ORGANIZED BY NATIONAL INTERUNIVERSITY CONSORTIUM OF MATERIALS SCIENCE AND TECHNOLOGY (INSTM)

IN COLLABORATION WITH Società Chimica Italiana Gruppo Giovani

BOOK OF ABSTRACTS

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Dear colleagues

It is our great pleasure to welcome you to the **INSTM Young Researchers' Forum 2025**, organized by the **INSTM Consortium** in collaboration with the **Young Group of the Italian Chemical Society (SCI)**. This event was conceived to enhance the potential of the new generation of researchers working across the 53 universities that make up INSTM, by providing them with tools, opportunities for exchange, and visibility. Our aim is **to transform academic knowledge into tangible solutions with a real impact on society**. The Forum aspires to create fertile ground for the exchange of ideas, breaking down disciplinary boundaries and promoting dialogue across chemistry, physics, engineering, nanotechnology, life sciences, and materials science. Through this interdisciplinary approach, we seek to strengthen a collaborative system in which **young researchers can engage, interconnect their expertise, and contribute to the development of solutions** geared towards sustainability, industrial innovation, materials eco-design, and the ecological transition. The scientific program will include both specialized insights and broader interdisciplinary sessions, while also offering young participants visibility and opportunities to initiate joint research projects. The **conference will be structured into five thematic sessions**:

1. Materials and technologies for Life Sciences and Food Sciences
2. Materials and technologies for Made in Italy, Advanced Manufacturing, and Aerospace
3. Materials and technologies for the ecological transition: Energy and Sustainable
4. Mobility Materials and technologies for the Green Economy and Circular Economy
5. Materials and technologies for Built Heritage and Cultural Heritage

Each session will open with **a Keynote Lecture** delivered by outstanding young Italian scholars who have distinguished themselves through the quality and impact of their research in both academia and industry, in Italy and abroad. These authoritative voices - close in age and career path to the participants - embody not only the future, but also the present of Italian scientific research. **The program also includes more than 90 flash presentations**, offering participants the opportunity to present the progress of their work. Among the most anticipated moments is the **Meet-to-Match event**, designed to promote connections between researchers with complementary interests and spark new synergies and projects at both national and international levels. All contributions to the Forum are collected in this Book of Abstracts, made available in electronic format for participants and sponsors.

We sincerely hope you will enjoy this conference as much as we enjoyed organizing it.

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KEYNOTES

KN1 |

BIOMEDICAL APPLICATIONS OF BIOORTHOGONALLY CROSSLINKED HYDROGELS

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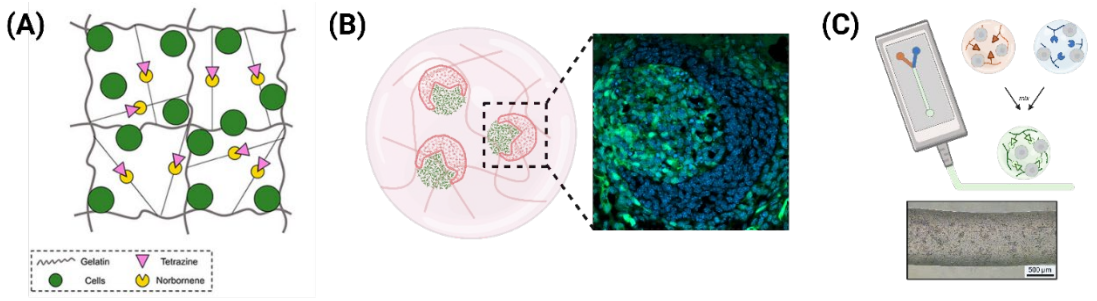
Hydrogels (water-swollen polymeric networks) are powerful platforms for three-dimensional (3D) cell culture, offering unique opportunities for tissue engineering, regenerative medicine, and in vitro modeling. Among them, gelatin stands out as an accessible, low-cost, and highly versatile biomaterial. Derived from collagen, it preserves essential bioactive sequences (e.g., cell-adhesion motifs and MMP-sensitive sites), is water-soluble, and is less immunogenic than collagen, making it a widely used foundation for cell–material systems. Recent advances in bioorthogonal chemistry have introduced cross-linking strategies that are highly selective, cytocompatible, and effective under mild, physiological conditions. In our team, we exploit a tetrazine (Tz)–norbornene (Nb) click reaction to prepare gelatin hydrogels with tuneable mechanical and biochemical properties (Figure A). By adjusting the degree of modification and the Tz/Nb ratio, we can precisely control hydrogel architecture and functionality, creating versatile platforms for diverse biomedical applications. We have demonstrated the potential of our bioorthogonally crosslinked gelatin hydrogels in multiple contexts. First, we established a defined and tuneable platform for tooth organoid engineering, where encapsulation of dental epithelial–mesenchymal cell pellets in a hydrogel library revealed the formulations that supported growth kinetics and morphogenesis of embryonic tooth germs (Figure B). Second, we developed a robust lymphangiogenesis assay, encapsulating human dermal lymphatic endothelial cell spheroids in the hydrogels to study sprouting dynamics. Remarkably, hydrogel stiffness modulated sprouting within 48 h, offering a rapid and reliable model for investigating vascular biology and informing regenerative strategies. Finally, we explored bioprinting applications, introducing an *in situ* approach for fabricating biofunctional and bioadhesive click hydrogels tailored to personalised wound treatment. By optimising cross-linking kinetics and extrusion parameters, we achieved precise shape fidelity and deposition control using both robotic and handheld bioprinters (Figure C). Together, these studies highlight the adaptability of bioorthogonally crosslinked hydrogels as platforms for 3D culture, organoid engineering, disease modeling, and bioprinting. Their tuneable and bioorthogonal design provides a powerful foundation for advancing tissue engineering, regenerative medicine, and the development of human-relevant in vitro models.



