed tubular furnace under nitrogen flow. The pyrolysis thermal profile utilizes a 10 °C heating rate to reach target temperatures between 350 and 550 °C, followed by a 15–30 minute hold time. To systematically assess the redistribution of chemical energy and the enhancement of bioavailability, a Chemical Oxygen Demand (COD) approach is employed as the primary monitoring parameter. This methodology allows for a direct comparison of thermochemical depolymerization efficiency against conventional hydrolysis, tracking how "chemical energy" is partitioned into solid (biochar), liquid (WS), and gaseous (syngas) fractions. Preliminary results indicate that hydrothermal treatment and/or intermediate pyrolysis can effectively increase the soluble organic fraction of anaerobically treated sewage sludge (i.e. sewage sludge digestate). Furthermore, this study includes a systematic, data-based analytical literature review of digestate-derived pyrolysis products to establish a comparative framework for process optimization. By combining HTC's ability to dissolve hemicellulose-like fractions and minerals with the selective depolymerization of pyrolysis, this integrated approach aims to "unlock" recalcitrant organic matter. While the thermochemical performance remains the focus, the obtained intermediates are ultimately designed to serve as accessible substrates for downstream anaerobic bioconversion, facilitating the production of value-added end-products such as bio-fuels, green-chemical, and bio-materials within a circular bioeconomy.



Pyrolytic conversion of rubber fig leaves into porous carbon material for environmental application

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

The rapid increase in waste, including municipal waste, industrial waste, agricultural and agroforestry waste, has become a serious environmental problem due to improper disposal methods. The use of agroforestry waste for biochar production and its application in environmental remediation has been progressing in recent years. The current study is focused on the production of porous carbon biochar from agroforestry biomass waste. In this study, rubber fig (Ficus elastica) leaves, an agroforestry waste biomass, were used as a precursor to produce biochar. Biochar was synthesised using a fixed-bed reactor under an inert nitrogen atmosphere at two different temperatures, 550°C and 750°C, with a controlled heating rate of 10°C/min. The pyrolysis process resulted in biochar yields of approximately 100g and 70g at 550°C and 750°C, respectively. This indicates that 550°C was the optimum temperature resulting in a higher yield. Further, to enhance the biochar's surface properties (surface area, pore volume), chemical activation was carried out using potassium hydroxide. Preliminary test such as proximate and ultimate analyses, were carried out to find the physicochemical and elemental composition of the biochar samples. Further characterisation techniques, such as Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), Brunauer-Emmett-Teller (BET) surface area analysis, and scanning electron microscopy (SEM), were undertaken to observe the functional group, structural, and morphological properties of the prepared biochar. This work will facilitate in converting waste biomass into value-added materials to produce porous carbon material, which could be applied in wastewater treatment techniques to achieve sustainable development goals (SDGs 6, 14 and 15) .

High-temperature pyrolysis of pine sawdust using metallurgical slag as oxygen carrier and gasification of solid residues

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14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

In the conventional chemical looping gasification (CLG) process, H2 content in the product gas typically does not exceed 40 vol.% with the usual range of H2/CO ratios from 0.7 to 1.6. Moreover, the tar is inevitable. Further composition adjustments and purification are necessary for the synthesis of aviation fuel and chemicals. To address these limitations, a staged chemical looping gasification (SCLG) process has been developed, decoupling gasification into two distinct stages: high-temperature pyrolysis (stage 1) and gasification of the solid residues (stage 2). This process is shown in the fig.1, the devolatilization reactions responsible for tar generation and the redox reactions that increase CO2 content in the gas product are isolated and conducted in stage 1. Stage 2 focuses on steam gasification of char and the upgrading of syngas using an oxygen carrier (OC). The core of the process involves establishing a pre-gasifier for stage 1 and a gasifier for stage 2, both designed for continuous operation. The bed material circulates sequentially through these reactors, with each reactor maintaining independent reaction atmospheres, allowing for optimal conditions for the respective reactions. Using pine sawdust as the feedstock and metallurgical slag as the OC, the decoupling gasification performance of this system was evaluated. Experimental results indicate that high-temperature pyrolysis gas contains more CO and less CO_2 due to the metallurgical slag carrier's superior CO selectivity. The tar produced during high-temperature pyrolysis primarily consists of polycyclic aromatic hydrocarbons and naphthalene derivatives, followed by monocyclic aromatic hydrocarbons and phenolic compounds, with minor amounts of furan compounds. As temperature increased, tar content decreased by 48% (from 21.2 g/Nm³ to 11.0 g/Nm³), with reductions in polycyclic aromatic hydrocarbons, phenols, and furan compounds, while naphthalene derivatives and monocyclic aromatic hydrocarbons increased. This shift stems from heightened oxygen carrier activity at elevated temperatures, which promotes tar cracking, catalytic cracking, and lattice oxygen oxidation. Tar removal becomes markedly effective when temperatures exceed 800°C. Additionally, significant amounts of calcium and iron, along with trace magnesium in the metallurgical slag, all of which play crucial roles in the process. Solid products from high-temperature pyrolysis include unreacted char and partially reduced oxygen carriers. The XRD patterns reveal trace amounts of metallic Fe and FeO phases. Steam is introduced for gasification. The gasifier temperature is a critical factor influencing the composition and yield of the product gas, as it affects the reaction rate within the gasifier and the effectiveness of reducing oxygen carriers in enhancing gas quality. Below 750°C, H_2 dominates the product gas (exceeding 96% by volume), but it drops sharply to 76% as the temperature rises, while the contents of CO and CO_2 show the opposite trend. Under gasifier conditions 850°C and steam-to-carbon mass ratio of 1.12, a hydrogen-rich syngas with H2 concentration of 74.0 vol.% and dry gas yield of 0.46 Nm3/kg was produced, with no detectable tar.

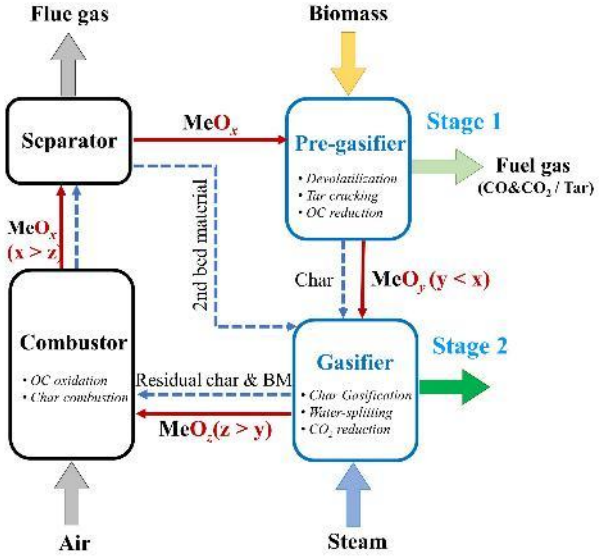


Fig.1 The Principle of staged Chemical Looping Gasification

Conversion of hazelnut shell waste into hard carbon materials for the sustainable production of hybrid capacitors

Stefania Volante (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Andrea Hainthaler (Institute for Technical Chemistry and Environmental Chemistry, Friedrich-Schiller University Jena, Germany, Germany) Domenico Licursi (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Sara Fulignati (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Anna Maria Raspolli Galletti (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy) Andrea Balducci (Institute for Technical Chemistry and Environmental Chemistry, Friedrich-Schiller University Jena, Germany, Germany) Claudia Antonetti (Department of Chemistry and Industrial Chemistry, University of Pisa, Italy, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

The development of sustainable electrode materials from biomass precursors has gained increasing attention for next-generation energy storage systems. In this context, hard carbons (HCs) have emerged as a promising electrode materials for hybrid capacitors due to its favorable charge storage mechanisms [1]. However, their practical implementation in hybrid capacitors is still limited by intrinsic challenges, including relatively low initial Coulombic Efficiency, complex solid electrolyte interphase formation and a strong dependence of electrochemical behavior on microstructural and surface chemical properties [1]. In fact, the choice of the most appropriate carbon precursor is pivotal in determining the final properties of HCs. Lignin-rich precursors are particularly suitable for HCs production, because they promote disordered structures with enlarged interlayer spacing and good structural stability, beneficial for ion storage [2]. Among the variety of carbon precursors, the waste biomass hazelnut shells (HS) represents a promising and abundant feedstock, although its use for HCs synthesis remains scarcely explored [2-4]. The present work aims to investigate the potential of HS-derived HCs as negative electrodes for lithium-ion capacitors, with particular attention to the influence of precursor treatment on the electrochemical performances in full-cell configurations [2-4]. For this purpose, the effects of different mild pre-treatments, including water washing, particle size selection, acid treatment and hydrothermal carbonization, applied to the pristine HS biomass before the final pyrolysis step were investigated on the electrochemical performances of the resulting HC materials in a full-device configuration. All the synthesized HCs were initially evaluated through electrochemical tests in half-cell configurations. Then, the most performing HCs were subsequently employed in full-cell devices. In all cases, the HCs were employed as anode materials, while an activated carbon derived from HS was used as the cathode material. Definitely, the final goal of this work was to develop sustainable hybrid energy storage devices, by integrating waste-derived materials into full-cell configurations for real electrochemical systems applications.

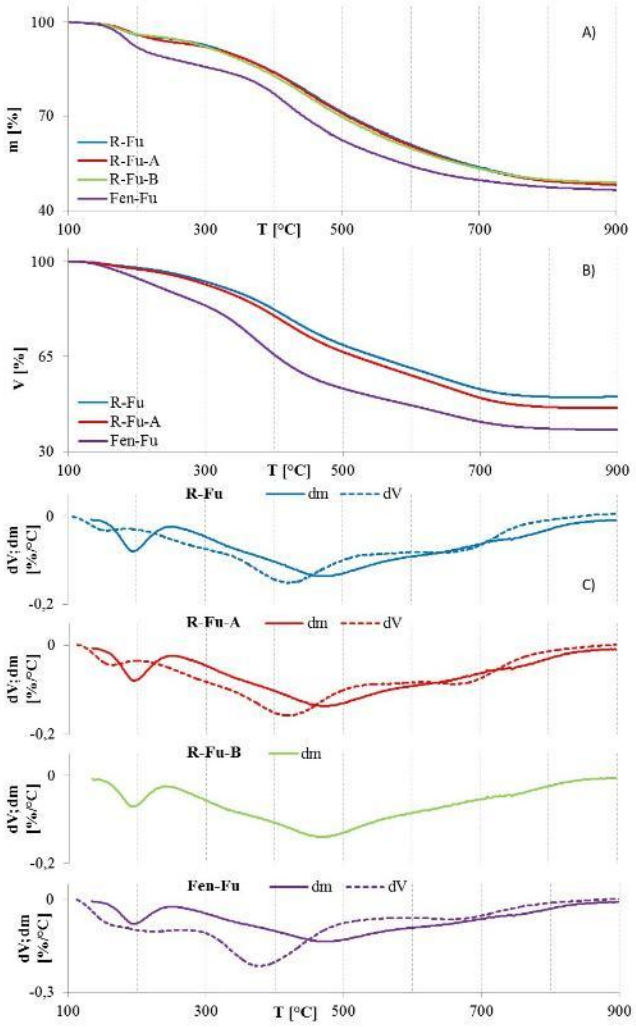
Pyrolysis of Carbonaceous Xerogels Synthesized via Polycondensation of m-Substituted Phenols with Furfural: Thermogravimetric and Thermomechanical Investigation

Petra Bulavová (University of Ostrava, Czechia) Petr Buchta (Public Health Institute in Ostrava, Czechia)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Four carbonaceous xerogels were prepared via a sol-gel route followed by pyrolysis, using furfural and m-substituted phenols as precursors. The drying and pyrolysis processes were investigated by thermogravimetric analysis (TGA) and thermomechanical analysis (TMA) up to 1,000 °C. The resulting materials were further characterized by scanning electron microscopy (SEM) and evaluated for adsorption of methylene blue, iodine, and phenol. TGA revealed total mass losses during pyrolysis in the range of 49–52 %, while volumetric losses measured by TMA ranged from 50–62 %. Prior pyrolysis, the drying step showed water removal up to ~100 °C with mass losses of 5.7–7.6 %. Pyrolysis proceeded in two distinct stages: (i) release of volatile compounds up to ~220–260 °C with mass losses of 4.1–11.4 %, and (ii) carbonization up to 1,000 °C with mass losses of 40.2–45.9 %. Mechanically, shrinkage patterns corresponded well with TGA mass losses, although slight shifts were observed: sample contraction during drying occurred around 100 °C in both TMA and TGA, whereas shrinkage during pyrolysis appeared at lower temperatures, likely due to differences in heating rates (10 °C min^{-1} for TGA vs. 1 °C min^{-1} for TMA). SEM images revealed that the samples shared a similar morphology, consisting of small, interconnected spherical particles. Adsorption capacities were determined as 0.04–0.15 mmol g^{-1} for methylene blue, 1.54–1.75 mmol g^{-1} for iodine, and 0.77–0.92 mmol g^{-1} for phenol.



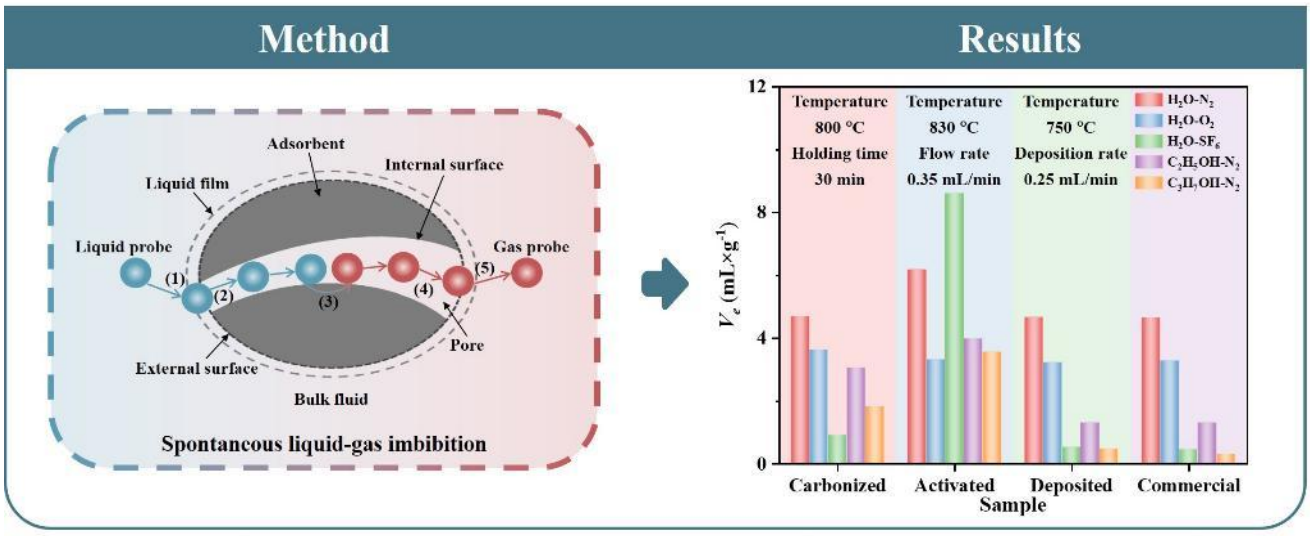
A novel application of the spontaneous liquid-gas imbibition method for pore structure characterization in pyrolytic porous materials

Yuting Wu (Dalian University of Technology, China) Yang Li (Dalian University of Technology, China) Shaoping Xu (Dalian University of Technology, China) Jingjing Yang (Dalian University of Technology, China) Haoquan Hu (Dalian University of Technology, China)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Carbon molecular sieve (CMS) is a carbonaceous adsorbent with an uniform and narrow pore size distribution, and be used for separation and purification of gases. The gas separation performance of CMS is mainly determined by its micropore volume and the micropore size, and the microporous structure is mainly affected by carbonization, activation and chemical vapor deposition during the preparation process. Based on the principle that the liquid spontaneously wets the surface of porous material to remove the gas adsorbed in the porous material, the theoretical model and derivation process were given, and the spontaneous liquid gas imbibition (SLGI) method has been applied to the preparation of the CMS. The SLGI depends on not only the porous structure of the adsorbent, but also the gas molecule (we call it gas probe) adsorbed in the pores and the liquid molecule (liquid probe) used to displace the gas. For both gas and liquid probe, they could only enter the pores of the sizes larger than their molecular kinetic diameters. The molecular probe method provides a useful way to get the pore structure information. The intermediate products of carbonization, activation and chemical vapor deposition under varied reaction conditions have been characterized by SLGI. The results show that, when the C2H5OH-N2 probe system is used in the carbonization stage, samples with larger pore volumes and pore sizes can be selected. The suitable carbonization condition is carbonization temperature 800°C and holding time 30 min. During activation, the micropore volume of the sample has been developed, and at the same time, the micropore size has increased. At this time, the difference in the H2O-N2/O2 probe system was used to determine the appropriate activation conditions. The optimized activation condition is: activation temperature 830°C and water flow rate 0.35 mL/min. The performance of laboratory CMS prepared by SLGI guidance is close to that of commercial CMSs. SLGI can more sensitively and accurately and rapidly express the micropore structure differences of the samples both qualitatively and quantitatively. Therefore, the SLGI method holds promise as a generalizable technique for the assessment of solid products in thermal pyrolysis. According to the different characteristics of the target products at different stages, a suitable liquid-gas probe system was selected to evaluate the pore structure changes.



Thermal-Analysis-Based Characterization of the Heating-Combustion Boundary in Biomass Systems

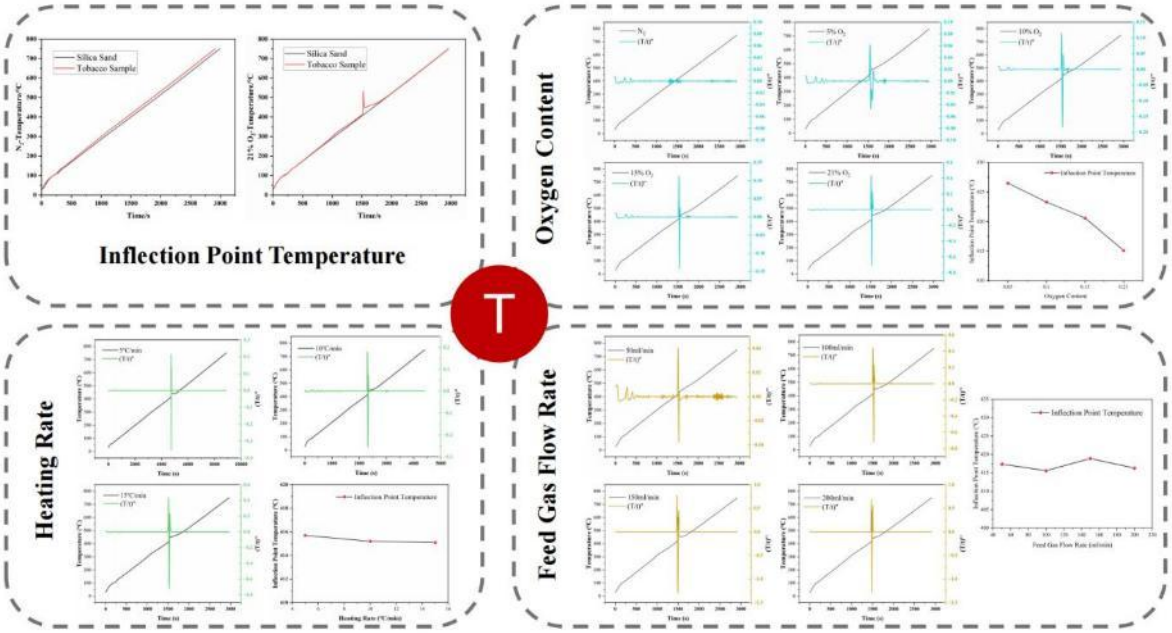
Anqi Jiang (Zhengzhou Tobacco Research Institute of CNTC, China) Jiaxi Du (Zhengzhou Tobacco Research Institute of CNTC, China) Yue Zhang (Zhengzhou Tobacco Research Institute of CNTC, China) Le Wang (wangleztri@outlook.com, China) Lili Fu (Zhengzhou Tobacco Research Institute of CNTC, China) Bin Li (Zhengzhou Tobacco Research Institute of CNTC, China)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Heated tobacco products (HTPs) are designed to heat tobacco without inducing combustion, making the accurate characterization of the boundary between thermal degradation and combustion a critical issue for both scientific understanding and product design. However, identifying this boundary in biomass systems remains challenging due to the coexistence of multiple physico-chemical processes and the absence of clear, operationally meaningful indicators. Existing approaches for determining heating-combustion boundaries, such as ignition point measurements and nitrogen-oxygen stable isotope tracing, are either poorly suited to the specific physical structure of HTPs or involve complex experimental procedures, which limits their practical applicability. In this study, a thermal-analysis-based method is proposed to characterize the heating-combustion boundary in fixed-bed biomass systems. The method identifies a temperature inflection point associated with changes in thermal behaviour, providing a simple, reproducible, and physically interpretable indicator of the transition from heating-dominated to combustion-influenced regimes. Using this approach, the effects of oxygen concentration, heating rate, and feed gas flow rate on the position of the temperature inflection point were systematically investigated. The results show that increasing oxygen concentration and heating rate causes the temperature inflection point to shift toward earlier stages of the heating process, indicating an enhanced contribution of oxidative reactions to the overall thermal behaviour. The validity of the proposed method was further evaluated through comparative characterization of homogeneous biomass samples using industrial analysis, elemental analysis, and the conventional ignition point method based on TG method. The consistency of the results supports the reliability of the inflection-point-based approach. This study provides a practical and physically meaningful framework for characterizing the heating–combustion boundary in biomass systems and offers methodological support for the thermal design and assessment of heated tobacco products.



Fluidised-bed pyrolysis of contaminated biomass – process parameters and product analysis

Patrycja Wąsik (Department of Thermal Technology, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Poland) Daniel Cieslak (Institute of Chemical, Environmental and Bioscience Engineering, Faculty of Technical Chemistry, TU Wien, Austria) Martin Sonnbichler (Institute of Chemical, Environmental and Bioscience Engineering, Faculty of Technical Chemistry, TU Wien, Austria) Nastaran Abbaspour (Institute of Chemical, Environmental and Bioscience Engineering, Faculty of Technical Chemistry, TU Wien, Austria) Giuseppe Pagliaro (Department of Chemical Sciences, University of Naples Federico II, Italy) Agnieszka Korus (Department of Thermal Technology, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Poland) Andrzej Szlęk (Department of Thermal Technology, Faculty of Energy and Environmental Engineering, Silesian University of Technology, Poland) Franz Winter (Institute of Chemical, Environmental and Bioscience Engineering, Faculty of Technical Chemistry, TU Wien, Austria)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

Pyrolysis is a thermochemical process in which a material undergoes decomposition in absence of oxidising agents. When realised in a fluidised bed reactor, an upward flow of inert gas (e.g. N2) is applied to create a suspension of the substrate mixed with bed particles. Such a solution improves the overall heat transfer of the system and results in a higher efficiency of the process, as compared to a fixed bed operation. In our work, we present the analysis of products (biochar, gas and tar) of pyrolysis experiments performed at different temperatures (500°C, 700°C, 900°C). As feedstock, pine and birch wood samples sourced from a post-industrial site polluted with Pb and Zn were used. The experiments were carried out in a fluidised bed mode, with quartz sand as the bed material, in a laboratory-scale BIOTA plant (Biogenic, Innovative and Optimized Thermochemistry Apparatus), operating at TU Wien. In each case, the composition of the produced gas was measured on-line throughout the reaction. Tar samples were captured simultaneously (in accordance with a standardised method) and later analysed qualitatively by means of GC-MS. To describe the surface chemistry of the obtained biochars, various methods were implemented, including ATR-FTIR and XPS. From a structural point of view, Raman spectroscopy was used to investigate the biochars' graphitisation degree. Morphology and surface area of the pores were determined based on CO2 and N2 adsorption isotherms, measured at 273 K and 77 K, respectively. Additionally, to trace the fate of the contaminants present in the biomass, ICP-OES analyses of the biochars and tar samples were performed. Acknowledgments: This research is a part of the project "Processes for metal-to-char encapsulation" supported by the Austrian Science Fund (FWF), project number I 5404-N and National Science Centre (Poland), project No. 2020/39/I/ST8/01484 (OPUS).

Residual Energy Recovery from Digestate via Py-AD approach: Water-soluble fraction of Bio-oil as Feedstock and its Molecular Characterization by Silylation-GC-MS

Federica Zimbardi (University of Bologna, Italy) Kussai Alrini (University of Bologna, Italy) Andrea Facchin (University of Bologna, Italy) Turkan Atkas (Namik Kemal University, Turkey) Daniele Fabbri (University of Bologna, Italy) Alessandro Rombolà (University of Bologna, Italy) Meryiem Caner (Università di Bologna, Italy) Cristian Torri (Università di Bologna, Italy)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Anaerobic digestion (AD) plays a key role in this waste valorization because it converts biomass residues into biogas, a mixture of methane (CH4) and carbon dioxide (CO2). Biogas represents a renewable energy source, that can be upgraded for applications such as transports or converted into heat and electricity1. However, only the easily degradable fraction of the feedstock is converted into biogas, while the recalcitrant components are accumulated in the digestate, resulting in a loss of potential energy production. To remove this bottleneck the application of hybrid Pyrolysis-Anaerobic Digestion (PyAD) on digestate can break refractory lignocellulosic structures through thermal degradation, producing smaller compounds accessible to anaerobic bacteria2, allowing to convert digestate into additional biomethane, biochar and water insoluble byproducts 3. This study evaluates a Py-AD configuration where biochar, gas and WS are subjected to AD and water insoluble fraction is used as source for energy rich fuels or bitumen for road paving. Digestate was subjected to slow pyrolysis at 450°C under CO_2; products were quantified to provide a detailed mass and COD balances. On mass basis, the pyrolysis of digestate converted the feedstock mainly into char (>60%), followed by WS fraction and syngas with 22.7% and 13%, respectively. On COD basis, most of the initial COD was recovered into the liquid fractions, with 32.9% in WS and 45.3% in WI, whereas biochar and syngas retained only a small fraction of the initial COD (about 14% and 6.6%, respectively). Mass and COD losses were below 3%, indicating a good closure balance. At the beginning of the experiment, WS fraction was co-fed to the bioreactor with chickpea flour to acclimate the microbial community. The chickpea flour-WS ratio was gradually reduced until reaching 100% WS. In the second part of the experiment, WS was co-fed with acetic acid which was used to mimic acetic acid production observed in the conducted syngas experiment. Biomethane conversion increased to 80% but dropped to 20% once the bioreactor was fed with 100% WS suggesting the inhibitory effect of the WS on microbial consortia. In the second phase, acetic acid was co-fed with WS fraction and the biomethane conversion increased again, suggesting that co-feeding with abundant and easily degradable feedstock is required when dealing with WS. Because WS represents the main substrate and may exhibit inhibitory effects, this fraction was for the first time characterized in detail at the molecular level. Using derivatization technique coupled to GC-MS, it was possible to investigate the molecular composition of WS fraction of bio-oil. The silylation technique improves chromatographic separation and stabilizes reactive analytes allowing to resolve up to 300 compounds, which is close to the theoretical limit of a capillary GC column. This allowed to quantify and tentatively identify about 65% of the organic compounds present in pyrolysis liquid.

The Influence of Physical Parameters and Puffing Conditions on the Thermal Characteristics of Cigar Combustion Cones

Qi Zhang (Zhengzhou Tobacco Research Institute of CNTC, China) Zilong Liu (Zhengzhou Tobacco Research Institute of CNTC, China) Le Wang (Zhengzhou Tobacco Research Institute of CNTC, China) Yue Zhang (Zhengzhou Tobacco Research Institute of CNTC, China) Bin Li (Zhengzhou Tobacco Research Institute of CNTC, China) Lili Fu (Zhengzhou Tobacco Research Institute of CNTC, China)

14:00-15:00 Session Posters P-S2F1: Pyrolysis instrumentation and methodology, Applied pyrolysis - other

Location: First Floor

ABSTRACT

The combustion state of cigars was of great significance to the quality of smoke and consumption experience. To enhance the smoking quality of cigar and optimize the design parameters of cigar, this study systematically investigates the effects of dry basis density, moisture content, and puff volume on the morphology and temperature distribution of cigar combustion cone, based on a rapid detection and characterization method for the temperature distribution of the cigar combustion cone. The results shown that: The dry basis density shows a strong positive correlation with both the morphology of the combustion cone (length, penetration depth, volume (V0)) and its temperature distribution (average volume temperature (Tm), maximum temperature (Tmax)). A higher moisture content increases the length and Tm of combustion cone. However, the intermediate moisture content (12%) results in the largest V0 alongside the lowest Tmax, suggesting that moisture regulates the intensity of combustion through phase change heat absorption during puffing. Increasing the puff volume directly expands the length and penetration depth of combustion cone, while also raising the Tm. Once the puff volume exceeds a certain threshold, the V0 and Tmax no longer increase significantly, indicating that the combustion has entered a stable and fully developed state. The study aims to provide a theoretical basis for cigar density control, combustion performance evaluation, and process optimization, with the goal of effectively regulating the combustion cone status and reducing the risk of internal combustion.

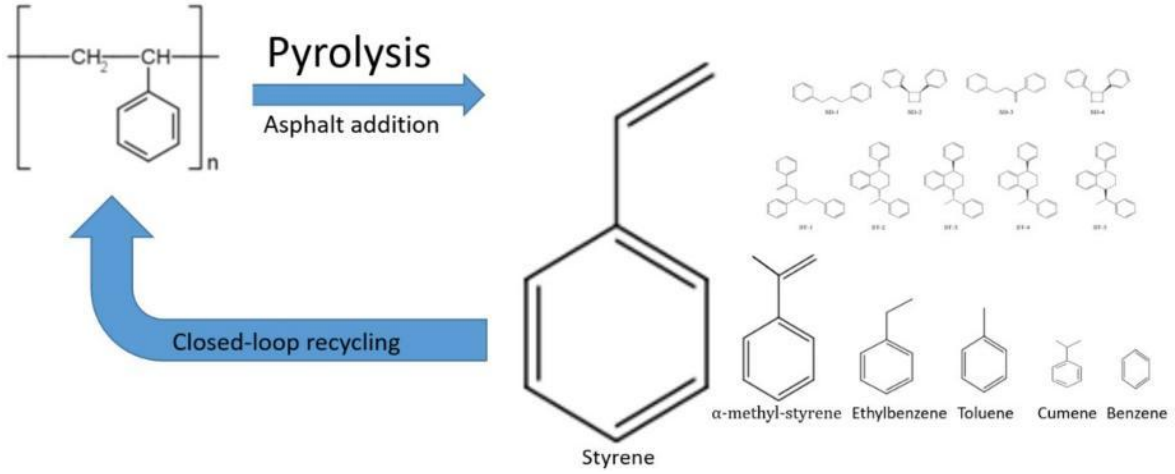
Improving liquid and BTEX production via co-pyrolysis of polystyrene and road asphalt waste

Youssef Ech'Chalh (Lorraine University, France) Valérie Vitzthum (Lorraine University, France) Raymond Michels (Lorraine University, France) Catherine Lorgeoux (Lorraine University, France)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Polystyrene is among the most widely used plastics due to its numerous advantageous properties, but its large-scale consumption generates substantial waste and significant management challenges. Pyrolysis offers a promising alternative to landfilling and incineration, which provide only partial solutions. This work focuses on the pyrolysis of polystyrene blended with road asphalt waste to evaluate possible synergistic effects, improve liquid yields, and maximize the recovery of BTEX compounds. Experiments were conducted in a semi-batch reactor equipped with a reflux system under atmospheric nitrogen at 500°C. The resulting liquid products were characterized using FTIR and GC–MS/FID, while gaseous products were analyzed with a µ-GC. Co-pyrolysis was found to be effective in increasing the liquid yield for all mass ratios tested, compared with the yield obtained from polystyrene alone. The strongest synergistic effect occurred at a PS/asphalt mass ratio of 67/33, producing a liquid yield of 93%, corresponding to a 9.3% increase relative to pure PS. Increasing the proportion of asphalt beyond this point reduced the observed synergy. Analysis of the liquid fraction showed styrene to be the dominant product in all experiments. The asphalt content exhibited a notable influence on the distribution of BTEX compounds: an increase of asphalt content from 18% to 33% leads to an increase of styrene yield in the liquid products from 80% to 84% before it decreases to around 74% when asphalt content was 67%.This decrease in styrene yield accompanied by an increase in ethylbenzene suggests a catalytic contribution from the mineral fraction, particularly when asphalt is present in excess. These results highlight the potential of PS/asphalt co-pyrolysis as a promising approach for the valorization of polystyrene waste, enabling its conversion into value-added products. In particular, the recovery of styrene offers opportunities for closed-loop recycling, as it can be reused directly as a monomer in new PS production.



Co-pyrolysis Characteristics of Polyethylene and Biomass in a Bubbling Fluidized Bed

An Taehwi (University of Seoul, South Korea) Kim Yoonseok (University of Seoul, South Korea) Yim Hoesuk (Seoul National University, South Korea) Park Young-Kwon (University of Seoul, South Korea) Seo Myungwon (University of Seoul, South Korea)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Due to global population growth, the production and consumption of waste plastics have steadily increased, making recycling a critical challenge. Meanwhile, biomass is a carbon-neutral resource that can be utilized as a clean fuel through appropriate treatment. This study evaluated the potential for waste resource circulation by comparing the pyrolysis characteristics of polyethylene (PE) and woody biomass under both single and co-pyrolysis conditions. Experiments were conducted in a lab-scale fluidized-bed reactor at 400, 600, and 800 ℃ under a nitrogen atmosphere with a superficial gas velocity to minimum fluidization velocity ratio (ug/umf) of 1.5. The produced gases were analyzed using NDIR and GC-FID, while the pyrolysis oils were characterized by GC–MS. Concentrations of H2, CO, CH4, CO2, and C2–C3 hydrocarbons in the pyrolysis gas were quantified, and oil compositions were determined by integrating the mass spectrometric peak areas of individual compounds. Co-pyrolysis was carried out using a 1:1 mixture of PE and woody biomass. Biomass exhibited a maximum oil yield at 600 ℃, whereas PE predominantly produced wax rather than oil at the same temperature. Biomass-derived oils consisted mainly of phenolic and ester compounds, with phenolic concentrations increasing as the temperature rose. This study demonstrates the potential of converting waste plastics and biomass into pyrolysis oils as a viable pathway for waste recycling and sustainable resource circulation.

Development and Validation of a Py-GC/MS Method for the Simultaneous Determination of Microplastics and Biomicroplastics in Seawater

Encarnación López Rodríguez (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Jesús Marín Sáez (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Roberto Romero González (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain) Antonia Garrido Frenich (Research Group "Analytical Chemistry of Contaminants", Dept. of Chemistry and Physics, University of Almeria, Spain, Spain)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

The versatility of plastics, characterized by their high chemical and mechanical resistance, has positioned them as essential components in material science. Consequently, global production has increased exponentially over the last three decades, as documented by the Organisation for Economic Co-operation and Development (OECD) [1]. However, this widespread use has led to the accumulation of persistent waste that resists complete degradation, eventually fragmenting into microplastics (MPs), ranging from 5 mm to 1 µm, and nanoplastics (NPs), with sizes lower than 1 µm. These particles pose a severe environmental threat due to their mobility across ecosystems, such as seawater. In response to the urgent need for standardized determination methods, this study presents the development of an analytical methodology based on pyrolysis coupled with gas chromatography-mass spectrometry (Py-GC/MS) for the simultaneous determination of twelve MNPs, including ten listed in the Commission Delegated Decision (UE) 2024/1441 [2] (polyethylene, polypropylene, polystyrene, among others), and four micro/nanobioplastics (MNBPs) (polylactic acid, polycaprolactone, polybutylene adipate terephthalate and poly 3-hydroxybutyrate) within a total analysis time of 26 minutes. While the goal is environmental monitoring, the primary objective of this current work is the design and rigorous performance evaluation of the method using controlled aqueous matrices to ensure its efficacy. For this purpose, a sequential filtration with 1.00, 0.45 and 0.10 µm cellulose nitrate filters was carried out to fractionate the sample and assess the particle size distribution, as Py-GC-MS analysis does not differentiate by size. Simulated seawater samples were employed during method development to ensure reliable results. Moreover, a comparison between full scan and Selected Ion Monitoring (SIM) was carried out as acquisition mode, observing that SIM mode was more selective and sensitive than full scan, improving the reliability during the identification of the polymers. The proposed method was validated through linearity, precision and recovery evaluation ranging from 0.005 to 0.1 mg. Finally, this method was evaluated analysing ten seawater samples from Mediterranean Sea (samples were selected according to their closeness to populated areas). The proposed analytical method enabled the simultaneous identification of MPs of polyethylene (5.12-21.31 mg·m-3) and polyvinyl chloride (0.85-5.83 mg·m-3) in all the seawater samples, as well as polylactic acid (1.38-3.75 mg·m-3) in two of them. In addition, NPs of polyvinyl chloride and polylactic acid were detected. This methodology offers a robust, high-throughput alternative to traditional microspectroscopy techniques, establishing a validated framework for future application in complex seawater samples. This publication is part of project PID2022-137122OB-I00, funded by MICIU/AEI/10.13039/501100011033/ and ERDF, EU. Encarnación López Rodríguez acknowledge grant FPU21/00858, funded by MICIU/AEI/10.13039/501100011033 and ESF+. Jesús Marín Sáez acknowledges the Andalusian government, the Counselling of University, Investigation and Innovation (CUII) and European Social Fund plus (Andalusia ESF+ 2021–2027) for financial support (POST_2024_00151). [1] OECD (2024), Policy Scenarios for Eliminating Plastic Pollution by 2040, OECD Publishing, Paris, https://doi.org/10.1787/76400890-en. [2] European Commission, 2024. Commission Delegated Decision (EU) 2024/1441 of 11 March 2024 supplementing Directive (EU) 020/2184 of the European Parliament and of the Council by laying down a methodology to measure microplastics in water intended for human consumption.

Synthesis and characterization of a promising energetic nitrochitosan

Mohamed Abderrahim Hamouche (Ecole militaire polytechnique, Algeria) Ahmed Fouzi Tarchoun (Ecole militaire polytechnique, Algeria) Djalal Trache (Ecole militaire polytechnique, Algeria) Hamdane Akbi (Ecole militaire polytechnique, Algeria)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

With the aim of valorizing the underutilized resource to explore new horizons in the energetic field, this work investigates the potential of Parapenaeus longirostris shrimp, an abundant species in the Mediterranean Sea, as a valuable source of chitin for the synthesis of high-energetic polysaccharide, namely nitrochitosane. And compares the impact of conventional extraction of chitin through acid hydrolysis and a DES- based extraction using lactic acid/choline chloride as a deep eutectic solvent, on the targeted products. Chitin was extracted from the shrimp shells using both methods, and high-quality chitosan (DDA% > 92%) was obtained through deacetylation process. Subsequently, nitrochitosan was synthesized from the chitosan derived from both extraction methods as well as a commercial source, resulting in three distinct types of nitrochitosan: NCS-Con, NCS-DES, and NCS-C. This article presents comprehensive assessments of the studied inert and energetic polysaccharides, including physiochemical properties (1.531 ≤ DCT ≤ 1.558, 1.531, 1.501 ≤ DCS ≤ 1.511, 1.698 ≤ DNCS ≤ 1.710), structural and morphological features, thermal behavior, thermal and mechanical sensitivities (110.8 °C ≤ Ti ≤ 117.1 °C, Is = 15 J, Fs > 360), combustion parameters and estimation of energetic performances (248 s ≤Isp≤ 251 s, 7865 ≤D≤ 7882). In addition, thermokinetic study was conducted to determine the energy of activation of each (74 kJ/mol ≤ Ea1ststep ≤ 86 kJ/mol, 117 kJ/mol ≤Ea2ndstep≤153 kJ/mol) among many other revelations.

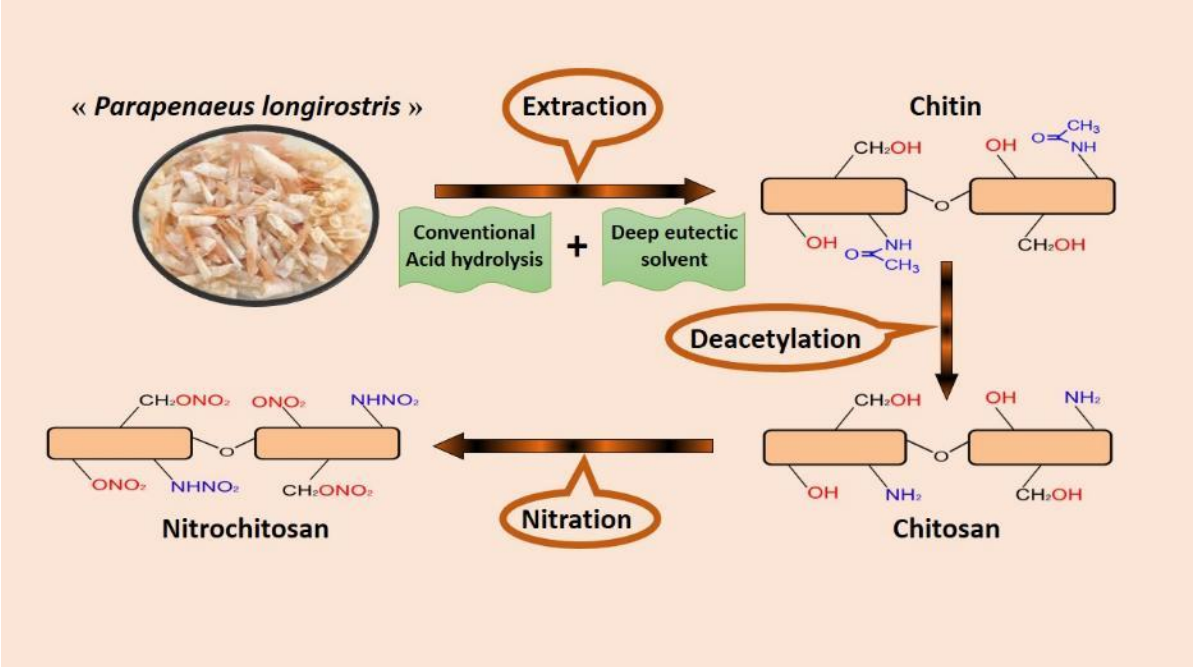


Figure 1: Graphical abstract.

Unveiling interactions of enzymatic hydrolysis lignin and waste tires during co-pyrolysis

Shuang Cui (Shenyang Aerospace University, China) Tianhua Yang (Shenyang Aerospace University, China) Rundong Li (Shenyang Aerospace University, China) Jian Wang (Shenyang Aerospace University, China)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

An in-depth understanding of co-pyrolysis interaction mechanisms is essential for efficient conversion of raw materials and optimizing the regulation of products. Herein, the interaction between enzymatically hydrolyzed lignin (EHL) and waste tires (WT) during co-pyrolysis was investigated using a novel strategy which combines principal component analysis (PCA) and characterization analysis (e.g., FT-ICR-MS, GC–MS, EPR, and so on). Results indicated that cooperative interactions were observed during the co-pyrolysis of EHL and WT, resulting in measured activation energy lower than theoretical calculation. PCA indicated that co-pyrolysis interaction pri marily occurred at 345–470 ◦C and was controlled by WT. The contribution of co-pyrolysis to the activation energy and radical spin concentration was most significant with WT blending ratio of 25 %, while the contri bution to the bio-oil yield was most significant when the ratio was 50 %. The mechanism analysis indicated that radical-mediated interactions are the key factors influencing the formation of pyrolysis products. Co-pyrolysis improved the bio-oil quality. When a small amount of WT was blended, the co-pyrolysis was manifested as WT-generated hydrocarbon radicals attacking the chemical sites of EHL-derived aromatic rings to form aromatic compounds with fatty structures. When a large amount of WT was blended, it was manifested as sufficient hy drocarbon radicals promoting the demethylation and dehydration of phenolic compounds to form aromatic compounds through hydrogen transfer. Notably, the aromatics content increased significantly from 0.64 % to 18.67 % when WT blending ratio was 75 %. The findings reveal the co-pyrolysis interaction mechanism from the perspective of free radicals and provide a theoretical basis for the targeted regulation of pyrolysis products.