(A) Schematic representation of the bioorthogonal click crosslinking between tetrazine and norbornene to form gelatin hydrogels. (B) Tooth organoid embedded into the gelatin hydrogels. (C) Handheld bioprinting device engineered to print bioorthogonal adhesive hydrogels.

KN2 |

3D PRINTED POLYMER FUEL GRAINS FOR ROCKET

Cerciello F[1], Gargiulo G[1], Celotto C[2], Sirignano M[2], Russo C[1], Sennaca O[1], Apicella B[1], Marra FS[1], Renzulli F[3], Rapacciuolo D[3], de Angelis T[3]

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The rapid growth of space activities calls for propulsion technologies that are efficient, safe, and environmentally sustainable. Hybrid rocket propulsion has emerged as a promising compromise between solid and liquid systems, offering significant advantages such as thrust modulation, restart capability, throttling, safer handling and transportation, lower development and operational costs, and reduced environmental impact. Despite these benefits, the relatively low regression rate of solid fuels remains the primary limitation hindering their full potential and broader application. Advancing hybrid propulsion research requires a comprehensive understanding of combustion processes and the coupled chemical, thermal, and fluid-dynamic phenomena within the combustion chamber. This becomes particularly important when investigating bio-based propellants, which offer renewability and the potential to reduce the overall environmental footprint. This study introduces a structured methodology aimed at evaluating the chemical, thermal, and mechanical behavior of renewable polymer-based fuels, with a focus on biopolymers, to support the optimal design of hybrid rocket systems and define operational limits under both nominal and extreme conditions. The thermal and chemical properties of the solid fuel are crucial factors to take into account. They include how it decomposes, melts, and reacts during combustion, as well as how these processes depend on material composition and thermal conductivity. Understanding these aspects is fundamental for evaluating the potential of bio-based fuels for hybrid rocket applications. Particular attention is given to polylactic acid (PLA), a renewable and biodegradable polymer that shows promise as a sustainable fuel but also presents significant challenges. Its viscosity changes with temperature, its combustion involves pyrolysis-driven mass loss, and combustion efficiency is still not fully characterized. Furthermore, although PLA is environmentally attractive, its combustion emissions must be assessed to verify its true ecological impact. To address these issues, PLA samples were analyzed using thermogravimetric analysis (TG/DTG) and pyrolysis gas chromatography–mass spectrometry (PyGC–MS). These techniques provided insight into decomposition rates, chemical composition, and pyrolysis products. The findings contribute to assessing the feasibility of PLA and similar bio-based polymers as alternative fuels, paving the way toward safer, cleaner, and more sustainable hybrid rocket propulsion systems.