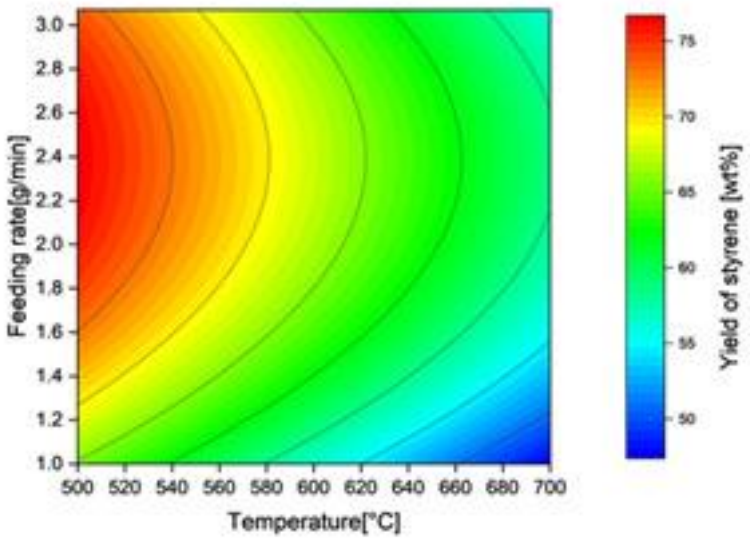
Design of Experiments for PS pyrolysis in a conical spouted bed reactor

Sajan Sivanandan (PhD, Belgium) Kseniia Vikanova (PostDoc, Belgium) Toon Van Vaerenbergh (PhD, Belgium) Jonathan Van Waeyenberg (PhD, Belgium) Bert Sels (Full Professor, Belgium)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Polystyrene (PS) is well-known as one of the most used commodity plastic; however, the recycling rate of PS is accounted only to 7% globally. Mechanical recycling overwhelmingly dominates current polystyrene reprocessing, while chemical recycling, particularly thermal pyrolysis provides a great potential for closing the material loop and tackling contaminated or mixed waste streams. Polystyrene has a backbone of saturated carbon-carbon (C–C) bonds similar to polyolefins, but its key distinguishing feature is the presence of pendant aromatic (phenyl) rings attached to every other carbon atom in the backbone. This structural motif creates relatively weaker benzylic C–H and C–C bonds adjacent to the aromatic rings, which are more reactive and easier to cleave during depolymerization compared to the stronger, more inert aliphatic C–C and C–H bonds in polyolefins. Additionally, the benzylic position stabilizes radicals formed during bond scission thus lowering the energy required for bond cleavage and making depolymerization by thermal or catalytic means more efficient . The mechanism of thermal PS pyrolysis and process peculiarities were extensively studied in small scale. However, the upscaling always requires additional optimization in order to obtain higher target product yield. When it comes to upscaling, use of an efficient reactor and optimized reaction conditions are critical factors. Conical spouted bed reactor (CSBR) configuration is known to be particularly effective when high selectivity and productivity are the primary objectives. Among the advantages of a CSBR are (i) short residence times, thereby minimizing secondary reactions, (ii) cyclic movement of the sand, accordingly avoiding defluidization and (iii) excellent mass and heat transfer. In the current research the influence of different parameters was studied for PS thermal pyrolysis in CSBR and evaluated using statistical modeling. The data analysis revealed temperature and feeding rate as crucial reaction parameters largely defining the styrene yield. The developed model allowed to predict the optimal conditions for maximization of the target product yield which were further successfully validated using real post-consumer waste PS as feedstock.



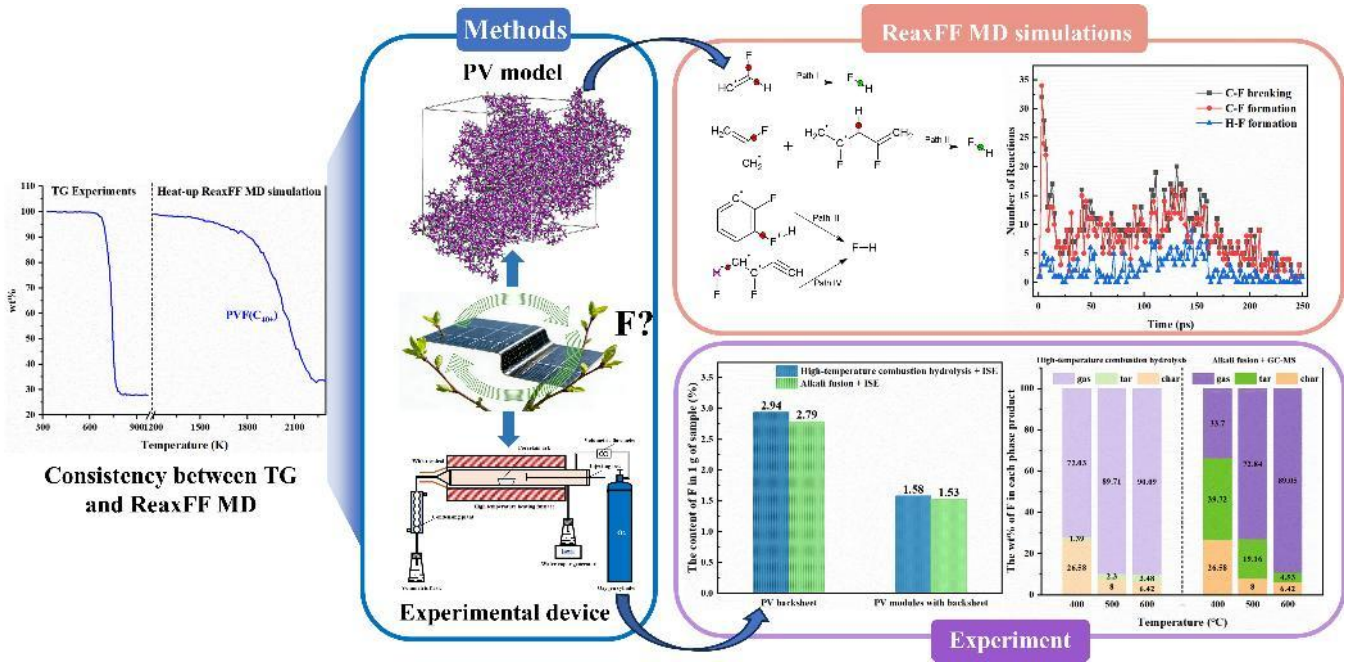
Deep insights into fluorine transformation mechanisms during pyrolysis of retired photovoltaic backsheets: Experimental validation and ReaxFF molecular dynamics simulations

Min Zhang (Xi'an JiaoTong University, China) Xuebin Wang (Xi'an JiaoTong University, China) Shuanghui Deng (Xi'an JiaoTong University, China)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

To address key challenges in the pyrolysis of retired fluorine (F)-containing photovoltaic (PV) module backsheets, namely unclear F migration mechanisms, insufficient experiment-simulation coupling, and ambiguous F distribution/hydrogen fluoride formation pathways, this study combines experiments with ReaxFF molecular dynamics simulations. Pyrolysis characteristics and F transformation behaviors of polyvinyl fluoride (PVF), PV backsheets, and PV modules containing backsheets were systematically investigated. Experimentally, thermogravimetric analysis (TGA), high-temperature combustion hydrolysis coupled with anion selective electrode (ISE), alkali fusion-ISE, and gas chromatography-mass spectrometry quantified F distribution among gas, liquid, and solid products at 400-600℃. Results showed more F retained in tar than gas, with characteristic fluorinated compounds identified. Parallel ReaxFF molecular dynamics simulations based on a 12,050-atom PVF model were conducted to elucidate atomic-scale C-F cleavage mechanisms, HF formation pathways, and competitive F reaction dynamics. The simulation results showed qualitative agreement with TGA experiments. F was preferentially released as HF in gas, while most F radicals from C-F bond cleavage recombined with carbon to form complex fluorohydrocarbons in tar. Fluorine critically promoted radical-driven cyclization of fluorinated carbon chains through electronic effects, promoting free radical generation, intramolecular bonding, and small-to-large ring conversion. Distinct temperature-dependent F behaviors were observed during backsheet pyrolysis. At low temperatures, F predominantly accumulated in the tar, whereas at high temperatures, 90.10% of F migrated to gas. Ethylene vinyl acetate synergistically affected F transformation. HF formation was dominated by F• capturing H atoms, and the largest detected fluorinated fragment (C1060H548F252) retained 12.6% of the total F, influencing char graphitization through cross-linked structures. Overall, this study provides integrated experimental-simulation evidence that clarifies F transformation pathways during PV backsheet pyrolysis, and offers guidance for development of low-F-emission recycling processes.



Experimental and Modelling Investigation of Primary and Secondary Reactions in LDPE Pyrolysis

Mariangela Guastaferro (Department of Civil and Industrial Engineering, University of Pisa, Italy) Letizia Marchetti (Consorzio Polo Tecnologico Magona, Cecina, Italy) Chiara Barbara Aresi (CRECK Modeling Lab, Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Matteo Pelucchi (CRECK Modeling Lab, Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Alessio Frassoldati (CRECK Modeling Lab, Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Tiziano Faravelli (CRECK Modeling Lab, Department of Chemistry, Materials, and Chemical Engineering "G. Natta", Politecnico di Milano, Italy) Leonardo Tognotti (Department of Civil and Industrial Engineering, University of Pisa, 56122 Pisa, Italy) Cristiano Nicolella (Department of Civil and Industrial Engineering, University of Pisa, Italy)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

The development of predictive models for plastic pyrolysis is required to achieve a mechanistic understanding of the underlying phenomena and, in turn, to facilitate and accelerate the deployment of pyrolysis-based recycling technologies through improved process design and operation. However, the strong variability of real plastic waste streams and the complexity of degradation mechanisms still represent major challenges for reliable model formulation, validation, and extension. In this work, an existing modelling framework is assessed and supported through a set of well-characterized experiments designed to probe degradation pathways at increasing levels of complexity and to identify directions for further model refinement. A well-defined virgin polymer system is selected as a starting point to ensure consistency between experimental observations and model assumptions before progressively moving toward more complex reaction environments. Low-density polyethylene (LDPE) virgin pellets were selected as a reference material to generate high-quality experimental data suitable for model validation and development. Thermogravimetric analysis was first performed under an inert nitrogen atmosphere to investigate the intrinsic thermal degradation behaviour of LDPE, primarily associated with primary decomposition reactions. Experiments were conducted up to 800 °C with a heating rate of 20 °C/min, representative of fast and flash pyrolysis conditions, providing insight into the main degradation stages and overall conversion behaviour. Pyrolysis experiments were subsequently carried out in a laboratory-scale batch setup capable of reproducing reaction environments of increasing complexity and enabling the development of secondary chemistry. Both single-stage and double-stage pyrolysis configurations were investigated. In the single-stage configuration, pyrolysis was performed in a single reactor operated at 500 °C, whereas in the double-stage configuration a second reactor operated at 800 °C was placed downstream of the first one to promote further thermal cracking and secondary reactions. Both reactors were continuously fed with nitrogen at 300 mL/min to ensure inert conditions and to transport pyrolysis products through the system. The reaction section was followed by a separation unit, where condensable vapours were collected using a cryogenic condensation system based on a liquid CO2-ethanol mixture, while permanent gases were collected in Tedlar® bags and analysed by microGC to determine their volumetric composition. Solid, liquid, and gaseous products were quantified at the end of each experiment to calculate product yields, and samples were collected for further characterization. The resulting dataset, including thermal degradation profiles, product yields, and gas compositions under different pyrolysis configurations, is used to validate and further develop a semi-detailed kinetic model for LDPE thermochemical recycling based on a functional-group approach. The model explicitly accounts for primary degradation reactions as well as secondary reaction pathways and is applied to reproduce mass-loss profiles and product speciation under static and dynamic conditions at moderate to high temperatures. This study represents a first step toward a systematic, model-driven description of plastic pyrolysis, with the long-term goal of extending the approach to increasingly complex plastic mixtures and real waste-derived feedstocks.

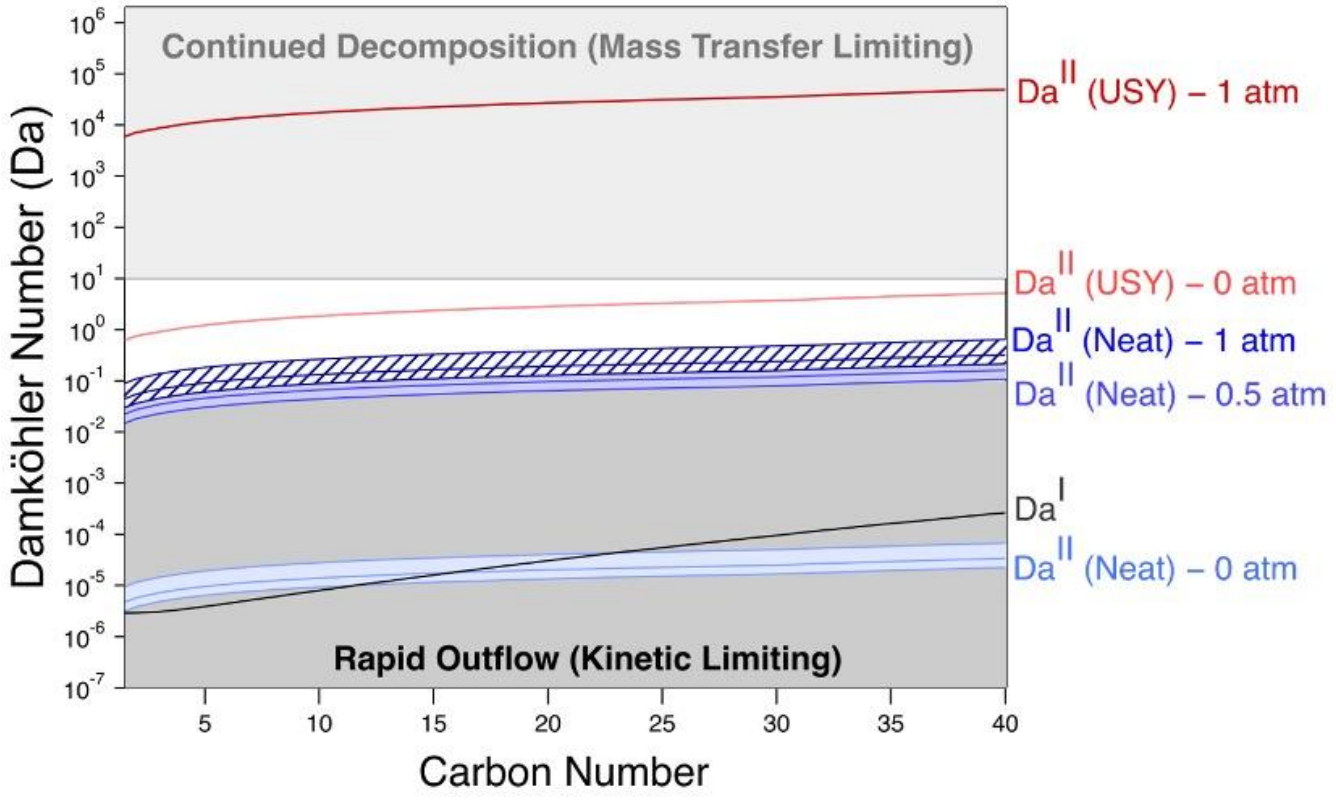
Modulating Neat and Catalytic Polyolefin Pyrolysis using Damköhler Numbers

Doga Tekbas (University of Massachusetts Lowell, United States) Matthew Wright (University of Massachusetts Lowell, United States) Hsi-Wu Wong (University of Massachusetts Lowell, United States)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Pyrolysis offers a practical route for large-scale waste plastic treatment, particularly for polyolefins where other approaches do not offer success. However, diverse product distributions from polyolefin pyrolysis are typically observed where complex interplay between chemical kinetics and mass transfer exists. In this work, we demonstrate the use of dimensionless Damköhler numbers to guide the modulation of chemical kinetics–mass transfer coupling in both neat and catalytic polyolefin pyrolysis for tuning product distributions. High-density polyethylene (HDPE) is selected as an illustrative example, and its pyrolysis was conducted at pressures between near vacuum and 1 atm in a microreactor to vary the mass transfer environments, with USY zeolite catalysts used to alter chemical kinetics. Our experiments revealed that neat pyrolysis at near-vacuum conditions gave a product distribution closer to that obtained from the kinetic-limited regime, representing primary products that readily escape from the reaction zone. Increasing pressure and adding catalysts both promoted HDPE conversion, caused by decelerated species outflow and increased reaction rate in the gas phase, respectively, facilitating continued decomposition of the primary products. Two dimensionless Damköhler numbers, one for the melt polymer phase and the other for the headspace directly above the vapor–liquid interface, are defined to characterize the competition between mass transfer and continued decomposition of a species. It is shown that the first Damköhler number is small for all experimental conditions studied (see Figure), suggesting fast escape of the products from the melt polymer phase. On the other hand, the second Damköhler number suggests that higher system pressure or the presence of a catalyst favors continued decomposition in the headspace. This Damköhler number analysis accurately predicts the experimental findings. Such a dimensionless analysis provides insights into future pyrolysis process optimization or novel catalyst design to manipulate chemical kinetics–mass transfer coupling in polyolefin pyrolysis for achieving desired product distributions, advancing plastic recycling technologies for full circularity.



Characteristics of pyrolysis products from waste polyolefin plastics using 15 kg/hr continuous auger system

Kim Jong Su (korea institute of industrial technology, South Korea) Jeong Soohwa (KITECH(Korea Institute of Industrial Technology), South Korea)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Polyolefin plastics primarily polyethylene (PE) and polypropylene (PP) are the most abundant components of plastic waste globally, driving a significant portion of the world's pollution crisis. Waste plastic is one of the most promising resources for fuel production. We can convert waste plastic into valuable energy resources. Thermochemical conversion technologies primarily combustion, gasification and pyrolysis are recognized globally as advanced cleaner alternatives to more than traditional landfilling waste management. Pyrolysis offers significant advantages by turning waste into valuable resources (char, oils, gas) through heat in an oxygen-free environment. Reducing landfill dependency, lowering greenhouse gas emissions compared to incineration, enabling energy recovery and supporting the circular economy.The reported is that chemically, pyrolytic oil is constituted by paraffin, olefins, and aromatics. Moreover, the relevant physical properties (density, viscosity, pH value etc) and the heating value of pyrolytic oil are like those of diesel. In this study, 1:1 mixture of waste polyethylene and waste polypropylene was pyrolyzed at a reaction temperature of 550 °C using auger system with a maximum capacity of 15 kg/hr. Additionally, CaO and talc 2.5 wt.% was added to reduce the chlorine content in the pyrolytic oil. The proximately and ultimate analysis results of the feedstocks are described in Table 1. An auger system is a device utilizing a rotating helical screw blade enclosed in a tube to transport feedstocks. The experimental apparatus consisted of a stainless-steel tube with an electric furnace and a temperature controller (as shown in Fig. 1). A staged oil recovery system was applied to capture high boiling point wax and low boiling point oil together. Nitrogen gas (N2) was introduced during the pyrolysis experiment. The yield of pyrolytic oil was about 51 wt.%. The recovered pyrolytic oil was properties analyzed by GC-MS(Gas Chromatography - Mass Spectrometry), Combustion-IC(Ion Chromatography) and kinetic vicosity. In GC-MS analysis, obtained pyrolytic oil components mainly consisted of Naphtha (as shown in Fig. 2). Combustion-IC analysis results showed that the chlorine concentration inside the pyrolytic oil without additives was 34.9 ppm. When 2.5 wt.% of CaO and talc were added, the chlorine concentration in the pyrolytic oil was confirmed to be 21.2 ppm. It was confirmed that 32.9 wt.% of chlorine in the pyrolytic oil was removed through the addition of additives. At this time, The kinematic viscosity of pyrolytic oil was about 1.0 cSt.

Table 1. Proximately & ultimate analysis results of waste polyethylene & polypropylene

Proximately analysis (wt.%)	Moisture	Volatile matter	Fixed carbon	Ash
Polyethylene	0.2	99.2	0.1	0.5
Polypropylene	0.4	97.4	0.1	2.1
Ultimate analysis (wt.%)	Carbon	Hydrogen	Nitrogen	Oxygen
Polyethylene	84.3	14.2	0.0	1.5
Polypropylene	83.9	13.9	0.1	2.1



Fig. 1. 15kg/hr continuous auger system

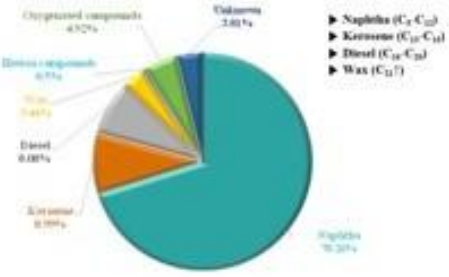


Fig. 2. Classification by carbon number in oil

Circular Economy Pathways for Artificial Turf Waste: Pyrolysis as a Recycling Strategy

Michèle Jampolski (Research Institute for Innovative Surfaces FINO, Aalen University, Germany, Germany) Katharina Weber (Research Institute for Innovative Surfaces FINO, Aalen University, Germany, Germany) Iman Taha (Institute for Sustainable Polymers and Composites iSPC, Aalen University, Germany, Germany)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

Complex plastic waste streams constitute a significant barrier to increasing recycling rates. Artificial turf soccer pitches are complex multi-material systems composed of various polymer types and represent a particularly challenging example. After a typical service life of approximately 12 to 15 years, these systems exhibit substantial material degradation due to mechanical wear as well as environmental exposure [1, 2]. A standard full-size pitch covers an area of approximately 7,000 m² and has a total mass of around 230 tones, of which roughly 100 tones consist of different plastic fractions [1, 3, 4]. In Europe, approximately 1,000 artificial turf pitches are currently decommissioned each year [2, 5]. Given the continuing demand for synthetic turf systems, a further increase in the associated waste streams can be expected. The heterogeneous material composition consisting of different thermoplastics, thermosets, elastomers and mineral components as sand and calcium carbonate. This significantly complicates sorting, separation, and subsequent material recycling, thereby posing a major challenge for the development of efficient and sustainable end-of-life strategies. Whilst mechanical recycling reaches its limits due to its lack of efficiency and high resource consumption, pyrolysis as chemical recycling process represents a promising perspective for the valorisation of cross-linked and mixed plastic waste. This work identifies the most challenging aspects of recycling complex multi-material systems with regard to pyrolysis based on the example of artificial turf. Lab-scale pyrolysis experiments are discussed with regard to their technical feasibility for industrial-scale processes. Based on the findings, this work provides recommendations for recycling-friendly product design to enhance recycling rates for complex plastic waste streams.

[1] EMEA Synthetic Turf Council, 2021. ESTC Guide Processing End of Life Synthetic Turf Sports Surfaces. https://www.estc.info/wp-content/uploads/2021/07/ESTC-guide-Processing-End-of-Life-Synthetic-Turf-Sports-Surfaces-Edition-2021-FINAL.pdf (accessed Oct 2025)

[2] PLAYGROUND@LANDSCAPE 5, 2019. Entsorgung von Kunstrasensystemen - Recyceln statt verbrennen, https://playground-landscape.com/de/article/2242-entsorgung-von-kunstrasensystemen-recyceln-statt-verbrennen.html (accessed Dec 2024)

[3] Eunomia Research & Consulting Ltd, 2017. Environmental Impact Study on artificial football turf. https://eunomia.eco/reports/environmental-impact-study-on-artificial-football-turf/ (accessed Oct 2025)

[4] EMEA Synthetic Turf Council, 2023. Recycling facilities for synthetic turf systems in Europe, https://www.estc.info/wp-content/uploads/2023/06/RECYCLING-FACILITIES-FOR-SYNTHETIC-TURF-SYSTEMS-IN-EUROPE-ESTC-Guide.pdf (accessed Mar 2026) [5] Tarkett Sports FieldTurf, 2025. Sustainability Commitment – Turf, Innovate. https://fieldturf.com/en/why-fieldturf/sustainability-commitment/ (accessed Jun 2025)

One-pot synthesis of hierarchical ZSM-5 for lifetime improvement in catalytic conversion of plastic waste

Cunfeng Ke (Southeast University, China) Huiyan Zhang (Southeast University, China) Leilei Dai (Southeast University, China)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Hierarchical ZSM-5 catalysts were synthesized via a one-pot route at crystallization temperatures between 120 and 220 °C and applied to microwave-assisted catalytic pyrolysis of plastic waste at 500 °C under continuous operation. All materials preserved the MFI framework, while crystallization temperature strongly tuned secondary porosity and acidity; for example, the mesopore volume increased from 0.075 $cm^3\ g^{-1}$ (T-220) to 0.157 $cm^3\ g^{-1}$ (T-180). Catalyst lifetime was quantified using a TGA-defined gasoline fraction (≤200 ℃) of the condensed liquid as a product-relevant activity descriptor. The gasoline fraction decreased monotonically with time-on-stream for all catalysts, but with markedly different decay rates. T-120 showed the highest stability, maintaining gasoline yields above 70% for 6.83 h and still achieving 63.55% after 11 h, whereas catalysts synthesized at higher crystallization temperatures deactivated much faster, with T-200 and T-220 crossing the 70% threshold after only 2.36 and 3.16 h, respectively. Time-resolved product analysis further revealed that deactivation is accompanied by a strong decline in aromatic upgrading (e.g., BTX dropping from 38.3 to 4.0 wt% for T-140) and an increase in less-upgraded aliphatic fractions. These results demonstrate that controlling crystallization temperature offers a simple, scalable means to balance hierarchical porosity and acidity, thereby extending catalyst lifetime and improving liquid-fuel quality in plastic waste valorization.