KN3 |

EXPLOITING LIGHT AS FUEL: FROM MOLECULAR SWITCHES TO PHOTO-RESPONSIVE MATERIALS

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Molecular photo-switches are able to harness the energy of light, undergoing a reversible change in their structural geometry and chemical properties, typically interconverting between two stable forms. This light-induced isomerization changes the molecular properties, such as color, polarity, refractive index, and fluorescence, with applications in areas like photo-pharmacology, data storage, and responsive photonics. Indeed, the introduction of molecular switches in polymeric architectures is one of the main strategies to obtain intelligent materials, whose properties can adapt to the environment or can be controlled ad hoc by external stimuli. Azobenzenes are the most commonly used photo-responsive molecules due to their easy synthesis, wide modulation of optical properties, and lifetime of the cis isomer, which is controlled by selective irradiation. In this communication, I will show several examples of photo-responsive materials based on azobenzene or their analogues to demonstrate the high versatility of these smart materials in using light energy for technological applications. Examples will include solar thermal fuels, able to store light as chemical energy within their molecular bonds, or soft actuators able to transform directly the light input into mechanical work. The combination of advanced lithographic techniques with photo-responsive polymers will be shown as a powerful tool for the realization of micrometric robots entirely powered by light and able to walk on surfaces, swim, or manipulate micrometric objects

KN4 |

ADVANCING PACKAGING SYSTEMS: INNOVATION-DRIVEN STRATEGIES FOR SUSTAINABILITY, FUNCTIONALITY AND SAFETY

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In the evolving landscape of global food systems, packaging plays a pivotal role in addressing the key challenges of sustainable food consumption, as it ensures quality and safety while minimizing losses throughout the whole supply chain. When properly designed and tailored to specific food preservation needs, packaging can significantly extend the shelf life and reduce food waste. At the same time, next generation packaging must tackle the urgent issue of environmental sustainability. This is increasingly critical considering recent legislative developments, such as the Packaging and Packaging Waste Regulation (PPWR), which sets ambitious targets for recyclability, reuse, and overall waste reduction across the European Union. Achieving these objectives requires a shift in mindset—one that views food and packaging as a single, integrated system whose sustainability must be optimized holistically. This presentation explores how packaging can be a key enabler of sustainable food systems by simultaneously reducing food losses and the environmental burden associated with packaging production and disposal. Central to this is the adoption of eco-design strategies, which include: reducing material thickness and weight, developing mono-material structures to enhance recyclability, incorporating renewable, biodegradable or compostable materials, using recycled polymers with validated safety, converting plastics to paper-based alternatives, and valorizing agro-industrial by-products as raw materials or functional additives. However, sustainability alone is not sufficient, as packaging must also maintain satisfactory functional performance. Emerging technologies such as high-barrier coatings, surface plasma treatments, nanocomposite structures, and smart packaging solutions are being developed to achieve multifunctional packaging that offer tailored barriers, mechanical and sealing performance, while still aligning with sustainability goals. Several case studies will be presented to illustrate how such innovations can lead to packaging systems that are both high-performing and environmentally responsible. In this scenario, safety remains a fundamental requirement. Although the use of recycled and bio-based materials is expanding, ensuring their suitability for food contact is essential. The potential presence of non-intentionally added substances (NIAS) or other contaminants will be discussed, requiring careful monitoring and compliance with food safety regulations. Finally, the presentation will underline the importance of early-stage guidance tools for packaging developers and users to facilitate material selection and accelerate innovation. In this context, conducting Life Cycle Assessment (LCA) emerges as a scientifically grounded framework for comparing alternative solutions and quantifying their impacts across multiple environmental categories, thereby supporting informed, responsible, and strategic decision-making.

KN5 |

TRADITION AND INNOVATION IN RAW EARTH ARCHITECTURE

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Raw earth is one of the oldest building materials used by humans. Numerous studies and research projects have catalogued the many earthen structures built in many parts of the world since ancient times. Today, earthen architecture is considered an architectural heritage to be studied and preserved, but it is not commonly used to construct contemporary buildings, except in very rare cases. In recent years, however, interest in raw earth as a building material has been rekindled for two main reasons: on the one hand, because it is widely available almost everywhere and, on the other, because of the low energy impact it has in the production processes of building materials. Research in the field of innovation in raw earth construction is therefore undoubtedly undergoing rapid evolution, as demonstrated by many of the experiments exhibited at the last Venice Architecture Biennale curated by Italian architect Carlo Ratti. The exhibition also documents how these innovation processes are closely related to the use of new design and construction processes that employ automation, parametric design, and digital manufacturing. The work presented here provides an overview of this evolving research and illustrates some of the most significant experiments carried out by the FabLab POLIBA research group, the digital manufacturing laboratory at the Polytechnic University of Bari, which has been investing in research in the field of innovative raw earth for several years.

Vision of a suburban park project that uses an innovative prototype from the POLIBA FabLab research group.

SESSION 1

S1-1 |

ANTIOXIDANT SMART COATINGS BASED ON QUERCETIN FOR PRESERVING FRESH-CUT AVOCADOS

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Fresh-cut produce is particularly vulnerable to oxidative degradation, which negatively impacts sensory attributes such as color, texture, and flavor, along with reducing nutritional quality. Oxygen exposure accelerates these deterioration processes and raises food safety concerns due to the formation of reactive oxygen species. In this context, smart packaging technologies integrating natural antioxidants into biodegradable materials are emerging as sustainable and effective strategies to extend the shelf life of fresh-cut foods. Quercetin, a plant-derived flavonoid, is attracting growing interest in the development of functional packaging due to its well-documented antioxidant, antimicrobial, and anti-inflammatory properties. Moreover, its classification as Generally Recognized as Safe (GRAS) makes it suitable for food-contact applications. This study explores the development of an active biodegradable packaging film by coating a substrate composed of polybutylene succinate (PBS) and polyvinyl alcohol (PVOH) with a polylactic acid (PLA)-based layer containing Quercetin (QUE). The PBS/PVOH substrate was selected for its optimized mechanical and barrier properties and coating technology was adopted to preserve the bioactivity of quercetin, which is thermally sensitive and could degrade during conventional film processing. The PLA coating was enriched with increasing concentrations of QUE (3%, 5%, and 7% w/w_{PLA}) to evaluate the influence of active compound loading on the film's performance and antioxidant release behavior. The resulting films underwent comprehensive characterization to evaluate chemical, thermal, mechanical, and barrier properties, as well as sealing behavior. Antioxidant performance was tested using DPPH radical scavenging assays in 95% v/v and 10% ethanol v/v to simulate fatty and aqueous food environments, respectively. The release kinetics of quercetin in both simulants were also studied and modeled. Results revealed that antioxidant activity increased with higher quercetin content, particularly in fatty simulants, where up to 77.3% activity was observed at 7% QUE, accompanied by faster release rates. In contrast, in aqueous simulants, antioxidant performance was lower, and release occurred more gradually, extending up to 18 hours. This behavior highlights the importance of the food matrix in modulating the release and efficacy of active compounds. Additionally, the films demonstrated adequate barrier properties to oxygen, carbon dioxide, and water vapor in maintaining the quality of high-respiration fresh-cut fruits. Shelf-life testing on avocado slices confirmed the effectiveness of the active films in delaying oxidative browning and quality deterioration. These results highlight the potential of biodegradable smart packaging with natural antioxidants like quercetin, offering both enhanced food preservation and reduced environmental impact in line with current sustainability demands.

S1-2 |

4D PRINTING OF CROSSLINKED POLYCAPROLACTONE SYSTEMS WITH ONE-WAY AND TWO-WAY SHAPE-MEMORY BEHAVIOR

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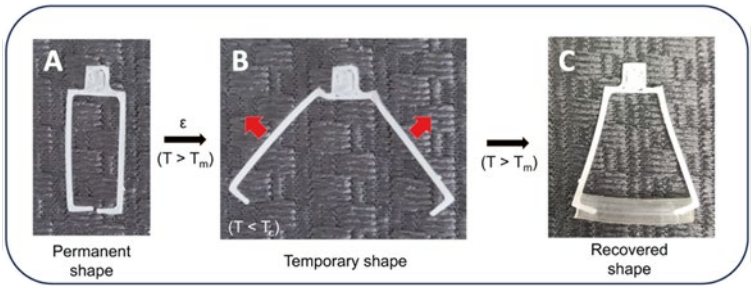
Over the last few years, several 3D printing techniques have been employed for shape-memory polymers (SMPs), including extrusion-based, digital light processing, and material jetting approaches. However, the SMPs used in 4D printing are generally studied only for their one-way shape-memory effect (SME), significantly limiting the breadth of possible applications, e.g., when a reversible behavior of the printed structures is needed. In this panorama no works have been found in the literature on the 4D fabrication via fused deposition modeling (FDM) technology of structures with reversible, two-way SME. This work introduces a novel approach to 4D printing tailored structures with two-way SME via FDM technology. Methacrylated poly(ε-caprolactone) was synthesized and evaluated from a rheological perspective to determine its suitability for FDM. Following a printability assessment, an optimal set of printing parameters (pressure, temperature, speed) was identified to fabricate 3D structures, UV-crosslinked during printing. A physicochemical (gel fraction) and thermo-mechanical (DMA, DSC) characterization was then carried out to evaluate the performance of the obtained structures. When tested for their one-way shape-memory behavior, the printed structures displayed excellent shape fixity and recovery rate values (both > 95 %). Moreover, the printed structures displayed remarkable two-way shape-memory behavior (under load) under multiple heating/cooling cycles and different pre-strains. As an overview of potential applications, 4D printed structures with significant promise in multiple research and industrial fields were fabricated (Figure). Lastly, the obtained structures were *in vitro* challenged on HS-5 cells, showing no cytotoxic effects resulting from their synthesis or the presence of other cytotoxic compounds. These results support further investigation of these structures for biomedical applications. This work opens the floodgates to implementing 4D printing via FDM, specifically targeting structures with two-way SME. Because of its cost-effectiveness, user-friendly nature, and wide availability of thermoplastic polymers, FDM offers noteworthy advantages over other additive manufacturing approaches when a reversible behavior of the printed structures is needed.