A Study on Rapid Analysis of Pyrolysis Oil Using the High-resolution GC-MS and Blank Tube Field Ionization Method

Takaya Satoh ((JEOL Ltd.), Japan, Japan) Takao Fukudome ((JEOL Ltd.), Japan, Japan) Masaaki Ubukata ((JEOL Ltd.), Japan, Japan)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Pyrolysis oil derived from waste plastics is attracting significant attention as a sustainable feedstock for alternative fuels and recycled materials in the circular economy. However, conventional GC-MS analysis of pyrolysis oil is often complicated by the large number of hydrocarbon peaks, making both compositional characterization and impurity analysis time-consuming and difficult. In this study, a rapid analytical workflow combining the blank-tube FI method with Kendrick mass defect (KMD) analysis, high-resolution GC-TOFMS, and an unknown compound structural elucidation approach was developed using the JMS-T2000GC (JEOL). The blank-tube FI method enabled soft ionization detection of molecular ions with minimal fragmentation, while KMD plots visualized hydrocarbon distributions according to carbon number and unsaturation degree. High-resolution GC-TOFMS and unknown compound analysis further supported detailed characterization of impurity-related compounds. The method successfully classified hydrocarbon components into distinct groups originating from different polymer feedstocks, enabling rapid type analysis of pyrolysis oil. In addition, heteroatom-containing compounds such as oxygen-, nitrogen-, sulfur-, and phosphorus-containing species were clearly detected outside the hydrocarbon lattice on the KMD plot. These impurity-related components included compounds derived from PET, nitrile rubber, polyphenylene sulfide, and antioxidant additives. The combined workflow provided rapid preliminary information on both hydrocarbon type distribution and trace impurities simultaneously. The results demonstrate that this approach is highly effective for comprehensive characterization of pyrolysis oils, supporting quality assessment and feedstock evaluation for chemical recycling processes.

Chemical upcycling of waste plastics over metal–acid bifunctional catalysts

Xiao Chen (Dalian University of Technology, China) Changhai Liang (Dalian University of Technology, China)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

The resource utilization of waste polyolefin plastics is expected to be achieved through upgrading and reconstruction processes, but the primary scientific challenge lies in the development of efficient and cost-effective catalysts. In this paper, we present Ni nanoparticles supported on Nb2O5 with tunable acid sites (Ni/Nb2O5-T) as noble-metal-free catalysts for the upcycling of waste plastics. These catalysts efficiently facilitate a one-pot, solvent-free hydrogenolysis-isomerization of waste plastics, converting them into aromatic-free, highly branched alkane aviation fuels under mild conditions. Notably, the bifunctional Ni/Nb2O5-400 catalyst, characterized by highly dispersed metallic Ni sites and strong Brønsted acid sites, promotes key reactions such as hydrogenation/dehydrogenation, skeletal rearrangements, and β-scission of linear low-density polyethylene. This process achieves 100% conversion with a yield of over 80% for liquid products at 250 °C and 3 MPa H_2 for 4 hours. The carbon distribution of the resulting liquid fuels primarily ranges from C6 to C18, with 71% consisting of isoparaffins, highlighting them as promising candidates for aviation fuels. Additionally, the Ni/Nb2O5-400 catalyst exhibits versatile activity, delivering high yields of highly branched alkane aviation fuels through the chemical upcycling of various types of waste polyolefin plastics. A techno-economic analysis further confirms that this Ni-catalyzed plastic-to-fuel process offers significant economic advantages, underscoring its potential for industrial-scale implementation.

Pretreatment improving in-situ catalytic pyrolysis of plastic waste feedstocks

Hendrik Van Leuven (KU Leuven, Belgium) Brent Smeyers (KU Leuven, Belgium) Kseniia Vikanova (KU Leuven, Belgium) Bert Lagrain (KU Leuven, Belgium) Bert Sels (KU Leuven, Belgium)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

The rising volume of postconsumer plastic waste (PCW) necessitates recycling strategies capable of processing highly contaminated post-consumer feedstocks. direct feedstock-catalyst contact, or in-situ catalytic pyrolysis is a promising route to selectively convert PCW into valuable chemicals such as light olefins, naphtha or BTX fractions. However, catalyst deactivation caused by feedstock impurities (i.e., polymer sorting errors, (in)organic additives and use phase contaminants) remains a key challenge that needs to be addressed. From an in-house developed two-dimensional thermogravimetric analysis (2D-TGA) method, two promising catalysts are taken as model catalysts: an MFI zeolite catalyst and an amorphous silica alumina catalyst. Upon reaction with PCW feedstocks, both catalysts show high degrees of deactivation. In this work, a hydrothermal pretreatment strategy for sorted PCW waste mitigates deactivation from multilayer polymer contaminants including polyamides (PA) and polyethylene terephthalate (PET) as well as food residues and selected additives. Pretreatment using biphasic water/n-butanol mixtures, rather than water alone, significantly reduces the presence of catalyst-poisoning species due to hydrolysis/alcoholysis pathways. Removal of these impurities prior to catalytic conversion preserves acid catalyst activity and enhances process robustness. This impurity-focused pretreatment enables the direct catalytic valorisation of low-value post-consumer polyolefins and represents an important step toward scalable, resilient plastic recycling.

Catalytic pyrolysis of polystyrene over zeolite materials toward BTEC fraction production

Kseniia Vikanova (KU Leuven, Belgium) Michiel Aerts (KU Leuven, Belgium) Thomas Smits (KU Leuven, Belgium) Brent Smeyers (KU Leuven, Belgium) Sajan Sivanandan (KU Leuven, Belgium) Bert Sels (KU Leuven, Belgium)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

In this work, we present a systematic screening of 46 acidic zeolite catalysts with varying pore dimensionality for the catalytic pyrolysis of polystyrene. Initial activity trends were established through thermogravimetric analysis and subsequently validated at larger scale in a bench-scale semi-batch reactor to assess the effects of catalyst activity and stability on product formation. Comprehensive product distribution analysis studied by GC-MS/FID and GC-VUV methods, combined with detailed acidity characterization, enabled the establishment of clear structure–performance relationships. The results demonstrate that external acid sites govern the initiation of polystyrene degradation, while internal porosity and acid site distribution strongly influence product selectivity and coke formation. Zeolites with narrow pore channels exhibited slower deactivation and reduced coke yields, whereas three-dimensional frameworks promoted rapid coke accumulation due to their complex intersecting pore architectures.

Utilization of plastic waste-derived heavy hydrocarbons as steam cracking feedstock

Beatrix Csutorás (University of Pannonia, MOL Department of Hydrocarbon and Coal Processing, Veszprém,, Hungary) Katherin Dayana Suarez Macias (University of Pannonia, MOL Department of Hydrocarbon and Coal Processing, Veszprém,, Hungary) Norbert Miskolczi (University of Pannonia, MOL Department of Hydrocarbon and Coal Processing, Veszprém,, Hungary)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

Steam cracking is one of the key technologies for the production of light olefins, especially ethylene and propylene. The conventional feedstock for steam cracking is refinery-derived naphtha, characterized by a narrow boiling point range and strict quality specifications. In recent years, several studies have investigated the compatibility of sustainable sourced hydrocarbon fractions with existing technologies. This work focuses on the feasibility of heavy hydrocarbon fractions obtained from plastic waste pyrolysis as alternative feedstocks in bench-scale experiments. Waste plastic pyrolysis results hydrocarbons with high carbon numbers, as well, which can be characterized by high final boiling point, complex compositions and contaminants. Beside feedstock composition, operating parameters such as reaction temperature and steam-to-hydrocarbon ratio play a crucial role in product properties and coke formation. In this work, the effect of main process parameters using waste plastic derived hydrocarbons as steam cracker feedstock to the product yield and properties had been investigated.

Pyrolysis as the gateway thermochemical route for plastic-to-hydrogen-rich gas valorization

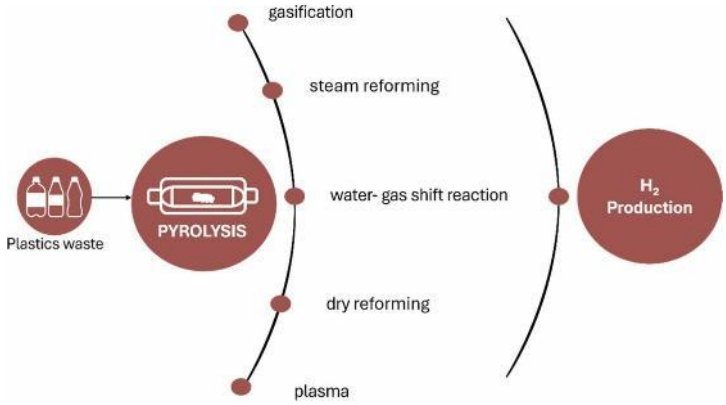
M. Alejandra Quintana (Department of Chemical Engineering, University of Granada, Spain) G. Garcia-Garcia (Department of Chemical Engineering, University of Granada, Spain) G. Blazquez (Department of Chemical Engineering, University of Granada, Spain) M.A. Martín-Lara (Department of Chemical Engineering, University of Granada, Spain) M. Calero (Department of Chemical Engineering, University of Granada, Spain) M.J. Muñoz-Batista (Department of Chemical Engineering, University of Granada, Spain)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

The rapid growth of plastic production has intensified environmental challenges, while conventional management routes such as recycling or incineration remain constrained by costs, emissions, and limited circularity. In this context, pyrolysis emerges as a key enabling step within multi-stage thermochemical routes for plastic conversion. This contribution critically assesses the role of pyrolysis as the primary platform for hydrogen-oriented valorization, highlighting its ability to convert diverse polymeric feedstocks into intermediate gas and liquid streams. The effects of operating parameters, including temperature, residence time, heating rate and particle size on product distribution are analyzed. Downstream upgrading strategies, such as gasification, catalytic and thermal reforming, water-gas shift reactions, and plasma-assisted processes, are described, emphasizing their synergistic contribution to enhancing hydrogen yield and purity. Thermal and catalytic pathways are comparatively analyzed, together with emerging integrated configurations. Finally, recent techno-economic and life-cycle assessments are examined to evaluate scalability, energy efficiency, and environmental performance. Overall, pyrolysis is positioned as a pivotal gateway step for sustainable hydrogen production from plastic waste within circular economy frameworks. [1] Journal of Analytical and Applied Pyrolysis 193 (2026) 107480



Pyrolysis of Multilayer Plastic Packaging to Yield Steam Cracking Feedstock

Miloš Auersvald (UCT Prague, Czechia) Vít Vyskočil (UCT Prague, Czechia) Petr Straka (UCT Prague, Czechia) Jaroslav Pátek (Enress a.s., Czechia)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

Multilayer plastic-containing packaging represents difficult-to-recycle waste streams. An example is the polyethylene (PE)–aluminum films present, e.g., in Tetra Pak® beverage cartons. These days, only paper is recycled from this waste. In this research, we studied the pyrolysis of beverage cartons under various conditions to produce hydrocarbon-rich feedstock suitable for the steam cracking process. This enabled increasing the valorization potential of this waste in line with the circular economy. During the conference, the results of this ongoing research will be presented. The following aspects will be discussed during the presentation: 1) The mass balance of the process, including the yield of gas, liquid, and solid product 2) The dependence of oil properties and composition on pyrolysis conditions 3) The oil quality comparison with the specifications for steam cracking feedstock

On the purification of tire pyrolysis oil using a lab-scale TRL-4 packed distillation column for limonene and BTEX recovery

David Royuela (Instituto de Carboquímica (ICB-CSIC), Spain) Juan Esteban Henao (Instituto de Carboquímica (ICB-CSIC), Spain) Juan Daniel Martinez Angel (Instituto de Carboquímica (ICB-CSIC), Spain) Alberto Veses (Instituto de Carboquímica (ICB-CSIC), Spain) José Manuel López (Instituto de Carboquímica (ICB-CSIC), Spain) María Soledad Callén (Instituto de Carboquímica (ICB-CSIC), Spain) Tomás García (Instituto de Carboquímica (ICB-CSIC), Spain) Ramón Murillo (Instituto de Carboquímica (ICB-CSIC), Spain)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

Tire pyrolysis oil (TPO) is one of the main products resulting from the pyrolysis of end-of-life tires (ELTs). Recently, this fraction has begun to play an important role as an alternative to petroleum-derived fractions, reducing the use of fossil resources in the petrochemical industry. This is because of the significant deployment of various pyrolysis technologies for both ELTs and plastic waste, which have reached the highest technology readiness level (TRL-9). Depending on the type of tire pyrolyze (passenger car or truck tire) and the conditions employed in the pyrolysis reactors, the TPO can contain significant amounts of limonene. Additionally, single aromatics such as benzene, toluene, ethylbenzene and xylenes (BTEX) are also commonly found it in the TPO. This study used a fully instrumented, laboratory-scale, TRL-4 packed distillation column equipped with a 1250 mm long wire mesh packing (approximately 40 theoretical plates) and a DN25 column diameter. The system features a 2 L removable glass flask equipped with electric heating and magnetic stirring. The distillation column was used to assess the effect of reflux ratio (0, 1 and 2) and different temperature cuts on limonene recovery. All tests were conducted using a TPO derived from an industrial-scale TRL-9 pyrolysis plant containing 3.6 wt% limonene and 5.2 wt% BTEX. Four temperature cuts were evaluated by setting the low cut at <150 °C and the high cut at >180 °C, while varying the low-middle and high-middle cuts between 150 °C and 180 °C, to maximize limonene recovery. The experimental results revealed a yield of 11 wt% for the high-middle cut (160-180 °C), which had the highest limonene concentration (26.4 wt%) among all the experiments performed. This cut accounted for over 80% of limonene recovery when the distillation column operated with a reflux ratio of 2. Under these conditions, the low-cut yield (<150 °C) was 14.1 wt%, resulting in a BTEX concentration of 31.6 wt%. Limonene is a valuable compound in the petrochemical industry with many uses. It is widely used as a solvent, cleaning agent, and dispersing agent. It is also a key ingredient in various pesticides and repellents. It can also be used as a precursor for plasticizers and adhesives. Similarly, BTEX is a valuable commodity with diverse applications in the plastics and polymers industry. The results of this study serve as a foundation for designing large-scale purification plants to meet the growing global demand for carbon-based chemicals and derivatives while sustainably utilizing waste.

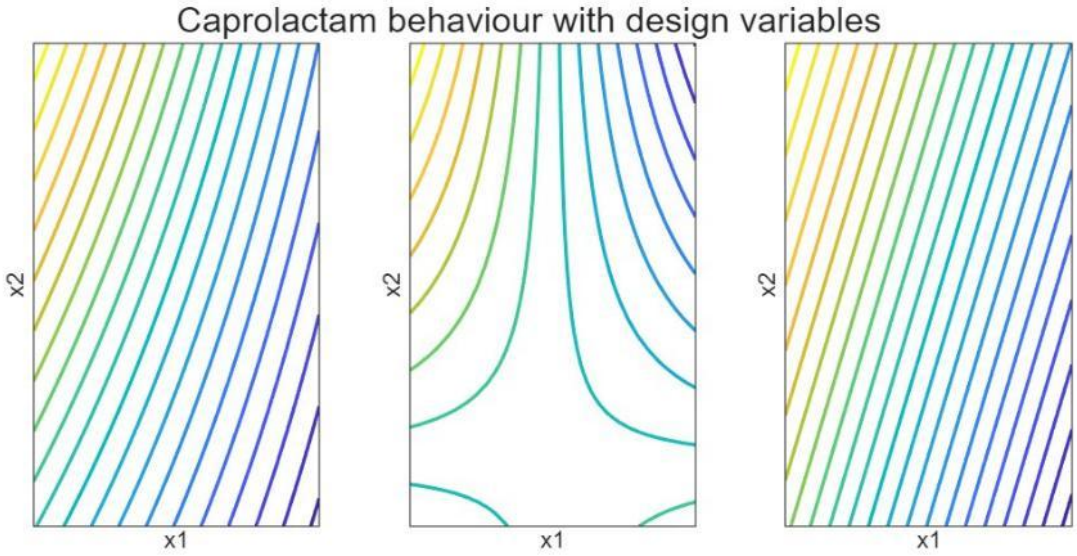
Pyrolysis of multilayer plastics: Optimising the process

Joona Lahtinen (VTT, Finland) Farhan Hashmi (VTT, Finland)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

In this study, the pyrolysis of multilayer plastics was investigated in a bench-scale fluidized bed reactor with the aim of optimising the process conditions for the recovery of valuable products, especially caprolactam. The effects of temperature, residence time, catalyst share and the of steam as carrier gas, were systematically studied. The influence of these parameters on product distribution and caprolactam yield was evaluated. The results show that process conditions have a significant impact on both the overall conversion and the selectivity towards target compounds. The findings provide practical insights for improving the efficiency of multilayer plastic recycling through pyrolysis and for supporting the development of more sustainable chemical recycling routes.



Steam Cracking of HDPE over different FCC Catalysts in a Fountain-Enhanced Conical Spouted Bed Reactor

Manomita Mollick (Department of Chemical Engineering, University of the Basque Country., Spain) Jon Alvarez (Department of Chemical and Environmental Engineering, University of the Basque Country, Spain) Maider Amutio (Department of Chemical Engineering, University of the Basque Country., Spain) Laura Santamaria (Department of Chemical Engineering, University of the Basque Country., Spain) Martin Olazar (Department of Chemical Engineering, University of the Basque Country., Spain) Gartzen Lopez (Department of Chemical Engineering, University of the Basque Country., Spain)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling

Location: Ground floor

ABSTRACT

This study assesses the catalytic steam cracking of plastic wastes as a valorization route for producing valuable chemicals and fuels. The work evaluates the application of a fountain confined conical spouted bed reactor (FCSBR) for the steam cracking of high-density polyethylene (HDPE) at 600–700 °C, while systematically examining the performance of three commercial fluid catalytic cracking (FCC) catalysts under these reaction conditions. The FCSBR represents an efficient configuration for plastic conversion, minimizing defluidization problems associated with fused polymers and ensuring stable operation at elevated temperatures [1]. The FCC catalysts differ in origin and pretreatment, enabling evaluation of the influence of catalyst condition on product distribution. One catalyst was collected from the purge stream at the outlet of the FCC unit regenerator at Petronor (Spain). The remaining two catalysts were supplied by Albemarle: one was used without pretreatment (fresh), whereas the other underwent severe steaming at 816 °C for 8 h following a procedure reported elsewhere [2]. This treatment alters catalyst composition through dealumination and modifies structural properties such as surface area, potentially affecting cracking pathways and selectivity toward light olefins and aromatics. HDPE pellets (4 mm) were supplied by Dow Chemical Company (Tarragona, Spain) with an average molecular weight of 46.2 kg mol^{-1}, polydispersity of 2.89, and density of 940 kg m^{-3}. The higher heating value (43 kJ kg^{-1}) was measured using a isoperibolic bomb calorimetry (Parr 1356). Experiments were conducted at 600, 650, and 700 °C with a bed containing 100 g of FCC catalyst (90–150 µm). Steam was fed at 2 mL min^{-1}, $^{-1}$, equivalent to 2.49 NL min^{-1} of steam. Products were analyzed online using an Agilent 7890 GC through a line maintained at 250 °C. Products were grouped into six fractions: CO and CO_2, hydrogen, light alkenes (C1–C4), light olefins (C2–C4), BTX (benzene, toluene, and xylenes), and a remaining liquid fraction composed of C5+ hydrocarbons (excluding BTX). The FCC catalysts exhibited high selectivity toward gasoline-range liquids and light olefins. At 600 °C, the liquid fraction predominated for both the steamed catalyst and the Petronor catalyst (36.2 and 38.2 wt%, respectively); however, increasing temperature shifted the primary product toward light olefins, reaching about 40 wt% at 650 °C.). Although the higher acidity of the fresh catalyst would suggest greater BTX yields, it showed the highest production at 600 °C (9.2 wt%) but lower yields at 700 °C (14.7 wt%) than the other catalysts due to dealumination at elevated temperatures and the resulting reduction in active sites. In addition to typical cracking products, CO and CO_2 were detected, reaching maximum yields of approximately 3 wt% at 700 °C for all catalysts, likely promoted by steam reforming reactions. [1] M. Mollick, L. Santamaria, Z. Wang, P. Comendador, M. Artetxe, E. Fernandez, M. Olazar, G. Lopez. Particuology, 103, pp 206-216, 2025. [2] T.F. Degnan, G.K. Chitnis, P.H. Schipper, Micropor. Mesopor. Mater. 35–36, pp 245-252, 2000.