This work was funded by the European Union ERC CoDe4Bio Grant ID 101039467



Representative structure of a 4D printed gripper: A) permanent shape after fabrication, B) temporary shape obtained by deforming the gripper at high temperature (T > Tm) and fixing it at low temperature (T < Tc), and C) recovered shape after reheating above the transition temperature (T > Tm), demonstrating its ability to grap an object (a small tube).

S1-3 |

HEXAGONAL BORON NITRIDE: SAFETY ASSESSMENT AT THE SKIN LEVEL

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Hexagonal boron nitride (hBN) is a promising two-dimensional (2D) nanomaterial that is attracting considerable interest in scientific and industrial fields thanks to its revolutionary physico-chemical properties. However, the increasing development of hBN technological applications requires a careful evaluation of its impact on human health, acquiring robust and reliable toxicological data. Cutaneous contact is one of the most feasible exposure routes both for workers, involved in hBN manufacturing, and consumers of hBN-enabled nanotechnologies.The present study aimed at investigating the toxicological potential of hBN at the skin level using an in vitro approach. In detail, two models with different levels of complexity were considered: a simplified one, composed of human epidermal keratinocytes (HaCaT cells), and a more predictive and complete tool, represented by the three-dimensional (3D) reconstructed human epidermis, mimicking all the functional and morphological features of an intact skin tissue. According to transmission electron microscopy and structured illumination microscopy analyses, HaCaT cells were able to significantly internalize hBN particles. The material was clearly accumulated into cytoplasm mainly around nuclei, but without penetrating them. However, despite its significant uptake, hBN exerted only weak adverse effects on keratinocytes, such as slight alterations of cells parameters indices of cytotoxicity (cell viability, cell mass and plasma membrane integrity) and mitochondrial-related dysfunctions (mitochondrial depolarization, ATP depletion and reactive oxygen species production), detectable only at high concentrations (>25 µg/mL) and mainly after a long exposure (72h). In addition, the adoption of two Test Guidelines (TGs) defined by the Organization for Economic Cooperation and Development (OECD) No. 431 and 439 on the 3D reconstructed human epidermis model demonstrated that hBN is a non-corrosive and non-irritant material, with a particularly low pro-inflammatory potential. Altogether, these results denote a good biocompatibility of hBN with the skin contributing to the elucidation of its toxicological profile and to the definition of its safety at the cutaneous level, acquiring a particular interest for a safe use of hBN-enabled nanotechnologies directly in contact with the skin.