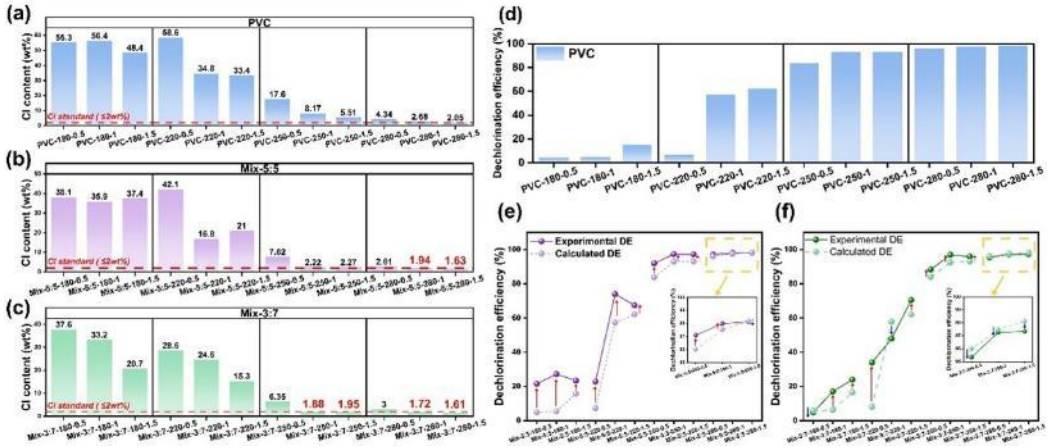
Synergistic Effects of Co-Hydrothermal Carbonization of PVC and Spent Coffee Grounds for Enhanced Dechlorination and Fuel Quality

Seungtaek Lee (Department of Environmental Engineering, University of Seoul, South Korea) Jai-Young Lee (Department of Environmental Engineering, University of Seoul, South Korea)

14:00-15:00 Session Posters P-S3F0: Applied pyrolysis: Polymers and recycling
Location: Ground floor

ABSTRACT

The increasing consumption of plastics has intensified challenges in plastic waste management, particularly for polyvinyl chloride (PVC), which contains a high chlorine content that leads to hydrogen chloride (HCl) release and toxic by-product formation during thermal treatment. Consequently, effective dechlorination pretreatment is essential for safe energy recovery and material valorization. Hydrothermal carbonization (HTC) has attracted attention as an alternative technology capable of dechlorinating PVC under subcritical water conditions, primarily through dehydrochlorination reactions that become pronounced above approximately 220 °C. However, when PVC is treated alone, sufficiently high dechlorination efficiency generally requires elevated reaction temperatures, limiting process efficiency and practical applicability. To overcome these limitations, co-hydrothermal carbonization (co-HTC) with biomass has been proposed, as biomass-derived organic compounds can promote dechlorination via substitution reactions under hydrothermal conditions. In this study, spent coffee grounds (CG) were employed as a co-feedstock due to their high organic content and favorable fuel properties. Co-HTC experiments were conducted in a 1 L batch reactor using PVC and CG mixed at mass ratios of 3:7 and 5:5, alongside single-feedstock HTC for comparison. Approximately 50 g of feedstock was reacted with distilled water at 180–280 °C for 0.5–1.5 h. After reaction, hydrochar was recovered and analyzed to evaluate hydrochar yield, chlorine content, and alkali and alkaline earth metal (AAEM) concentrations. In PVC-alone HTC, dechlorination was initiated at temperatures above 220 °C; however, the solid fuel chlorine standard (≤2 wt%) was not satisfied under most conditions. In contrast, co-HTC of PVC with CG resulted in a significant reduction in chlorine content at comparable temperatures, with higher CG mixing ratios leading to enhanced dechlorination efficiency (DE). Notably, experimentally obtained DE values exceeded theoretically calculated values based solely on the dilution effect, clearly demonstrating a synergistic effect arising from material interactions during co-HTC. This synergistic behavior was most pronounced at intermediate temperatures, whereas thermochemical reactions became dominant at higher temperatures. Additionally, experimental hydrochar yields under co-HTC conditions were consistently lower than calculated values, indicating non-additive behavior beyond simple dilution. The simultaneous reduction in hydrochar yield and enhancement in DE suggest that synergistic interactions—primarily substitution reactions on C–Cl bonds and HCl-induced acid catalysis—played a key role in promoting PVC dechlorination while facilitating AAEM removal. As a result, the co-HTC process produced hydrochar with reduced chlorine and AAEM contents, thereby improving solid recovered fuel (SRF) quality. Overall, these findings demonstrate that co-HTC of PVC and spent coffee grounds is an effective material recycling and recovery strategy for simultaneously valorizing chlorine-containing plastic waste and biomass through synergistic reaction pathways.



Catalytic pyrolysis of biomass using BECCS-derived ash: enhanced biochar yield, carbon retention, and process performance

Jiacheng Sun (UK Biochar Research Centre, University of Edinburgh, UK) Liang Wang (SINTEF, Norway) Ondrej Masek (UK Biochar Research Centre, University of Edinburgh, UK)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The performance of biomass pyrolysis is strongly governed by mineral matter and catalytic species, which influence thermal degradation pathways, product distribution, and solid carbon stabilisation. This study investigates the use of BECCS-derived ash as an in-situ catalytic additive during biomass pyrolysis, with a focus on enhancing biochar yield, carbon retention, and overall pyrolysis process efficiency. Co-pyrolysis experiments were conducted using agricultural residues blended with BECCS ash under controlled slow pyrolysis conditions. The presence of ash significantly altered devolatilisation behaviour and secondary char-forming reactions, promoting enhanced solid carbon formation. Compared to conventional pyrolysis, ash-assisted pyrolysis increased biochar carbon retention by 20.1–27.9% and produced biochars with carbon contents of 63.1–84.3% (dry ash-free basis). Thermochemical analysis indicates that alkaline and alkaline-earth metal species in the ash catalysed cracking, tar reforming, and gas-solid interactions, shifting reaction pathways toward increased char formation and reduced volatile carbon losses. In addition to improving solid product yields, the ash-assisted pyrolysis process demonstrated favourable impacts on reactor mass balance and process performance, with implications for optimising residence time, heating rate, and additive loading. The resulting biochars exhibited properties suitable for long-term carbon storage and downstream applications. These results demonstrate that BECCS-derived ash can function as a low-cost, circular catalytic material for process-intensified biomass pyrolysis, linking waste mineral streams with enhanced thermochemical conversion performance. This work highlights a new route for coupling carbon capture residues with advanced pyrolysis systems to improve biochar production efficiency and carbon stabilisation in thermal biomass conversion.

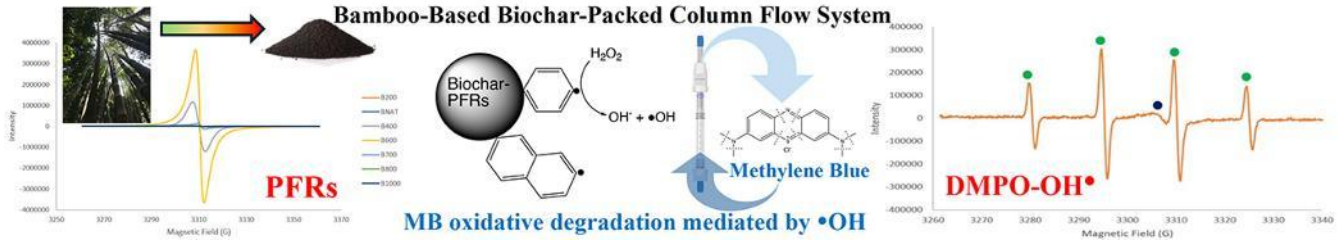
Tuning Pyrolysis Temperature to Engineer Bamboo Biochar for Laccase Immobilisation and Water Treatment

Omar Ginoble Pandoli (Pharmacy department, University of Genoa, Italy) Alessandro Pellis (Department of Chemistry and Industrial Chemistry (DCIC), University of Genoa, Italy) Lizet Marlen Moreno Pascual (Department of Chemistry and Industrial Chemistry (DCIC), University of Genoa, Italy) Myleidi Vera Otero (University of Concepcion, Chile., Chile) Yadiris Garcia Almanza (University of Concepcion, Chile)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Biomass derived materials are emerging as sustainable and cost effective platforms for water remediation. In this work, bamboo based biochars (BBs) were produced via fast and slow pyrolysis at temperatures ranging from 300 to 1000 °C under N_2 and CO_2 atmospheres and subsequently evaluated as carriers for laccase immobilisation. The resulting enzyme functionalised BBs were integrated into a packed column flow system to investigate their performance in removing organic pollutants through combined adsorption and catalytic oxidation. The removal efficiency was found to depend strongly on both the concentration of carbon centred persistent free radicals (PFRs) within the BB (10^{16}–10^{19} spins g^{-1}, quantified by electron paramagnetic resonance, EPR) and the redox activity of immobilised laccase. Experiments conducted with and without oxygen purging demonstrated the crucial role of dissolved oxygen in generating reactive oxygen species (ROS), particularly hydroxyl radicals (•OH), and in promoting laccase mediated oxidation in the absence of chemical mediators. Using a newly developed BB packed flow system, we quantified the removal efficiency (R%) of organic polluntans under controlled oxygenation conditions. The results reveal a synergistic mechanism in which PFR driven radical generation and laccase redox catalysis act cooperatively, enabling an advanced oxidation process (AOP) without the need for external chemical oxidants. This work highlights the potential of engineered bamboo based biochars as multifunctional catalytic materials for sustainable water treatment and points toward the development of greener AOP technologies with reduced operational costs and environmental impact.



References:

1. O. Ginoble Pandoli, "Permanent free radicals in bamboo biochar-based flow bed reactor: a sustainable solution for dye degradation via adsorption and radical oxidation", Catal. Sci. Technol., 15, 20, (2025): 10.1039/D5CY00632E. 2. O. G. Pandoli, "Pivotal Contribution of EPR-Characterized Persistent Free Radicals in the Methylene Blue Removal by a Bamboo-Based Biochar-Packed Column Flow System", ChemCatChem, 16, 21, (2024): https://doi.org/10.1002/cctc.202401042. 3. S. Riva et al., Biocatalysis with Laccases: An Updated Overview Catalysts 2021, 11, 26. https://doi.org/10.3390/

Spent coffee biochar contained poly(dimethylsiloxane) composites as membranes for gas separation

Rebecca Di Salvo (Politecnico di Torino, Italy) Mattia Bartoli (Istituto Italiano di Tecnologia, Italy) Giuseppe Ferraro (Politecnico di Torino, Italy) Valeria Agostino (Istituto Italiano di Tecnologia, Italy) Giulia Giordano (Politecnico di Torino, Italy) Sergio Bocchini (Politecnico di Torino, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Coffee grounds are largely available under-valorised biowaste stream with significant potential for conversion into functional carbonaceous materials through pyrolysis. Among the products of thermal decomposition, biochar is particularly attractive due to its structure and surface chemistry that can be tailored by tuning process conditions, enabling their use as functional building blocks in advanced materials. Coffee-derived biochar was obtained by pyrolysis at 550 °C in a tubular furnace with a heating rate of 15 °C/min to preserve the surface textures. Coffee biochar was integrated into a silicon elastomer matrix via solvent-free route. Commercial polydimethylsiloxane (PDMS) and its curing agent were mixed with the biochar to prepare three formulations: neat PDMS (0 wt% filler) and composites containing 10 wt% and 20 wt% biochar. The mixtures were cast on glass and cured for 24 h at room temperature to obtain free-standing films. This solvent-free approach was selected to minimise potential alteration of the char surface and to demonstrate the feasibility of translating pyrolysis-derived solids into functional composite materials with minimal post-processing. Gas-material interactions were investigated using dynamic vapour sorption as an analytical screening tool. Measurements were performed at 40 °C under stepwise relative partial pressures (p/p0 = 0.2, 0.4, 0.6, 0.8) for N2, H2, CO2, and CH4, enabling consistent comparisons across gases and compositions. This protocol provides insight into gas-dependent uptake behaviour and into how biochar loading influences gas-material interactions in a rubbery polymer matrix, thereby informing subsequent separation-relevant evaluation. Overall, the study highlights pyrolysis as an enabling technology for transforming coffee waste into a functional solid that can be directly leveraged in composite materials. The work illustrates a practical route from biowaste to new materials and supports the potential of coffee-biochar as building blocks for composites-based membranes.

Biowaste Valorization Using a Pilot Scale Continuous Pyrolysis Unit within the ENREGAT Large Research Infrastructure

Barbora Grycová (Vysoká škola báňská - Technická univerzita Ostrava, CEET, IET, Czechia) Lucie Obalová (Vysoká škola báňská - Technická univerzita Ostrava, CEET, IET, Czechia) Kateřina Klemencová (Vysoká škola báňská - Technická univerzita Ostrava, CEET, IET, Czechia) Pavel Leštinský (Vysoká škola báňská - Technická univerzita Ostrava, CEET, IET, Czechia)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Sustainable management of biowaste plays a crucial role in reducing environmental impacts, improving soil quality, and supporting long-term carbon sequestration. Pelletized rhizomes of Miscanthus × giganteus were processed into biochar using a pilot scale continuous pyrolysis unit within the ENREGAT large research infrastructure. The pyrolysis was carried out at 600 °C with a feed rate of 2.1 kg h^{-1} and a residence time of 1 h under an argon atmosphere. The produced biochar was subsequently applied to soil, illustrating a closed-loop approach. ENREGAT provides a comprehensive platform for both fundamental and applied research focused on waste valorization and resource recovery. In the area of thermochemical processes, this includes conventional and microwave reactors operating at different scales, supported by a strong analytical background allowing detailed characterization of input materials, process performance, and resulting products. In addition, ENREGAT serves as a unique base for research on combustion, anaerobic digestion, catalytic, sorption, and photocatalytic gas cleaning and membrane-based separation. ENREGAT operates under a free open access policy, promoting research with high industrial relevance. To date, more than 600 projects from universities and institutions within the Academies of Sciences worldwide have been granted open access status. Acknowledgment: Financial support from MEYS, project No. LM2023056 is acknowledged.

Novel activated bonechar prepared by microwave pyrolysis of waste animal bones for xylene adsorption from air

Zuzana Jankovská (Institute of Environmental Technology, CEET, VSB–Technical University of Ostrava, Czechia) Pavlína Peikertová (Nanotechnology Centre, CEET, VSB-Technical University of Ostrava, Czechia) Jonáš Tokarský (Department of Thermal Engineering, FMT, VSB–Technical University of Ostrava, Czechia) Lenka Matějová (Institute of Environmental Technology, CEET, VSB–Technical University of Ostrava, Czechia)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

This study presents the first reported preparation and evaluation of bonechar and activated bonechar derived from waste animal bones for the adsorption of xylene from waste gas streams. To enhance their adsorption performance, the activated bonechar were chemically activated using K_2CO_3, H_3PO_4 and KOH under optimised microwave-assisted pyrolysis conditions. Microwave pyrolysis of waste animal bones, performed without chemical activation, showed no clear correlation between the applied microwave power levels and the development of the porous structure. The materials exhibited meso- and macroporous structure, but no significant microporosity. Activated bonechar with K_2CO_3 shows improved porous structure made by micro-, meso- and macropores. The meso- and macropores dominate the total pore volume, significantly contributing to the increased surface area. The treatment with H_3PO_4 and KOH resulted in the formation of meso- and macroporous activated bonechar structures with no micropores. In the case of H_3PO_4, the acid reacts with the inorganic salt matrix, disrupting the original layered arrangement of hydroxyapatite and $CaCO_3$. This reaction yields randomly deposited $CaHPO_4$ particles within the disintegrated matrix, forming predominantly mesopores. Similarly, activation with KOH induces structural modifications within the hydroxyapatite matrix, reducing the surface area and total pore volume. Of all the textural and structural parameters and surface functional groups investigated, the key factors influencing xylene adsorption performance were identified as a combination of total pore volume, specific surface area, fixed carbon content, graphitization and metal cation content. These results highlight the potential of activated bonechar as a sustainable, low-cost adsorbent for removing VOCs, contributing to the fulfilling of demands of circular economy. Funding: The work was supported by the OP JAK project "INOVO!!!", No. CZ.02.01.01/00/23_021/0008588 supported by the Ministry of Education, Youth and Sports and co-financed by the European Union. Experimental results were accomplished by using Large Research Infrastructure ENREGAT supported by the Ministry of Education, Youth and Sports of the Czech Republic under projects no. LM2018098 and LM2023056.

Iron tailored biochar for waterborne bacteriar treatment

Israr Ahmed Memon (US Pakistan Center for Advanced Studies in Water, Pakistan) Najeebullah Channa (Politecnico di Torino, Pakistan) Tanveer A. Gadhi (US Pakistan Center for Advanced Studies in Water, Pakistan) Mauro Giorcelli (Politecnico di Torino, Italy) Mattia Bartoli (Fondazione Istituto Italiano di Tecnologia, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Water treatment represent one of the key applications of biochar. Nowadays, it is generally limited to the removal of pollutants such as organic and inorganic contaminants. Nevertheless, the biochar surface tailoring can open the way to advance applications including bacterial removal. In this work, we functionalized the biochar through carbothermal reduction process creating a iron tailored material for promoting the bacterial removal. The antibacterial activity of biochar was evaluated against two common waterborne pathogenic bacteria, E. coli and S. aureus, using an initial bacterial concentration of approximately log 3 CFU/mL, two biochar dosages (1.5 g/L and 2.0 g/L) were tested. Preliminary assessments were conducted on solid agar media, where the highest inhibition zones were observed at a dosage of 2.0 g/L, measuring (20.5 ± 6.3) mm for E. coli and (15.2 ± 1.0) mm for S. aureus. Furthermore, antibacterial efficacy was examined in liquid suspension. The results demonstrated complete reduction (100%) of E. coli and a 98% reduction of S. aureus at the 2.0 g/L dosage. This work represent a first approach of potabilization of water using biochar as antimicrobial agent.

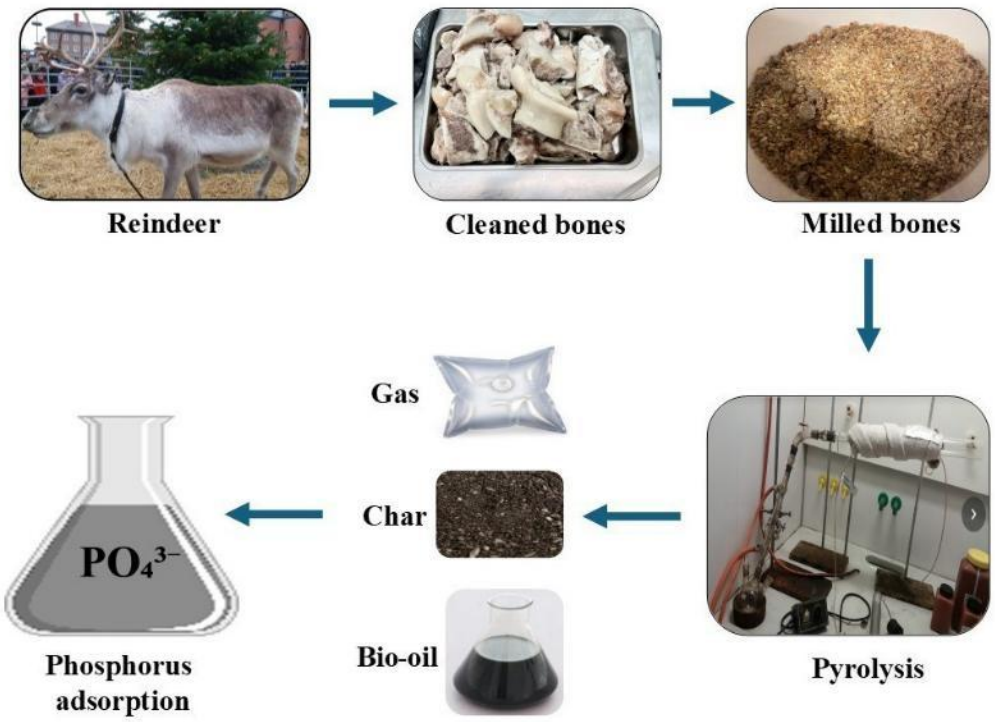
Valorisation of reindeer bone via pyrolysis: Product distribution and characterisation for environmental applications

Premchand Premchand (Swedish University of Agricultural Sciences, Sweden) David A. Agar (Swedish University of Agricultural Sciences, Sweden)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Pyrolysis of biogenic waste streams is an important strategy for producing sustainable materials and managing circular resources. Livestock bones are a particularly interesting pyrolysis feedstock due to their distinct organic-mineral composition, which is dominated by collagen and calcium phosphate phases. This unique composition can produce mineral-rich chars with potential environmental functionality, as well as hydrocarbon-rich bio-oil and gaseous products due to the presence of fat. This study examines reindeer (Rangifer tarandus fennicus) bones, an underutilised regional waste resource in Nordic regions, through controlled slow pyrolysis to assess the impact of pyrolysis temperature on product yields, material properties, and potential valorisation pathways, particularly focusing on pyrolytic char as a functional material for wastewater treatment. Pyrolysis experiments were carried out using a laboratory fixed-bed reactor in an inert atmosphere at three different temperatures: 350, 500, and 650 °C for 30 minutes. The products yield (solid, liquid, and gas) was quantified by applying mass balance calculations across the system. The compositions of liquid and gaseous products were analysed using gas chromatography/mass spectrometry and micro gas chromatography. Characterisation methods used on chars included Fourier transform infrared (FT-IR) spectroscopy, suspension pH, point of zero charge (PZC) measurements, and elemental analysis. Preliminary phosphorus adsorption experiments were performed using produced chars to demonstrate their environmental valorisation potential. Initial results indicate that pyrolysis temperature strongly affects the distributions of products and their properties. The solid char fraction dominated the product distribution at all pyrolysis temperatures ranging from 74 % at 350 °C to 53 % at 650 °C. Analyses of chars showed alkaline behaviour, with pH increasing from 7.7 to 11.0 as pyrolysis temperature increased due to the increasing inorganic (ash) fraction of the char. Subsequently, the PZC shifted toward higher values (7.8 to 11.3), indicating progressively more positively charged surfaces under neutral conditions. FT-IR analysis showed that increasing pyrolysis temperature progressively removes collagen-derived functional groups and enriches calcium phosphate mineral phases, leading to increasingly inorganic, apatite-dominated char surfaces as evidenced by increased pH and PZC. Batch adsorption experiments revealed that chars from pyrolysis at 500 °C performed best, removing 57% of orthophosphate from water, which may be attributed to an optimal balance between surface charge, mineral exposure, and solution pH. This study contributes to the growing body of applied pyrolysis research focusing on product characterisation and environmental value by linking pyrolysis conditions to product yields, char characteristics, and functional performance and the findings serve as a foundation for future optimisation of bone-derived chars for wastewater treatment and resource recovery applications.



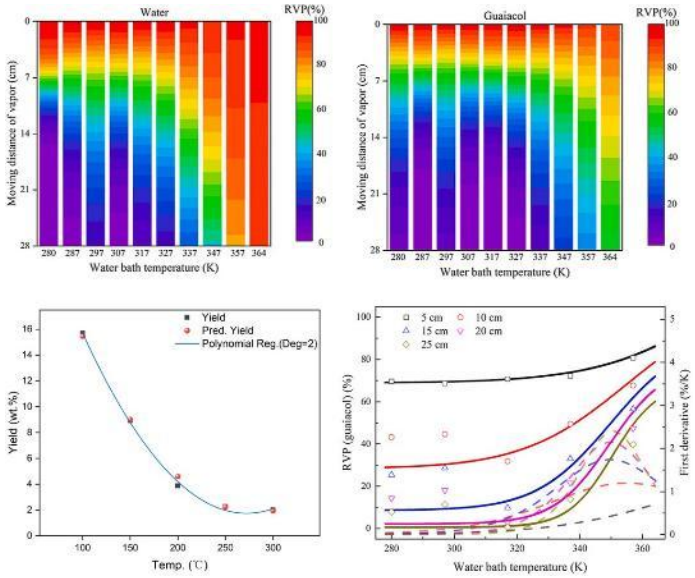
Selective Condensation Behavior of Biomass Pyrolysis Vapors at Wide Condensation Temperatures: Component Evolution, Prediction, and Validation

Wentao Ge (Dalian University of Technology, China) Yulin Wang (Dalian University of Technology, China) Haorui Ni (Dalian University of Technology, China) Lin Mu (Dalian University of Technology, China) Ming Dong (Dalian University of Technology, China) Liang Wang (Stiftelsen for industriell og teknisk forskning, SINTEF, Norway) Chu Wang (Dalian University of Technology, China)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Selective vapors condensation is a critical technology for producing high-quality bio-oil from biomass pyrolysis. Existing research has largely been confined to low-to-medium condensation temperature ranges, limiting its applicability for process optimization across wider temperature spans. This study systematically investigates the selective condensation behaviors of biomass pyrolysis vapors over an extended temperature range of 280–573 K. An integrated approach, combining fractional condensation recovery, vapor-composition inversion through functional fitting, and data-driven machine learning, was employed to systematically investigate the condensation characteristics and yield distributions of key bio-oil constituents, specifically water and phenolic compounds. Experimental results indicate that increasing the condensation temperature from 280 K to 337 K facilitates a 50% recovery of the aqueous phase, albeit with a concomitant increase in condensation residence time. In contrast, an equivalent recovery of guaiacol was achieved within a significantly shorter duration. Within the 280–364 K range, while the Logistic function exhibited a localized prediction accuracy below 50%, it maintained a robust global predictive accuracy of approximately 70% for representative components. Under small-sample constraints, a second-order polynomial regression model demonstrated superior performance, showing excellent alignment with experimental yields, with minimal deviations of -1.47% at 100 °C and -1.21% at 250 °C. This study establishes a comprehensive component-evolution profile and a predictive framework for the selective condensation of biomass pyrolysis vapors across a wide temperature range. These findings offer critical theoretical insights and technical benchmarks for optimizing cross-temperature selective condensation processes, thereby advancing the efficient production of high-quality bio-oil. Graphical abstract: heat maps of representative components & prediction and validation curves for AI and the logistic function.