S1-4 |

HYDROGEL SUPPORT LIGNIN-BASED FOR MICROGREENS CULTIVATION

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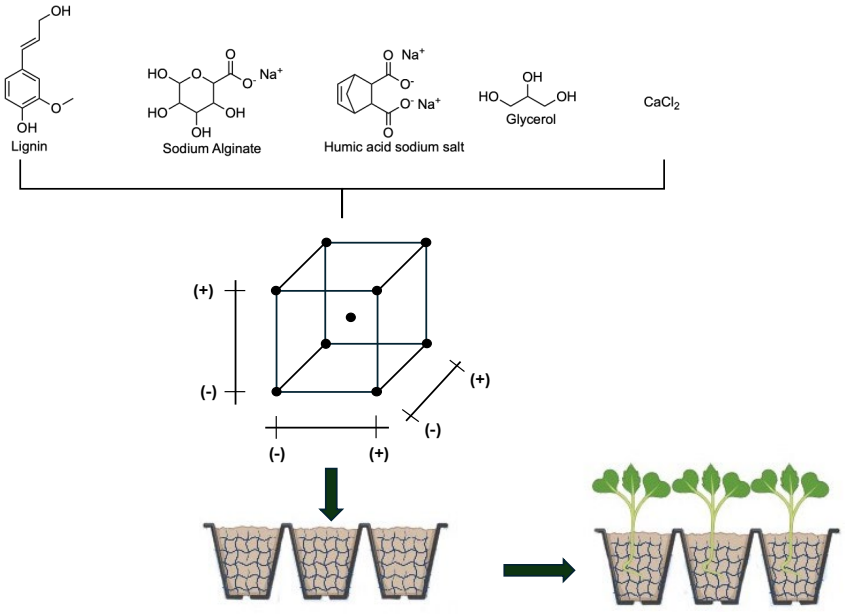
Microgreens are edible seedlings harvested shortly after germination, they have attracted growing interest due to their high nutritional value and short cultivation cycle. Their production, however, demands efficient, sustainable substrates capable of supporting rapid and uniform growth, particularly in urban or indoor farming systems. In this context, lignin-based hydrogels may offer a promising alternative. Lignin is an abundant byproduct of the pulp and paper industry; it is a biodegradable aromatic biopolymer that can be used to develop hydrophilic materials capable of water retention and controlled release. The aim of this study was to develop and optimize a lignin-based hydrogel as an innovative substrate for microgreens cultivation, using a factorial design approach to identify the most effective formulation. A two-level factorial design was employed to assess the influence of five independent variables: lignin, Sodium Alginate, Glycerol concentration (w/w%), Humic Acid Salt Sodium concentration (w/w%) and cross-linker dosage (calcium chloride). This approach required 25 experiments, and it was also studied the middle value's hydrogel: these experiments were performed in twice replicates. Experimental results should identify the optimal formulation based on physio-chemical proprieties and nutrient release behavior. In conclusion, lignin-based hydrogels demonstrate strong potential as sustainable and biodegradable substrates for microgreens production. This approach contributes to the valorization of lignocellulosic waste materials, aligning with circular economy principles. The factorial design methodology proved to be an effective tool for rapid optimization of the hydrogel formulation.



Factorial design to identify the optimal formulation.