References: [1] Vilas-Boas ACM, Tarelho LAC, Marques CC, Moura JMO, Santos MC, Paradela F, et al. Improving bio-oil fractions through fractional condensation of pyrolysis vapors from Eucalyptus globulus biomass residues in a prototype auger reactor. J Anal Appl Pyrol. 2025;192:107329. [2] Li L, Luo Z, Miao F, Du L, Wang K. Prediction of product yields from lignocellulosic biomass pyrolysis based on gaussian process regression. J Anal Appl Pyrol. 2024;177:106295. [3] Chai S, Kang BS, Valizadeh B, Valizadeh S, Hong J, Jae J, et al. Fractional condensation of bio-oil vapors from pyrolysis of various sawdust wastes in a bench-scale bubbling fluidized bed reactor. Chemosphere. 2024;350:141121. [4] Akinpelu DA, Adekoya OA, Oladoye PO, Ogbaga CC, Okolie JA. Machine learning applications in biomass pyrolysis: From biorefinery to end-of-life product management. Digital Chemical Engineering. 2023;8:100103. [5] Zhang Y, Liang Y, Li S, Yuan Y, Zhang D, Wu Y, et al. A review of biomass pyrolysis gas: Forming mechanisms, influencing parameters, and product application upgrades. Fuel. 2023;347:128461. [6] Wang C, Diao R, Luo Z, Zhu X. Study on the influence of residence time on the componential evolution of biomass pyrolysis vapors during indirect heat exchange process through a combining method of bio-oil composition inversion and function fitting. Applications in Energy and Combustion Science. 2022;9:100047.

Effect of pyrolysis temperature on the Cristal Violet adsorption performance of ball-milled functionalized biochar

Corinna Maria Grottola (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Paola Giudicianni (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Raffaele Ragucci (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Giuliana Gorrasi (Department of Industrial Engineering, University of Salerno, Italy, Italy) Elena Lamberti (Department of Industrial Engineering, University of Salerno, Italy, Italy) Gianluca Viscusi (Department of Industrial Engineering, University of Salerno, Italy, Italy) Maria Rosaria Acocella (Department of Chemistry and Biology "A. Zambelli", INSTM Research Unit, University of Salerno, Italy, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Crystal Violet (CV), a cationic dye belonging to the triarylmethane family, is primarily used in the textile industry, printing processes, and inks due to its strong tinting power and high chemical stability. However, CV is toxic and highly water-soluble, a property facilitated by its cationic groups ($-N^{+}(CH_3)_2$), which allows for easy dispersion in aqueous environments. Increasing attention has been given to biochar as a promising, sustainable strategy capable of removing organic and inorganic pollutants from water bodies [1], making it a viable and cost-effective solution also for CV removal. By acting on the pyrolysis conditions, depending on the initial feedstock composition, it is possible to direct the process toward conditions producing biochar with properties effective for dye removal, such as well-developed porosity and the presence of active functional groups (e.g., carboxyl, hydroxyl, aromatic rings). To improve the biochar performance as an adsorbent, ball milling stands out as a mechanical approach able to modify the structure and the chemical functionalities of biochar by reducing particle size, increasing the BET surface, and introducing oxidized functional groups on the biochar surface, thereby enhancing the overall adsorption performance of the biochar [2]. In this study, we provide a novel and systematic investigation of the combined effect of pyrolysis temperature and ball milling on the physicochemical properties of biochar relevant for CV adsorption. Wheat straw was selected as the feedstock, as it represents an abundant agricultural residue whose valorization into high-value biochar aligns with circular economy principles and promotes the sustainable recycling of biomass waste. The performance of wheat straw-derived biochar, produced via slow pyrolysis at temperatures ranging from 360 to 600°C, is evaluated and compared before and after ball milling for its ability to remove different concentrations of CV from aqueous solutions. Overall, ball milling significantly improves the adsorption performance primarily by accelerating the adsorption kinetics, with the most pronounced benefit observed at intermediate temperature (450°C), where the milled biochar achieves near-complete dye removal within a few hours, demonstrating the highest performance in adsorption.

Effect of blends of hydrochar and straw during co-pyrolysis for biochar production

Corinna Maria Grottola (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Francesca Di Lauro (DICMAPI, University of Naples Federico II, Italy, Italy) Giusy Marotta (Department of Chemical Sciences, University of Naples Federico II, Italy, Italy) Davide Amato (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Marco Balsamo (Department of Chemical Sciences, University of Naples Federico II, Italy, Italy) Fabio Montagnaro (Department of Chemical Sciences, University of Naples Federico II, Italy, Italy) Roberto Solimene (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Paola Giudicianni (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy) Raffaele Ragucci (Institute of Sciences and Technologies for Sustainable Energy and Mobility - CNR, Italy, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

A circular economy could increase the efficiency of bio-resource use and improve bio-waste handling practices. Considering lignocellulosic plant residues from agriculture and manure as the most abundant and inexpensive feedstock for the biorefinery model in agriculture, a valuable approach could be the integration of different processes aimed at biofuel, biomaterial, and chemical production. Hydrothermal liquefaction (HTL) process is considered a viable thermochemical route to convert high-water-content biomasses in a liquid energy vector (biocrude). In fact, in HTL conditions (200–374°C and 40–200 bar), water acts as a catalyst, reactant, and thermal flywheel, and thus the biomass organic components can be directly converted without a drying step. While biocrude oil can be upgraded to bio-fuels for liquid transport and as a source of other chemical products, there is still considerable uncertainty for the carbon solid residue from HTL, the hydrochar (HC). HC is not under regulation for its use as a soil amendment, but its transformation into biochar could be a valuable route for a safe and standard application [1]. Nowadays, biochar is gaining ever greater recognition as a material with valuable applications in several fields, ranging from soil improvement and carbon sequestration to bio-based material for soil/water remediation, energy production, or filler as composite materials [2]. This study is focused on the exploitation of digestate through the HTL process for biocrude production and co-pyrolysis of HC and straw (S), lignocellulosic biomass representative of agricultural waste, to obtain the biochar and evaluate its properties. HTL of digestate will be performed in a 500 mL batch autoclave reactor, to study the yield and properties of the biocrude produced at different temperatures (300 and 350°C) and isothermal reaction times (0–30 min) [3]. Co-Pyrolysis of blends composed by different ratios of S and HC will be tested for biochar production, and the volatile phase will be explored as an energy vector to sustain the whole process. Preliminary results on biochar produced at a pyrolysis temperature of 450°C showed that the yields, for blends ranging from S90%-HC10% to S50%-HC50%, are in the range of 42.8–62.9 wt%. The corresponding biochars produced have respectively 28.3 to 51.66% ash content, whereas the H/C values are in the range 0.68 to 0.61. Both ranges of values are within the threshold limits reported in Regulation (EU) 2019/1009 for fertilizers and specified in detail in the Italian regulation (D. Lgs. 75/10, all. 2) that include biochar in their agricultural and environmental frameworks.

Wood Cell Wall Ultrastructure Investigated via Hydrolyzable Sugars in Char and TG-MS Analysis

Haruo Kawamoto (Kyoto university, Japan) Yu Wang (Kyoto university, Japan) Daijiro Taira (Kyoto university, Japan) Ramadan Eljamalra (Kyoto university, Japan) Eiji Minami (Kyoto university, Japan)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Woody biomass such as wood and herbaceous plants is composed of cells with cell walls. These cell walls exhibit a nanostructured assembly in which cellulose microfibrils—having a cross-sectional size on the nanometer scale—are embedded in a matrix of hemicelluloses (xylan and glucomannan) and lignin. Our research group has been investigating the supramolecular structure of wood cell walls by analyzing the thermal degradation behavior of their constituent polymers. In this presentation, we will introduce our recent findings. Within the cell wall, molecular mobility is restricted, leading to pyrolytic reactivities that differ from those of isolated components. For instance, hemicelluloses such as xylan exhibit greater thermal stability within the cell wall than in their isolated forms. Although isolated xylan with uronic acid groups decomposes at lower temperatures than glucomannan, this difference in reactivity is significantly reduced in the native cell wall. The pyrolytic reactivity of these wood polysaccharides can be assessed by measuring the yield of hydrolyzable sugars obtained from hydrolysis of the pyrolysis char. While no reliable method had previously existed for evaluating the pyrolytic behavior of lignin in the cell wall, we have developed a TG–MS-based approach that enables such evaluation, allowing us to assess the reactivity of cellulose, hemicellulose, and lignin during wood pyrolysis. Using this approach, we evaluated the pyrolytic behavior of five softwood and five hardwood species. The results revealed species-specific differences; however, when using samples in which the exchangeable cations—present as salts of xylan's uronic acid groups—were replaced with only one type of cation, either an alkali metal (Na^+, K^+) or an alkaline earth metal (Mg^{2+}, Ca^{2+}), we found that the thermal degradation behavior of the components was determined solely by the cation species, irrespective of tree species. Notably, we discovered that these cations, although associated with xylan, primarily influenced the pyrolytic reactivity of glucomannan and cellulose, rather than xylan itself. In particular, cellulose decomposed at temperatures approximately 30 °C lower in the presence of Na^+ and K^+ compared to Mg^{2+} and Ca^{2+}. Interestingly, lignin was found to degrade in synchrony with cellulose at this lower temperature. These findings led us to propose a novel supramolecular structure in which cellulose and lignin are closely associated.

Study on the Recovery Method for Lacquer films in Epoxy Resin-Embedded Samples for Stratified Analysis by Py-GC/MS

Kanta Tsubouchi (Graduate School of Science and Technology, Meiji University, Japan) Takayuki Honda (School of Science and Technology, Meiji University, Japan)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Many cultural heritage items utilize lacquer, a natural polymer material. The tree species used for lacquer are primarily classified into three types: Toxicodendron vernicifluum, found in Japan, the mountainous regions of southern China, and Korea; Toxicodendron succedaneum, found in the coastal areas of southern China and Vietnam; and Gluta usitata, found in Thailand and Myanmar. While the main components and chemical compositions of these species differ by region of origin, their molecular structures are similar to each other. Therefore, identification methods using Py-GC/MS (Pyrolysis Gas Chromatography/Mass Spectrometry), which focuses on pyrolysis products specific to each species, have been effectively utilized as an analytical tool. However, conventional Py-GC/MS analysis involves cutting samples vertically for sampling, making it difficult to individually identify materials in each layer of multi-layered cultural properties. In contrast, a method involving interlayer delamination by gradually shaving small amounts from the sample surface to obtain material information per layer has been explored. However, problems such as sample disintegration during delamination have prevented its practical implementation. Therefore, in previous studies, the identification of lacquer tree species for each layer has primarily been performed using non-destructive methods, mainly IR analysis [1]. On the other hand, specimens embedded in epoxy resin for the purpose of cross-sectional observation of cultural heritage often have unused portions remaining that are not used for observation. These embedded specimens, reinforced by the epoxy resin, potentially allow for easier collection of micro-samples from each layer. However, analyzing microfragments collected from embedded specimens using Py-GC/MS presents a challenge: pyrolysis products derived from the epoxy resin are detected, interfering with the measurement results. Therefore, this study focused on existing research [2] that recovered carbon fibers embedded in epoxy resin and investigated a method to selectively decompose only the epoxy resin used to embed the specimens. Establishing this method would enable Py-GC/MS analysis of embedded samples, potentially yielding information on organic materials aligned with the coating's layered structure (Figure (a)). This is expected to enable more detailed and reliable tree species identification and material characterization based on Py-GC/MS, complementing conventional layer analysis using IR spectroscopy. In this study, we attempted to recover lacquer coatings (approximately 10 mg) embedded in epoxy resin by decomposing the epoxy resin using NaOH in a DMI solvent. As a result, we successfully decomposed only the epoxy resin and recovered the lacquer coating as a black precipitate. Analysis of the recovered precipitate by Py-GC/MS detected biomarkers derived from Toxicodendron vernicifluum, confirming the selective recovery and detection of the lacquer coating (Figure (b)). Furthermore, considering practical application to cultural property analysis, we also investigated micro-scale sample collection, resin decomposition, and lacquer coating recovery, which are reported here. [1] Nguyen, T. H. et al. Comprehensive multi-analytical investigations on the Vietnamese lacquered wall-panel “The Return of the Hunters”. Scientific Reports, (2019) 9, 17003. [2]Yasunori Minami et al. Degradation of stable thermosetting epoxy resins mediated by bases in amide solvents. Polymer Journal, (2025) 57, 149–162.

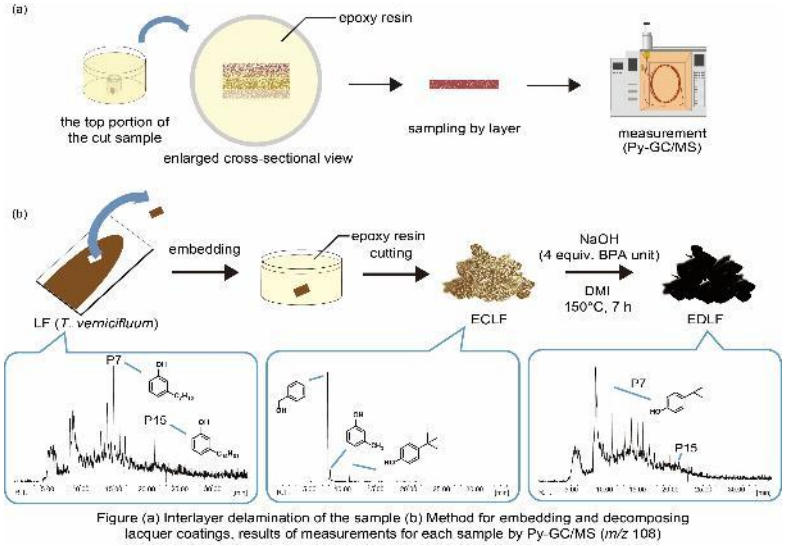


Figure (a) Interlayer delamination of the sample (b) Method for embedding and decomposing lacquer coatings, results of measurements for each sample by Py-GC/MS (*m/z* 108)

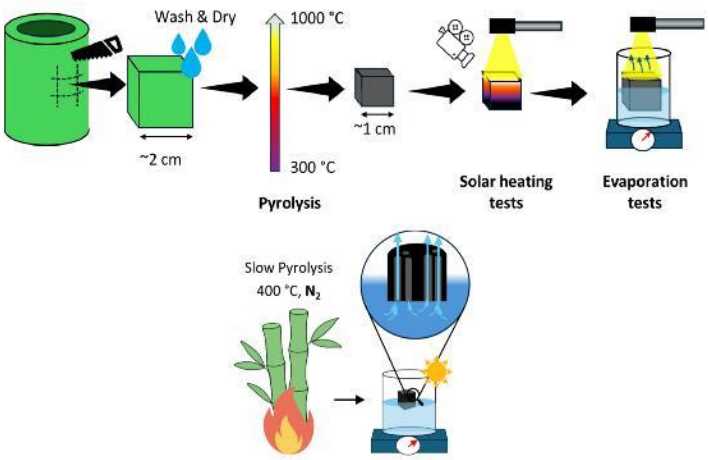
Untreated Pyrolysed 3D Bamboo as a Solar Steam Generation Device

Andrea Lanfranchi (Dipartimento di Chimica e Chimica Industriale, Università degli Studi di Genova,, Italy) Agnese Bausano (Università Genova, Italy) Davide Comoretto (Dipartimento di Chimica e Chimica Industriale, Università degli Studi di Genova,, Italy) Renata Lorenzoni (Bundesanstalt für Materialforschung und prüfung (BAM), Germany) Paola Lova (Dipartimento di Chimica e Chimica Industriale, Università degli Studi di Genova,, Italy) Omar Ginoble Pandoli (Pharmacy department, University of Genoa, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The growing global demand for clean water has intensified interest in sustainable technologies for desalination and wastewater purification. Among these, Solar Steam Generation (SSG) has emerged as a promising passive approach due to its low energy requirements, minimal carbon footprint, and ability to operate without fossil fuels. A key challenge in advancing SSG lies in identifying scalable, low-cost, and environmentally materials capable of efficiently converting solar energy into heat. Interfacial solar steam generation (ISSG), particularly when employing bio-derived carbon materials, offers significant advantages such as localized heating, enhanced evaporation rates, and compatibility with low-resource settings. In this study, we present a simple, sustainable ISSG device fabricated from untreated bamboo through low-temperature slow pyrolysis. Bamboo is an abundant, low-cost, and renewable biomass resource, making it particularly suitable for freshwater-stressed regions and low-income communities. Building on our previous investigations of bamboo's electric, electrochemical, and paramagnetic properties across a broad pyrolysis range (200–1000 °C), we examined how controlled thermal treatment between 300 and 1000 °C affects the photothermal performance of monolithic bamboo-derived carbon under simulated solar irradiation [1-2]. The fabrication route, schematically shown here, preserves the intrinsic hierarchical architecture of bamboo—including microchannels, parenchymatic cell arrays, and interconnected porosity—while converting the native lignocellulose matrix into a black monolithic carbon [3]. Pyrolysis temperature and residence time were found to be critical in tuning key physicochemical parameters such as porosity, hydrophilicity, microchannel integrity, degree of graphitization, and thermal and electrical conductivities. Among all investigated samples, the monolith pyrolyzed at 400 °C (B400) exhibited the most advantageous balance of structural and functional properties. Under one-sun illumination, B400 reached a maximum temperature of 59 °C for a single cube and an average of 65 °C for an array of nine cubes, with a rapid heating rate of 0.29 °C s−1. The material maintained stable performance over ten heating–cooling cycles, demonstrating robust reproducibility. The preserved channel-like bamboo architecture facilitated efficient water transport and vapor escape, enabling an evaporation rate of 1.17 kg m−2h−1. These results confirm B400's strong potential for solar thermal water purification applications. Notably, the enhanced photothermal response was achieved without chemical activation, dopants, or post treatment additives. The performance originates solely from the bamboo microstructure and the optimized low-temperature pyrolysis conditions. This minimal processing approach reduces environmental impact, lowers fabrication cost, and simplifies scalability, aligning with sustainable materials design principles. Overall, this work demonstrates that untreated, low-temperature pyrolyzed bamboo can serve as an efficient, durable, and entirely bio-derived photothermal material for ISSG. The findings open pathways toward affordable solar evaporators and broaden the use of biomass-derived carbon architectures in renewable energy and water purification technologies. References 1. O.G.Pandoli, 3D conductive monolithic carbons from pyrolyzed bamboo for microfluidic self-heating system, Carbon (2023) 2. O.G.Pandoli, Permanent free radicals (PFR) in bamboo biochar-based flow bed reactor: a sustainable solution for dye degradation via adsorption and radical oxidation, Catal. Sci. Technol., (2025) 3. O.G.Pandoli et al. An investigation of the fluid-holding cavities in a lignocellulose-based bamboo matrix via a combined X-ray microtomography and proton time-domain NMR approach, Cellulose, (2023)



Volatile composition and thermal behavior of hydrochars produced from carbohydrates and wood biomass

Bence Babinszki (Institute of Materials and Environmental Chemistry, HUN-REN Research Centre for Natural Sciences, Budapest,, Hungary) István Sándor Czirok (Institute of Materials and Environmental Chemistry, HUN-REN Research Centre for Natural Sciences, Budapest,, Hungary) Zoltán Sebestyén (Institute of Materials and Environmental Chemistry, HUN-REN Research Centre for Natural Sciences, Budapest,, Hungary) Betül Ercan (Department of Metallurgical and Materials Engineering, Karabük University, Karabük, Turkey, Turkey) Suat Ucar (Chemistry Technology Program, Izmir Vocational School, Dokuz Eylül University, Izmir, Turkey, Turkey) Kubilay Tekin (Department of Environmental Engineering, Karabük University, Karabük, Turkey, Turkey) Zsuzsanna Czégény (Institute of Materials and Environmental Chemistry, HUN-REN Research Centre for Natural Sciences, Budapest,, Hungary) Selhan Karagöz (Department of Chemistry, Karabük University, Karabük, Turkey, Turkey)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Among the various thermochemical methods for utilizing biomass, hydrothermal carbonization (HTC) is a promising technology. HTC converts renewable carbon sources, such as lignocellulosic biomass, into an energy-dense carbonized solid product known as hydrochar. Hydrochars of carbohydrates (i.e., glucose, cellulose, starch) and woody biomass samples (i.e., sawdust of fir and larch) were prepared by HTC at 200 °C for 24 h. The hydrochar yields of glucose, cellulose, and starch were nearly 40 % by mass, while larch and fir wood yielded a higher ratio at around 51 % due to their hydrothermally more stable lignin content. The properties of the hydrochars were characterized by ultimate analysis, higher heating values (HHV), Fourier transform infrared (FTIR) spectroscopy. In addition, morphological characteristics of the surface of the hydrochars were presented by scanning electron microscopy (SEM). The thermal behavior of the feedstocks and the hydrochars was determined by thermogravimertry/mass spectrometry (TG/MS), which also allowed us monitoring the evolution of devolatilizing compounds in the lower range of molecular weight. The comparison of the thermogravimetric curves showed that the carbohydrate contents significantly degraded during HTC, but a smaller volatile fraction remained in the hydro¬chars. Based on this observation, two-staged pyrolysis–gas chromatography/mass spectrometry (Py-GC/MS) measurements of the hydrochars were performed for the detailed analysis of the volatile contents of the hydrochars of carbohydrates and woody biomass samples. The findings of this study may enhance the production of hydrochars from different sources, which have the potential to be used as substitute products for coal and other fossil-based energy sources.

Impact of process conditions on hydrochars derived from the hydrothermal carbonization of goat manure

Kübra İrem Er (Karabuk University, Department of Chemistry, Turkey) Zoltán Sebestyén (HUN-REN Research Centre for Natural Sciences, Hungary) Bence Babinszki (HUN-REN Research Centre of Natural Sciences, Hungary) István Sándor Czirok (HUN-REN Research Centre of Natural Sciences, Hungary) Betül Ercan (Karabuk University, Department of Materials and Metallurgical Engineering, Turkey) Koray Alper (Zonguldak Bülent Ecevit University, Department of Chemistry and Chemical Processing Technologies, Turkey) Suat Uçar (Dokuz Eylul University, Department of Chemistry and Chemical Processing Technologies, Turkey) Kubilay Tekin (Karabuk University, Department of Environmental Engineering, Turkey) Selhan Karagöz (Karabuk University, Department of Chemistry, Turkey) Zsuzsanna Czégény (HUN-REN Research Centre for Natural Sciences, Institute of Materials and Environmental Chemistry, Hungary)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Hydrothermal carbonization (HTC) offers a promising pathway for converting organic residues with high moisture content into solid fuel without the need of energy-intensive drying. Conventional pyrolytic processes typically require a preliminary drying step, which limits the efficient utilization of wet biomass. Goat manure is an underutilized, highly available biomass with high moisture content in specific regions. In this work various HTC experiments were carried out on goat manure using a laboratory-scale, teflon-lined stainless-steel reactor. The influence of carbonization temperature was studied at four different temperatures between 200 and 275 °C using 8 h isotherm period. To evaluate the effect of carbonization time, HTC experiments were also performed at 225 °C with residence times of 4, 8, 12 and 24 h. The solid yield of the hydrochar products varied between 38 and 63 %, which decreased by the increasing process temperature. Proximate analysis, elemental analysis, and Fourier transform infrared (FTIR) spectroscopy measurements have been performed in order to characterize the composition of the samples. The raw goat manure sample had significant amounts of inorganic content (36 % ash), while the ash content of the hydrochars was even higher, indicating the dominating presence of water-insoluble inorganic components. The van Krevelen diagram of the raw and hydrochar samples reflected substantial deoxygenation during HTC with clear temperature-dependent trends. Hydrochars produced at 250 and 275 °C reached carbonization levels comparable to those of bituminous coal. The thermal behavior and the evolution profile of volatiles released from the raw and hydrothermally carbonized goat manure samples were characterized by thermogravimetry/mass spectrometry (TG/MS). The shape of the thermogravimetric curves reflected the development of carbonization increasing with residence time and process temperatures of HTC. The DTGmax temperature shifted to higher temperatures and the amount of residual char increased. A small decomposition peak at 650 °C in raw manure shifted to slightly higher temperatures in all HTC samples. This step was accompanied by the evolution of CO2, which indicated the decomposition of inorganic carbonates.

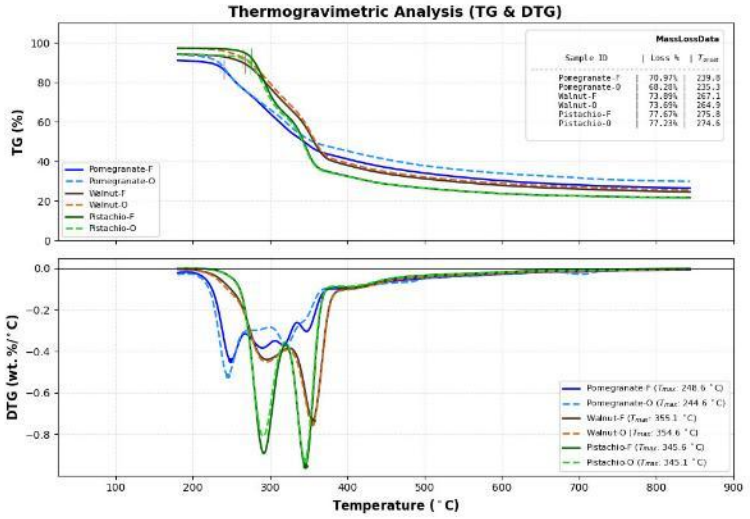
Comparative Thermal Degradation Analysis of Pomegranate, Walnut, and Pistachio Biomasses: Influence of Drying Method on Thermochemical Stability and Volatile Content

Samaneh Shaghaghi (University of Ostrava, Czechia) Petra Bulavová (University of Ostrava, Czechia)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

This study examines the thermal degradation behavior in nitrogen of three agro-waste feedstocks—pomegranate peel (Po), pistachio shell (Pi), and walnut shell (W)—under two stabilization methods: freeze-drying (F) and oven-drying (O). Thermogravimetric analysis (TGA) was used to determine onset temperature (Tonset), peak temperature (Tmax), and biochar yield. The aim was to establish TGA/DTG-based criteria for selecting suitable biomass feedstocks and pyrolysis conditions for high-performance porous carbon production. Results showed distinct differences in thermal stability and volatile release among the feedstocks. Pomegranate peel displayed the lowest stability, with Tonset values of 240 °C (PoF) and 235 °C (PoO). In the active pyrolysis zone (200–400 °C), mass losses were about 47.6 % (PoF) and 46.4 % (PoO), with DTG peaks at 249 °C and 348 °C corresponding to hemicellulose and cellulose decomposition, respectively. Freeze-dried PoF exhibited a higher total mass loss up to 1000 °C (71 %) compared with oven-dried PoO (68 %). This behavior aligns with reports that freeze-drying preserves thermally labile phenolics and creates a more open structure, promoting extensive devolatilization [1,2]. Conversely, oven drying partially degrades and densifies the peel matrix, resulting in slightly higher char residue [4]. Walnut shells exhibited higher thermal stability, with Tonset values of 267 °C (WF) and 265 °C (WO), and the highest Tmax (≈355 °C), reflecting their lignin-rich composition. In the active pyrolysis region (290–400 °C), mass losses were substantial (56.1 % for WF; 58.1 % for WO), leading to total losses of about 73.9 and 73.7 % up to 1000 °C. Despite different drying treatments, the final biochar yields remained nearly identical. Due to the dense, woody structure of the walnut shell, the drying method had no significant effect on the devolatilization process [3]. Pistachio shells exhibited the highest thermal stability (PiF Tonset = 276 °C; PiO Tonset = 274 °C), accompanied by the largest total mass loss (77.23–77.67 %). In the 290–400 °C range, devolatilization accounted for 64.7 % (PiF) and 61.7 % (PiO) with DTG maxima at 291 °C and 345 °C (hemicellulose and cellulose, respectively). The drying method had little effect: freeze-dried PiF showed a slightly higher Tonset than PiO, while Tmax and total mass loss were nearly identical, indicating limited structural or compositional change due to drying [5]. Overall, pistachio shells exhibited high thermal stability but released substantial volatiles during pyrolysis, resulting in moderate biochar yields. Pomegranate peel, less thermally stable, showed a stronger response to freeze-drying, with increased mass loss and lower biochar yields due to preservation of labile sugar and phenolic-rich fractions. The drying method exerted minimal influence on the hard shells but markedly affected pomegranate peel, as reflected by shifts in Tmax for the freeze-dried sample.



References:

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Hydrothermal Liquefaction of the invasive macroalga Chaetomorpha linum: Parametric optimization and product characterization

Roberto Giannelli (Università degli studi di Firenze, Italy) Chiara Riccardi (Università di Pisa, Italy) Massimo Losa (Università di Pisa, Italy) Luca Rosi (Università degli studi di Firenze, Italy)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The iterative unchecked growth of Chaetomorpha linum, an invasive macroalga, in nutrient-rich lagoon ecosystems like Orbetello Lagoon (Italy) makes it necessary to find environmentally friendly ways to get rid of and utilize the algae. This paper is a proof-of-concept for Hydrothermal Liquefaction (HTL), a process that could potentially yield energy-dense biocrude and material products from this wet and tough-to-digest biomass without the energy loss of drying the feedstock first. Experimentally, parametric optimization studies in a batch reactor equipped with temperature control and pressure matching were implemented to explore a wide range of process conditions. Reaction temperatures of 240-340 °C, processing times of 10-120 minutes, different biomass-to-water ratios, and the use of homogeneous alkaline catalysts were the variables tested. The experimental data revealed that the degree of the process has a strong effect on the distribution of the products. The best conversion was carried out under subcritical conditions of temperature 340 °C and duration of 60 minutes, which corresponded to the production of 19% biocrude and 56% solid hydrochar by weight, the rest was divided between the aqueous phase (16%) and gaseous products. The chemical characterization clearly shows that the different fractions obtained have a range of uses. The biocrude, which is formed of a mixture of aromatic hydrocarbons, nitrogenated heterocycles, and long-chain fatty acids, can be upgraded to transportation biofuels, or the platform molecules can be extracted for the chemical industry. Additionally, the heavier biocrude fractions have been found to possess the characteristics of bituminous additives or binders that are renewable sources. On the other hand, the solid fraction (hydrochar) is still a good source though it contains a considerable amount of ash. The combination of a large surface area and a porous structure makes it a candidate low-cost adsorbent for the remediation of heavy metals in wastewater; furthermore, after proper desalting and removal of other inhibitory components, it can be used as a fertilizer for the soil in agriculture. The nutrients and organics in the aqueous phase make it worth recovering by integrating it with biological treatment processes. It is here highlighted that by adjusting the HTL parameters, a flexible C. linum biomass valorization route can be opened without the input of a fossil resource-consuming step, whereby an environmental nuisance is converted into a suite of renewable energy, chemicals, and materials within a circular bioeconomy framework.

Thermochemistry as synthesis tool for new chemical building blocks from isosorbides and isomannides

Stef Ghysels (Ghent University - Thermochemical Conversion of Biomass Research Group (TCCB), Belgium) Arne Desmyter (Ghent University - Thermochemical Conversion of Biomass Research Group (TCCB), Belgium) Emile De Mol (Ghent University - Synthesis, Bioresources and Bioorganic Chemistry Research Group (SynBioC), Belgium) Frederik Ronsse (Ghent University - Thermochemical Conversion of Biomass Research Group (TCCB), Belgium) Sven Mangelinckx (Ghent University - Synthesis, Bioresources and Bioorganic Chemistry Research Group (SynBioC), Belgium)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The transition toward a bio-based economy necessitates the development of versatile platform chemicals, among which isosorbide (structure 1 in fig. 1a) (1,4:3,6-dianhydrosorbitol) is a primary candidate. While isosorbide is widely utilized for addition reactions to create polymers, solvents, and surfactants, its elimination products — specifically dihydrofuro[3,2-b]furan and 1,4:2,5:3,6-trianhydro-D-mannitol (structures 4 and 5 in fig. 1a) — have remained overlooked due to incomplete understanding of their formation and the lack of low-cost synthesis routes. This conference contribution shows for the first time how to harness the power of pyrolysis as a tool to simply synthesize these new elimination products. By utilizing the pyrolysis-driven Ei β-elimination mechanism of isosorbide esthers and carbonates (fig. 1b), we successfully triggered the formation of the target elimination products from isosorbide at good yield and selectivity. Key findings revealed that (i) isosorbide bis(dimethylcarbonate) (ISBMC, structure 15a in fig. 1b) is a superior precursor to elimination products compared to the diacetyl ester and (ii) the reaction time is crucial to achieve good yield and selectivity. Indeed, flash pyrolysis of ISBMC at 550 °C produced traces of dihydrofuro[3,2-b]furan (relative peak area of 2.16 area%). To maximize the yield of dihydrofuro[3,2-b]furan, prolonged residence times were applied at a lower temperature. ISBMC yielded a staggering selectivity of 21.22 area% for the target dihydrofuro[3,2-b]furan elimination product at 450 °C after 30 minutes (fig. 1c). This work thus demonstrates that by optimizing temperature and reaction time, heat can be used as a sustainable tool to unlock new chemical building blocks from isosorbide, avoiding the need for hazardous reagents typically found in traditional multi-step liquid-phase synthesis. Therefore, we deem this contribution to be fit for the pyro conference.

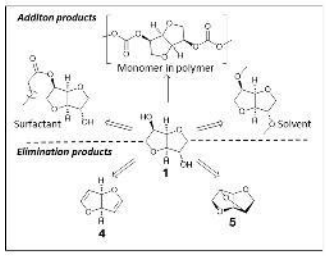


Fig 1a

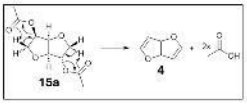


Fig 1b

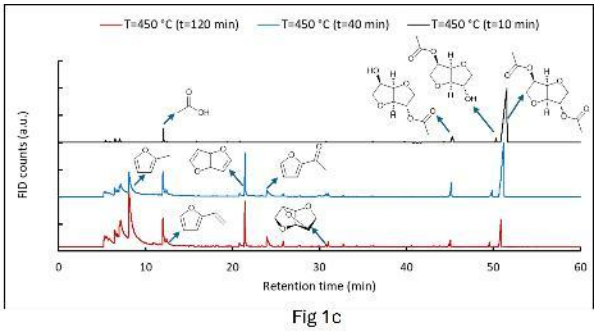


Fig 1c

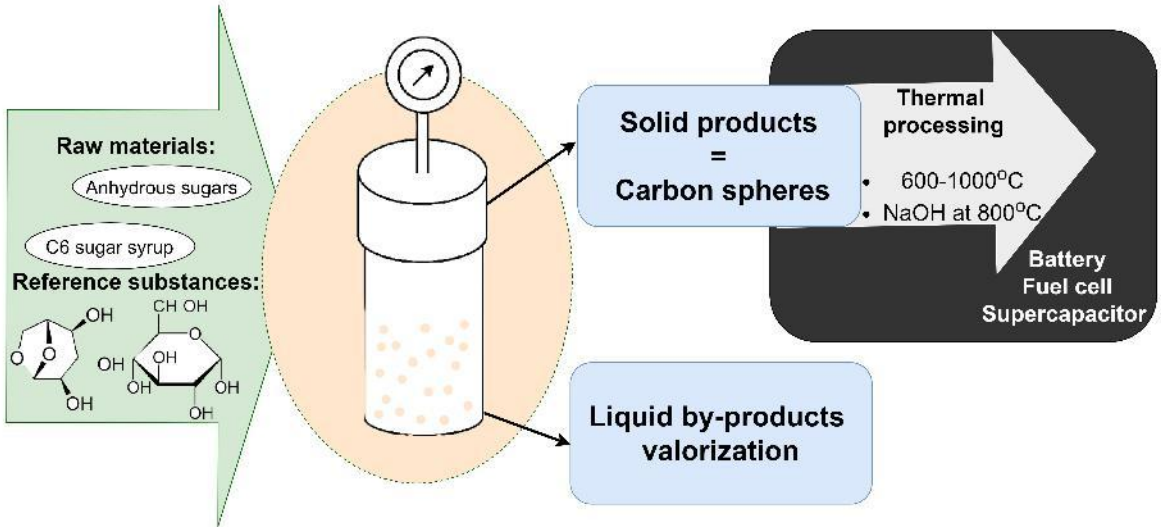
Comparative Study on the Hydrothermal Carbonization of Glucose and Levoglucosan: Understanding Carbon Sphere Formation Pathways

Ance Plavniece (Latvian State Institute of Wood Chemistry, Latvia) Galina Dobele (Latvian State Institute of Wood Chemistry, Latvia) Kristine Meile (Latvian State Institute of Wood Chemistry, Latvia)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The decline of fossil fuel resources and the negative impact of fuel combustion on the environment are forcing scientists to develop new technologies for producing functional carbon materials with various useful properties. To obtain carbon-containing materials with specified properties (shape, size, functional groups), interest arose in the thermochemical process of hydrothermal carbonization (HTC), due to the mild operating conditions (temperature up to 300 °C, self-generated pressure) in a subcritical water environment. The main objective of this work is to use analytical pyrolysis (Py-GC/MS) to expand our understanding of the chemical composition and structural characteristics of hydrochars during the formation of microspheres-containing carbons obtained by hydrothermal carbonization of monosaccharides – glucose and 1,6-beta-D-anhydroglucopyranose (levoglucosan). Two feedstocks were used for hydrothermal synthesis (HTC) – glucose (G) and levoglucosan (LG obtained at the Latvian State Institute of Wood Chemistry). 1, 10 and 20% feedstock solutions were prepared, which were subsequently treated at 200, 250 and 300 °C for 4 hours in in a 250 ml high pressure autoclave. After separation the carbonized solid particles will be studied by elemental analysis, Py-GC/MS and SEM. Liquid by-products will be tested by HPLC-UV/ELSD/MS. This work not only provides a study of the properties of solid and liquid products after hydrothermal treatment of biomass, but also offers a theoretical platform for obtaining new efficient carbon materials for energy.



PYROLYSIS CHARACTERISTICS AND THERMO-KINETIC PARAMETERS FOR HYDROCHARS PRODUCED FROM AGRICULTURAL INDUSTRIES

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The agricultural industry generates significant amounts of wet organic wastes, offering the potential for bioenergy generation through thermochemical processes [1]. Hydrothermal carbonization (HTC) converts wet feedstocks into value-added products (i.e., hydrochar) without the need for drying. Thus, coupling HTC and hydrochar pyrolysis seems to be a promising alternative for enhancing energy recovery from agricultural biomass wastes. This study explores the pyrolysis behavior, kinetics, and hydrochar production from Olive Pomace Waste (OPW) and Agave Salmania bagasse (AB) for renewable biofuel production (pyrolytic oil and gas) via fast pyrolysis, which is critical for advancing the industrial implementation of integrated HTC–pyrolysis systems. For this purpose, TGA experiments were conducted at 1000 °C as final pyrolysis temperature and at three different heating rates (100, 400, and 800 °C/min). The pyrolysis runs were carried out for the two raw feedstocks (OPW and AB) and hydrochars produced at different HTC conditions: (i) 180 °C, 30 min (HC1) and (ii) 250 °C, 30 min (HC2), with the lowest (~ 20%) and highest (~ 35%) fixed carbon content, respectively. It was seen that increasing the severity of HTC improved the thermal stability of hydrochars by increasing pyrolysis' characteristic temperatures (Ti, Tm and Tf) in terms of onset, maximum decomposition and burnout throughout the process. Moreover, three common model-free methods including Flynn-Wall-Qzawa (FWO), Kissinger-Akahira-Sunose (KAS) and Friedman, were examined for their suitability to determine the pyrolysis kinetics of the hydrochars and raw feedstocks under study. According to linear regression and statistical analysis, FWO presented the best linear fit for analyzing the mean activation energy (Ea), represented as 64.18 and 58.10 kJ/mol for HC1OPW and HC2OPW, respectively, vs. 59.95 kJ/mol for the raw OPW feedstock. Conversely for AB, the mean activation energies exhibited an increased trend from 51.31 kJ/mol for raw AB feedstock to 104.79 kJ/mol (HC1AB) and 67.24 kJ/mol (HC2AB). A representative lignin extract from AB was further investigated based on biomass fractionation, which presented great stability at high conversions (α>0.8), showing that biomass chemical composition influences the thermal degradation of the feedstock. Finally, thermodynamic analysis indicated the feasibility for the pyrolysis of hydrochars due to the low difference between Ea and ΔH for all samples. In addition, reactions were nonspontaneous needing additional energy to take place while demonstrating less disorder throughout the progress of the pyrolytic process. These findings clearly show the potential for transforming wet agro-industrial biomass residues and waste into valuable biofuels and renewable energy production through HTC and hydrochar pyrolysis. [1] Sangaré, D.; Bostyn, S.; Moscosa-Santillan, M.; Garcia-Alamilla P. ; Belandria, V.; Gökalp. I. Bioresour. Technol., 2022, 346, 126598.

Valorizing Blended Spent Coffee Grounds and Date Seeds for Hydro-gen Production: Pyrolysis, Kinetics, and Machine Learning Applications

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

• Context/Purpose: This study evaluates the bioenergy, spe-cifically hydrogen, potential of date seeds (DS), spent cof-fee grounds (SCG), and their blends, using a Deep Learn-ing model to optimize pyrolysis efficiency. • Methods: This study combines experimental methods—including compositional and thermogravimetric analysis (TGA), kinetic thermodynamic studies, and pyrolysis tests--with advanced predictive modeling using Long Short-Term Memory (LSTM) neural networks. By integrating experimental and AI-driven approaches, this study advanc-es biomass-based hydrogen production, contributing to a cleaner energy transition and a more circular hydrogen economy. • Results: Proximate, ultimate, fiber, TGA/DTG, kinetic, thermodynamic, and Pyrolysis tests were conducted for DS, SCG, and blends (75% DS–25% SCG, 50% DS–50% SCG, 25% DS–75% SCG). The blend ratio of 25%DS–75% SCG demonstrated the highest hydrogen yield potential. Three kinetic models were tested where KAS emerged as the most accurate one. An LSTM model, trained with lig-nocellulosic data, achieved exceptional accuracy in predict-ing TGA curves (R^2: 0.9996–0.9998) • Interpretation: The analysis of the kinetic parameters for the three blends reveals that the blend ratio can signifi-cantly affect the activation energy (Ea) and the energy ef-ficiency of the pyrolysis process. Among the blends, Blend 1 emerges as the most energy-efficient option compared to the other blends and pure samples, with the lowest average activation energy. The pyrolysis results demonstrate that blending DS with SCG alters thermal degradation dynamics, favoring volatile release over char production and Blend 3 (25% DS- 75% SCG) is the best candidate for a better hydogen production quality. This study demonstrates the effectiveness of LSTM models in predicting TGA profiles for pure biomass and their blends, achieving comparable or superior accura-cy to ANN models from the literature. • These advancements have the potential to reduce reliance on TGA machines, cutting energy costs and streamlining thermal analysis processes • Conclusion: This research emphasizes the importance of shifting from fossil fuel-based “gray hydrogen” to renewa-ble “green hydrogen,” and highlights how underutilized biomass resources as well as machine learning (specifically deep learning) applications can contribute to this transi-tion

Thermogravimetric and Kinetic Study of Pomegranate Peel, Prickly Pear Peel, and Their Mixture for Bioenergy Applications

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Agro-industrial residues such as pomegranate and prickly pear peels are abundant by-products with strong potential for renewable energy applications. This study examines their thermal degradation behavior and kinetic parameters, both individually and as a binary mixture, using thermogravimetric analysis (TGA) under a nitrogen atmosphere. Experiments were carried out from ambient temperature to 800 °C at heating rates of 5, 20, and 50 °C/min. Thermogravimetric (TGA) and derivative thermogravimetric (DTG) curves revealed multiple decomposition stages corresponding to moisture evaporation, degradation of hemicellulose and cellulose, and gradual lignin decomposition. Iso-conversional kinetic methods, including Flynn–Wall–Ozawa (FWO), Kissinger–Akahira–Sunose (KAS), and Friedman, were applied to determine the apparent activation energy and pre-exponential factor without assuming a reaction model. The calculated activation energies ranged from 96.61 kJ/mol for prickly pear peel to 185.72 kJ/mol for pomegranate peel, indicating differences in thermal stability and chemical composition. The binary mixture exhibited intermediate activation energy values (102.27–112.75 kJ/mol), suggesting possible interactions between the two biomasses during thermal decomposition. These results provide fundamental kinetic and thermochemical insights that are useful for the thermal conversion and energetic valorization of pomegranate peel, prickly pear peel, and their blends as sustainable biomass resources.