S1-5 |

LIPID NANOPARTICLES DESIGN, KINETICS OF ASSEMBLY AND STABILITY: A TIME RESOLVED SAXS INVESTIGATION

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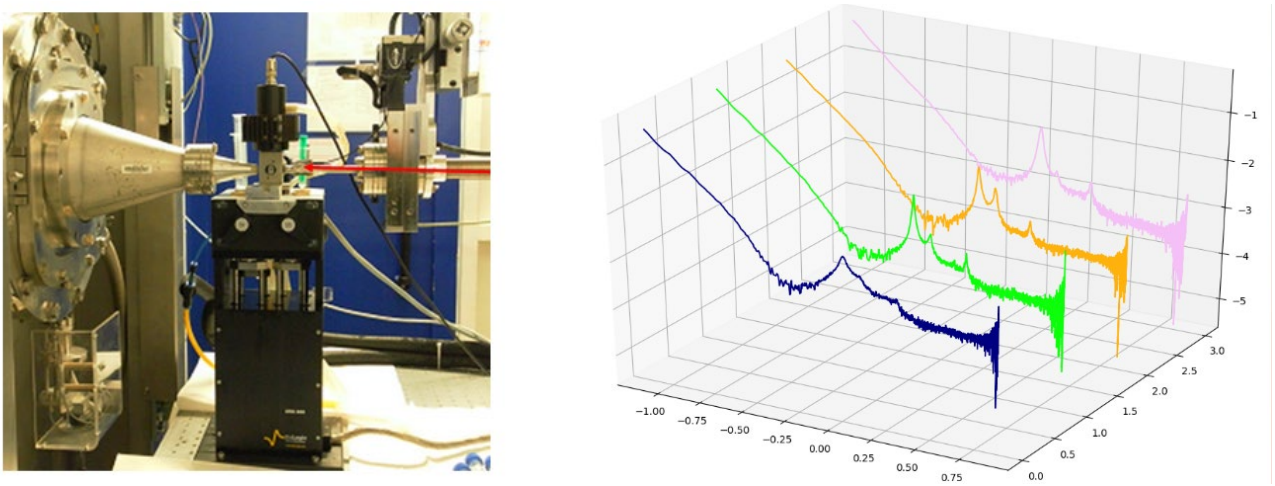
Lipid-based nanocarriers are currently the emergent technology for drug delivery, owing to the enhanced capability to load and protect the bioactive cargo, improve intracellular transport and release with minimal citotoxicity. Since their approval for clinical usage both as vectors for vaccines, anticancer drugs and gene therapy, several lipid nanocarrier formulations were investigated to obtain optimal physicochemical properties and enhanced therapeutic efficacy. However, despite their proven clinical success, precise knowledge of the mechanisms governing these processes is still lacking. Among the factors influencing structure, stability and intracellular uptake, the choice of lipid components plays a major role. Generally, the main constituents are helper/structural lipids (i.e. phospholipids and cholesterol), that provide stability and membrane fusogenicity. Then, ionizable lipids are employed to improve cargo encapsulation and protection from leakage. Finally, surfactant stabilizers or polyethylene glycol-lipids coatings are used to enhance stability and *in vivo* circulation time. Nevertheless, little is known up to date on the influence of pegylated lipids on lipid phase kinetics of assembly, stability and functionality. Thus, careful manipulation of composition and relative abundance results in dramatic modification of physicochemical properties and functionality. Microfluidic-assisted preparation of lipid-based nanocarriers allows to obtain monodisperse and stable formulations with high reproducibility, boosting screening and optimization potential for rapid clinical translation. In this work, high-throughput screening and optimization of lipid nanocarriers as candidates for drug delivery is proposed. Microfluidic synthesis allowed to screen a large set of lipid components, surface coatings and relative compositions following an experimental design approach. Supramolecular characterization by means of Dynamic Light Scattering, Zeta potential, Small Angle X-ray Scattering, and kinetics of assembly by Time-resolved Small Angle X-ray Scattering (Figure) allowed to investigate physicochemical and kinetic properties of optimized nanocarriers.



Stopped-flow rapid mixing setup (left) triggering Time-resolved SAXS measurements (right).

S1-6 |

EASY ACCESS TO TETRAHYDRO-[1,4]DIAZEPINO-INDOLES THROUGH INTRAMOLECULAR CYCLIZATION

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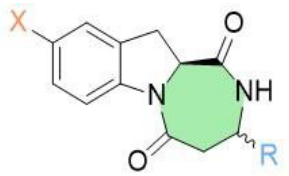
Diazepines are privileged scaffolds in medicinal chemistry, comprising a seven-membered ring with two nitrogen atoms that confer significant structural and functional versatility. These frameworks are core components of many bioactive compounds, particularly in the central nervous system (CNS), as exemplified by benzodiazepines. When fused to aromatic systems, diazepines give rise to structures like benzodiazepines and indolobenzodiazepines, both associated with psychoactive and pharmacological properties. In this work, we present a concise two-step synthetic strategy for accessing a novel class of 1,4-diazepine derivatives, specifically (S)-tetrahydro-[1,4]diazepino-indole-1,5-dione, which has demonstrated CNS- related pharmacological potential. The synthetic route features (2S)-indoline-2-carboxylic acid, a non- proteinogenic amino acid extensively studied by our group for its unique conformational behaviour. Unlike proline, which favours the trans-amide configuration, (2S)-indoline strongly promotes the cis- amide conformation, especially in polar solvents. This intrinsic preference facilitates intramolecular cyclization, a feature we exploit in constructing the diazepine ring. Structural diversity is achieved through coupling (S)-Ind-OMe with various β^3-amino acids, offering tunability of the diazepine side chains. Additionally, selective halogenation of the indole ring allows for late-stage functionalization via cross-coupling reactions, further expanding the accessible chemical space and enabling the design of novel CNS-active compounds.



R= side chain of any Amino acid
X= halogen

(S)-tetrahydro-[1,4]diazepino-indole-1,5-diones.