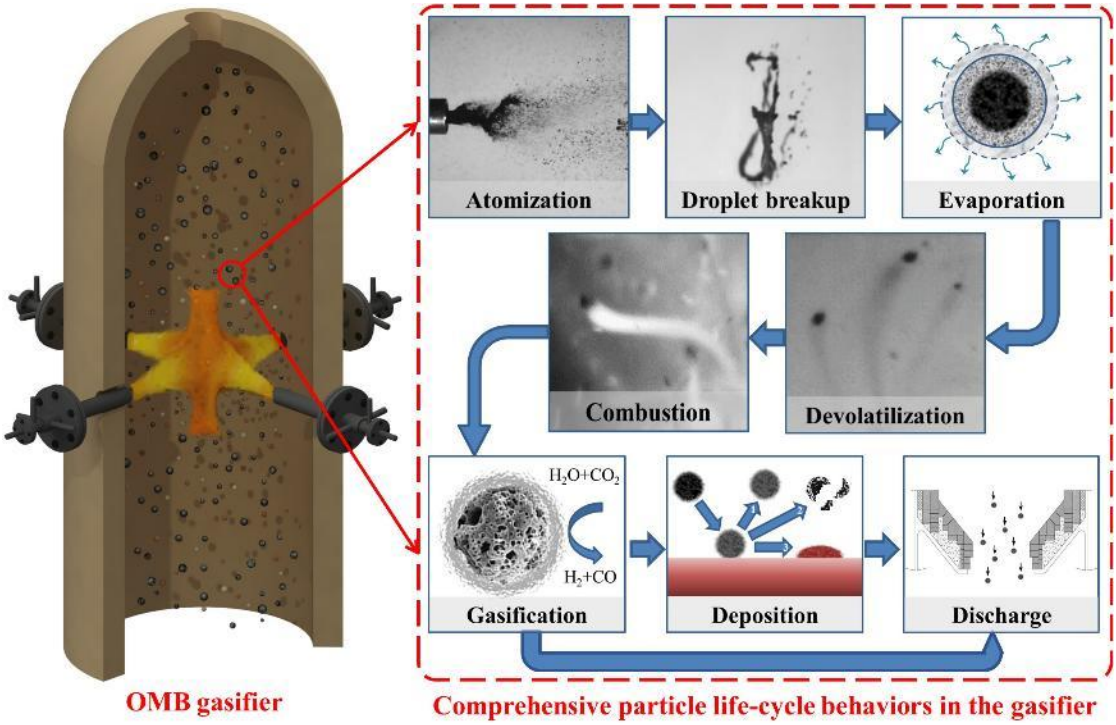
In-situ study of particle evolution at different stages during coal gasification process

Yan Gong (East China University of Science and Technology, China) Qinghua Guo (East China University of Science and Technology, China) Hantao Lu (East China University of Science and Technology, China) Guangsuo Yu (East China University of Science and Technology, China)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

As the largest coal consuming country in the world at present, coal continue to be an important strategic resource for the overall development of Chinese society for a long time to come. Entrained-flow gasification is the core technology for clean and efficient utilization of coal, and is a leading and key technology in process industries such as coal based bulk chemical synthesis, coal to liquid fuel, coal to natural gas, and hydrogen production. The opposed multi-burner (OMB) entrained-flow coal-water slurry (CWS) gasification technology developed by the research team from East China University of Science and Technology ranks first in the world in terms of production capacity and achieved good economic benefits. The behavior of coal particles in an entrained-flow gasifier is critically linked to the stable operation of the system. During the gasification process, the thermal behaviors of the particles have significant effects on the heat transfer and reaction in the gasifier. However, observing these particles has been a significant challenge due to the high temperatures and complex atmosphere within the gasifier. In this study, utilizing a bench-scale OMB CWS entrained-flow gasifier and a visualization system equipped with high-temperature endoscopes and high-speed cameras of varying specifications, the comprehensive behaviors of particles within the gasifier are thoroughly investigated. Detailed discussions are provided on CWS atomization, particle fragmentation, devolatilization, volatile combustion, coke oxidation, gasification and deposition. The findings reveal that as the relative velocity between oxygen and CWS increases, the primary atomization mode transitions from a Rayleigh-type breakup to a superpulsating atomization mode. The occurrence of pyrolysis and gasification reactions results in the consumption of the carbon matrix, which affects the internal skeleton structure of the particles and forms a porous structure that is prone to causing the main body of the particles to break. The fragmentation probability reaches an extreme value due to the combined shock of the upward impinging-flow from the burner plane and the reverse flow from the arch at a distance of 400 mm above the burner plane. The detailed conversion patterns between different particle types near the burner plane, above the burner plane, and below the burner plane with different axial positions are discussed, respectively. Additionally, it is noted that within the gasifier, the char oxidation process typically has the longest duration, ranging from 200 to 2000 ms. Deposition behaviors in the gasifier are categorized into three droplet deposition modes and four particle deposition modes. Ultimately, a comprehensive particle evolution model corresponding to the droplet/particle deposition stage is established



Effect of lignite Thermal Dissolution Solubles Addition on Coke Reactivity and Its Dissolution Loss Kinetics under a Hydrogen-Rich Atmosphere

Jialong Yao (Anhui University of Technology, China) Kaixiang Ma (Anhui University of Technology, China) Jingchong Yan (Anhui University of Technology, China) Hengfu Shui (Anhui University of Technology, China)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Hydrogen-rich blast furnace (HBF) technology holds significant potential for reducing carbon emissions in metallurgical industry. In HBF, H_2O generated via reverse water-gas shift reaction (RWGSR) influences coke dissolution loss (CDL) behavior. It is essential to understand these mechanisms to develop high-performance coke suitable for HBF. In this study, using conventional coke CA as a reference, cokes CB and CC were prepared by adding 5% coking coal and lignite thermal dissolution solubles (TDS), respectively. The reactivity (CRI) and strength after reaction (CSR) of these cokes were evaluated under CO_2 and H_2-enriched atmospheres. Microstructural characterization and CDL kinetic analysis of the coke were performed. Results showed that both coking coal and lignite TDS additions improved coke quality, reducing CRI and increasing CSR. In 5–10% H_2 atmospheres, CRI decreased and CSR increased for all cokes, indicating H_2's inhibitory effect on CDL. However, at 15% H_2, CRI increased and CSR decreased for CA and CB, as H_2O from RWGSR promoted CDL. In contrast, CC maintained stable performance. Kinetic studies under CO_2+10%H_2 revealed a significant decrease in the CDL reaction rate and activation energy, with the pre-exponential factor dropping by nearly two orders of magnitude, suggesting an altered reaction pathway. Due to its high diffusivity, H_2 preferentially occupies active sites in coke, reducing effective collisions with CO_2. In CC, oxygen-containing functional groups enable H_2 to be firmly adsorbed via hydrogen bonds, resisting displacement by H_2O and thereby mitigating its promoting effect on CDL. This study proposes a novel approach for producing high-quality HBF coke: adding low-rank lignite-TDS during coking can expand coking coal resources, reduce costs, and yield coke with superior resistance to CDL under H_2-rich conditions.

Unlocking Lignite’s Value through Structure-Guided Alkaline Depolymerization and Electro-Oxidative Upgrading

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The non-fuel valorization of low-rank coals, particularly lignite, represents a promising strategy for sustainable carbon utilization and CO2 mitigation. Mild depolymerization in alkaline media offers an attractive pathway to high-value oxygenated products such as humic acids, fulvic acids and aromatic carboxylic acids. However, the process efficiency is intrinsically governed by the complex macromolecular architecture of lignite, especially its cross-linked network composed of aromatic clusters, aliphatic bridges and oxygen-containing functional groups, which impedes solubilization and selective bond cleavage. In this study, several Chinese lignites were employed to elucidate the critical structure–reactivity relationships during the depolymerization in alkaline aqueous with different oxidative-assistance strategies, including O2 oxidation and electro-oxidation. Results reveal that depolymerization efficiency inversely correlates with cross-linking density and positively relates to the abundance of labile linkages and oxidizable moieties. Mild oxidation intensifies depolymerization and improves product selectivity. Notably, electro-oxidation not only circumvents the need for chemical oxidants but also enables concurrent hydrogen evolution at the cathode, thereby converting part of the oxidation energy into valuable H2 rather than dissipating it as heat. The tailored depolymerization products exhibit extensively potential for advanced materials applications, such as carbon dots, superplasticizer. This improved understanding of lignite’s structural reactivity supports the rational design of mild, efficient, and low-waste processes for producing oxygen-containing chemicals. Ultimately, leveraging the intrinsic structural features of lignite paves the way for its conversion from a low-grade fuel into a renewable feedstock for high-value applications, in alignment with circular carbon economy principles.

Study on the Modification of Coal Gasification Fine Slag for Corn-stalk Pyrolysis Catalysts

Qinghua Guo (East China University of Science and Technology, China) Ruofei Wu (East China University of Science and Technology, China) Yan Gong (East China University of Science and Technology, China) Lu Ding (East China University of Science and Technology, China) Guangsuo Yu (East China University of Science and Technology, China)

14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

The coal gasification fine slag (CGFS) with high carbon content and poor reactivity are the difficulties in the resource utilization of solid waste from entrained-flow coal gasification. Achieving graded utilization is essential to promote the valorization of CGFS. This study mainly employs CGFS as the feedstock for preparing biomass pyrolysis catalysts, and utilizes flotation-enhanced separation to isolate carbon-rich fractions (CF) for subsequent thermal conversion. Specifically, CGFS is activated via a combined NaOH/air–steam treatment and co-calcined with urea to synthesize N-doped catalysts, which are applied to corn-stalk pyrolysis for the production of phenol-rich bio-oil; the effects of catalyst preparation conditions on phenolic yield and the corresponding catalytic conversion pathways are systematically investigated. Meanwhile, mild oxidation was mainly utilized to regulate the structure of CF in order to improve its reactivity. The results show that the N-doped CGFS-based catalyst increases the yield of phenolic compounds in bio-oil by a factor of approximately 1.35 relative to non-catalytic pyrolysis. Nitrogen-derived basic sites promote C–O and C–C bond cleavage as well as demethoxylation and decarbonylation, while suppressing secondary polymerization and coking, thereby enabling highly selective production of phenolic compounds. Besides, oxidation treatment can also improve the secondary gasification or combustion reactivity of CF, and the increase in pore structure is the main reason for the improvement of the reactivity of oxidized CF, which is benefit for the utilization of CGFS.

Catalytic reforming of lignite pyrolysis volatiles over metal oxide and zeolite tandem catalysts for light aromatics production

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

This study proposes a metal oxide/zeolite tandem catalytic system that, through synergistic catalysis, more efficiently directs the conversion of lignite pyrolysis volatiles into light aromatics. Concurrently, the pre-cracking stage effectively removes oxygen-containing components, thereby reducing coke deposition on the zeolite and extending catalyst lifetime. Experiments were conducted in a drop-type fixed-bed reactor, where volatiles generated in the pyrolysis zone at 600 oC were carried directly by the carrier gas into the tandem catalytic section. The first stage consisted of a metal oxide catalyst bed (e.g., CaO, MgO, ZnO), in which large molecules in the volatiles primarily underwent deoxygenation, cracking, and partial reforming reactions. The second stage contained an HZSM-5 zeolite bed (SiO2/Al2O3 = 25), where the products from the first stage mainly underwent aromatization reactions, resulting in increased yields of light aromatics. The upper metal oxide with basic sites effectively promotes the cracking of volatiles, significantly increasing the yields of hydrogen-rich gases and light aromatics while notably decreasing coke formation and effectively extending catalyst lifetime. This work confirms the feasibility of tandem catalysis for the directional conversion of lignite volatiles and provides a new strategy for the high-value utilization of coal resources.

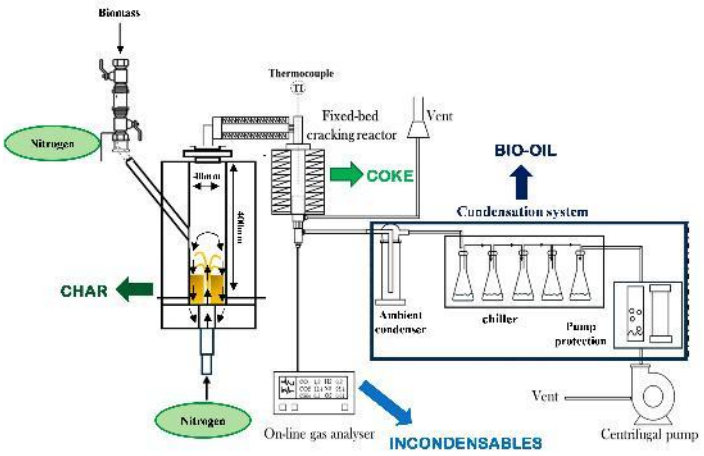
Thermal and Catalytic co-pyrolysis of Olive Stone and LDPE in a spouted bed reactor for sustainable drop-in Hydrocarbon

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Residual biomass is expected to play a central role in decarbonization strategies as a renewable resource aligned with sustainability goals. Among thermochemical conversion technologies, fast pyrolysis represents a promising approach for the production of liquid biofuels (bio-oils), chemicals, and renewable energy from biomass. However, crude bio-oil obtained from fast pyrolysis is typically characterized by a high content of oxygenated compounds, responsible for its unfavourable properties, including low heating value, high acidity, chemical instability, and poor storage performance. To overcome these limitations, several strategies have been investigated to reduce the complexity and abundance of oxygen functionalities in pyrolysis products. These approaches aim to promote efficient deoxygenation of bio-oils, thereby improving their physicochemical quality and conventional refinery compatibility. In this context, particular attention has been devoted to catalytic and non-catalytic co-pyrolysis processes, which represent promising solutions to enhance bio-oil quality. Due to the intrinsically high oxygen content of biomass feedstocks, the co-processing of biomass with hydrogen-rich materials, such as plastics, as well as the use of a catalyst, has been explored as an effective strategy to enhance deoxygenation efficiency. In co-pyrolysis, in fact, synergistic interactions between biomass- and plastic-derived intermediates can occur, with oxygenated compounds from biomass pyrolysis reacting with olefins generated from plastic degradation. These interactions can promote further deoxygenation and improve hydrocarbon selectivity toward more desirable products [1]. In the present study, preliminary co-pyrolysis tests of low-density polyethylene (LDPE) and Olive Stone (OS) were carried out using a plastic-to-biomass ratio of 10/90. Experiments were performed both in absence and in the presence of H-ZSM-5 zeolite catalyst (pore size ~5.8 Å, SiO_2/Al_2O_3 of 40) to evaluate its influence on the distribution and quality of the pyrolysis products. Acidic zeolites are well known for their effectiveness in enhancing selectivity toward valuable pyrolysis products, particularly aromatic hydrocarbons [2]. Reactor configuration also plays a crucial role in pyrolysis performance. Recently, spouted bed reactors have attracted increasing interest due to their distinctive hydrodynamic regime, which is favourable for achieving high bio-oil yields while limiting undesired, non-selective secondary cracking reactions, often promoted by prolonged contact with char particles. Therefore, in the present study, steady-state co-pyrolysis experiments were performed in a bench-scale plant consisting of a spouted bed reactor followed by an in-line fixed bed catalytic cracking reactor loaded with sand or zeolite catalyst. Both the pyrolysis and catalytic cracking stages were operated at 500 °C. The gas residence time in the spouted bed reactor was approximately 1 s, while catalytic tests were carried out at a space time of 20 (gcatalyst min/gOS). Preliminary results show that the presence of the catalyst affects both the yield distribution and the chemical quality of the pyrolysis products. However, an increase in the production of polycyclic aromatic hydrocarbons (PAHs) was also detected, highlighting the need for further optimization of operating conditions. Figure 1. Schematic representation of the experimental setup. [1] X. Zhang, H. Lei, S. Chen and J. Wu, Green Chemistry, 18 (2016) 4145-4169. [2] R. Cai, X. Pei, H. et al., Energy and Fuel, 34 (2020) 11771–11790.



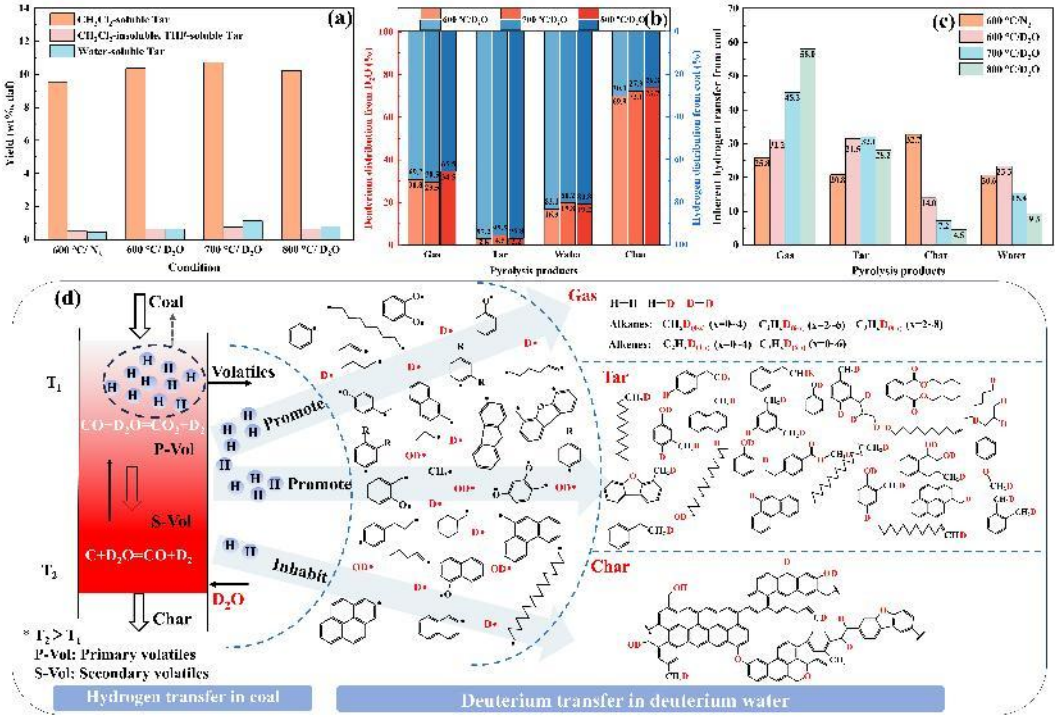
Hydrogen transfer and reaction mechanism during gradient temperature pyrolysis of coal under steam atmosphere

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

To enhance the yield and quality of coal tar, coupling the water gas shift (WGS) reaction with gradient temperature pyrolysis of coal has been demonstrated to significantly improve the quality of both tar and pyrolysis gas. However, the underlying mechanism by which this integrated process enhances tar and gas product quality under steam atmosphere remains poorly understood. In this study, a two-section moving bed with independent temperature control as the pyrolysis reactor was employed, and deuterated water was used as a tracer to systematically investigate hydrogen migration pathways and reaction mechanisms during gradient temperature pyrolysis of coal in the presence of steam. The results show that, compared with the N2 atmosphere, under steam atmosphere at the high-temperature zone with temperature of T2 at 700 ℃, tar yield increased by 22.1% (a 1.2-fold increase) and H2 yield reached 4.7 mmol/g, representing a 2.4-fold enhancement relative to the control condition. Steam also enhanced tar quality by increasing the contents of light fractions (e.g., light oil and phenol oil), benzene, naphthalene, aliphatic hydrocarbons and phenols. Furthermore, under these conditions, hydrogen derived from steam migrates into all pyrolysis products. The distribution of migrated hydrogen among pyrolysis water, pyrolysis gas, tar, and char were found to be 19.8%, 29.5%, 4.5%, and 72.1%, respectively. As the T2 temperature increases, both char gasification in the high-temperature zone and WGS reactions in the low-temperature zone are promoted, facilitating the incorporation of •D and •OD radicals derived from steam into reactive sites such as DUar, Dα, and Dβ within tar fragments. Furthermore, under steam atmosphere, the proportion of inherent hydrogen in coal converted into pyrolysis gas (mainly H2 and CH4) and tar (including CH2Cl2-soluble tar and water-soluble tar) significantly increases, whereas the proportions converted to char and pyrolysis water decrease correspondingly. This also indicates that steam promotes the transfer of inherent hydrogen from coal to tar components while suppressing secondary reactions of volatiles, thereby reducing the formation of char and pyrolysis water. This process is governed by a combination of chemical and physical mechanisms, including thermal cracking, WGS reaction, char gasification, hydrogenation, and steam entrainment effects. These findings provide a solid theoretical basis for the in-situ efficient utilization of coal resources.



(a) The effect of atmosphere and temperature of T_2 on the yield of tar; (b) Sources of deuterium/hydrogen in temperature gradient pyrolysis of coal with D_2O; (c) Migration of inherent hydrogen from coal during temperature gradient pyrolysis with D_2O; (d) Hydrogen/deuterium migration pathways during temperature gradient pyrolysis of coal under D_2O.

From Pyrolysis to Application: Long-Term Evaluation of Sewage Sludge Biochar (Greenchar) in Green Roof Substrates

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

Sewage sludge biochar (SSB) is a circular material with strong potential to enhance the ecological performance of extensive green roofs while valorizing nutrient-rich waste streams. This study presents results from a 40-month rooftop monitoring experiment conducted under temperate climatic conditions, assessing the effects of SSB incorporation (10% and 20% v/v) on substrate physicochemical properties, hydrological behavior, runoff quality, vegetation dynamics, and microbial diversity. Amendment with SSB decreased bulk density and increased total porosity and water-holding capacity, thereby improving substrate moisture availability. These changes translated into enhanced water retention, with annual runoff reduced by 3.3–8.5%. The greatest reduction was observed in the SB20 treatment during the driest year (2022), while cumulative seasonal retention reached up to 76% in dry years. Although SSB originates from nutrient-rich feedstock, runoff nutrient concentrations showed an initial increase followed by stabilization, reflecting gradual nutrient release patterns. Vegetation cover increased to 73% in the control and to 84% (SB20) and 89% (SB10) over the monitoring period, with no statistically significant difference between amendment rates. Microbial analyses demonstrated higher bacterial and fungal richness in SSB-amended substrates, particularly at the 20% v/v level. Structural equation modelling revealed that variations in microbial richness were linked to changes in runoff chemistry (pH, electrical conductivity, total suspended solids) and interannual variability, rather than being attributable to a single controlling factor. Overall, this long-term rooftop study provides robust evidence of the systemic responses of extensive green roofs amended with SSB, particularly in terms of water balance regulation, substrate physical development, and microbial diversity enhancement.

In-situ detection of catalytic cracking of Naomaohu pyrolysis volatiles over Fe and Al components in red mud

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14:00-15:00 Session Posters P-S3F1: Applied pyrolysis: Fossil fuels, Applied pyrolysis: Biomass valorisation, Applied pyrolysis - other
Location: First Floor

ABSTRACT

In-situ detection is an important technique to realize catalytic cracking of coal pyrolysis volatiles. In this, catalytic cracking of Naomaohu coal pyrolysis volatiles over Fe and Al components in red mud was investigated using in-situ pyrolysis vacuum ultraviolet photoionization time-of-flight mass spectrometry with acid-treated red mud (ARM), Fe2O3, and Al2O3 as catalysts.

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