S1-7 |

ANTIMICROBIAL BIONANOCOMPOSITES FOR SUSTAINABLE FOOD PACKAGING

Montefusco AV[1,2,3], Izzi M[2,3], Pugliese A[2], Sportelli MC[2,3], Pasqualicchio M[4], Incerti O[4], Sanzani SM[4], Cioffi N[2,3], Picca RA[2,3]

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In recent years, the increasing presence of microplastics in the environment has raised serious concerns about human and ecosystem health. Despite being widespread in aquatic systems, they have been identified in human biological samples, such as blood, breast milk and placentae. Therefore, more sustainable and less toxic alternatives for food packaging development are needed. Natural biopolymers, such as zein, casein and sodium alginate, have good film-forming properties and are biodegradable. However, they show mechanical fragility and have poor antimicrobial activity. One promising strategy to overcome these limitations is to incorporate functional nanoparticles in the biopolymeric matrix, thereby imparting new properties to the film. In this study, we present freestanding zein/casein films containing silver nanoparticles (AgNPs), as well as Ca^{2+}-crosslinked sodium alginate films entrapping zinc oxide nanostructures (ZnO NSs). AgNPs were synthesised using a chemical reduction process, whereas ZnO NSs were prepared by a green electrochemical-thermal route. The nanomaterials were incorporated into the film-forming solutions and the layers were produced by dry casting. Spectroscopic and morphological studies (UV-Visible, FTIR, XPS, TEM and Optical Microscopy) were performed to characterise the bionanocomposites. Moreover, water uptake and ion release tests were also carried out. The solubility aspect was also evaluated by swelling tests. Antifungal tests were carried out against plant pathogens such as *Alternaria alternata* and *Botrytis cinerea*. The results obtained indicated that the developed films possessed antimicrobial properties and promising structural characteristics, making them valid alternatives to conventional plastics, in particular for applications such as biodegradable coatings for the preservation of fruits and vegetables.

AVM acknowledges funding by the European Union –NEXTGENERATIONEU – NRRP MISSION 4, COMPONENT 1.

S1-8 |

ADVANCED MICROFLUIDIC STRATEGIES FOR CORE-SHELL NANOPARTICLES

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The scalable and reproducible production of pH-responsive nanoparticles is a major challenge in the development of advanced drug delivery systems. Conventional batch synthesis methods, such as nanoprecipitation and emulsification, often result in broad size distributions and significant batch-to-batch variability, limiting their clinical and industrial applicability. In this work, we employed lab-on-chip microfluidic systems to produce pH-responsive polymeric NPs with superior control over size, dispersity, and functionality. Ring opening polymerization (ROP) followed by two reversible addition-fragmentation chain transfer (RAFT) polymerization steps were performed to synthetize((PHEMA-graft-LA_{12})-co-PMAA)-b-PDEGMA. This strategy enables precise control over molecular weight, macromolecular architecture, and the incorporation of ionizable functionalities. These copolymers were specifically engineered to undergo conformational and solubility changes in response to acidic pH, a behavior driven by the presence of methacrylic acid units, which become protonated in acidic environments such as endosomes or tumor tissues, thus enabling controlled drug release. Continuous-flow nanoprecipitation was carried out in microfluidic lab-on-chip devices fabricated from PDMS, integrating circular geometries to ensure rapid mixing and minimize coalescence. Compared to conventional batch synthesis, the microfluidic approach consistently yielded nanoparticles with polydispersity index (PDI) values below 0.1, indicating an exceptionally narrow size distribution. These values represent a substantial improvement over the PDI of 0.2/0.3 typically obtained in batch processes. Functionally, the microfluidic-synthesized NPs exhibited sharper and more reproducible pH-responsiveness. In acidic environments (pH 5.5), simulating intracellular compartments such as endosomes, the particles underwent a rapid and targeted release of encapsulated compounds. At physiological pH 7.4, the NPs remained stable, maintaining their structural integrity and preventing premature drug leakage. The enhanced responsiveness is attributed to the improved control over polymer self-assembly kinetics and solvent exchange rates enabled by the microfluidic setup. The lab-on-chip platform also offers key advantages in terms of sustainability and process intensification. Reduced solvent consumption, minimized reagent waste, and the ability to conduct real-time monitoring through optically transparent microchannels make it ideal for iterative optimization and potential scale-up. These findings demonstrate that lab-on-chip microfluidics enable the continuous synthesis of highly uniform, pH-responsive nanoparticles with PDI < 0.1, outperforming batch synthesis both in quality and functional performance. This approach represents a significant step forward toward the industrial adoption of smart nanocarriers for biomedical applications.

S1-9 |

INNOVATIVE DECELLULARIZATION OF PLANT-BASED SCAFFOLD FOR FAT REGENERATION IN CULTURED MEAT

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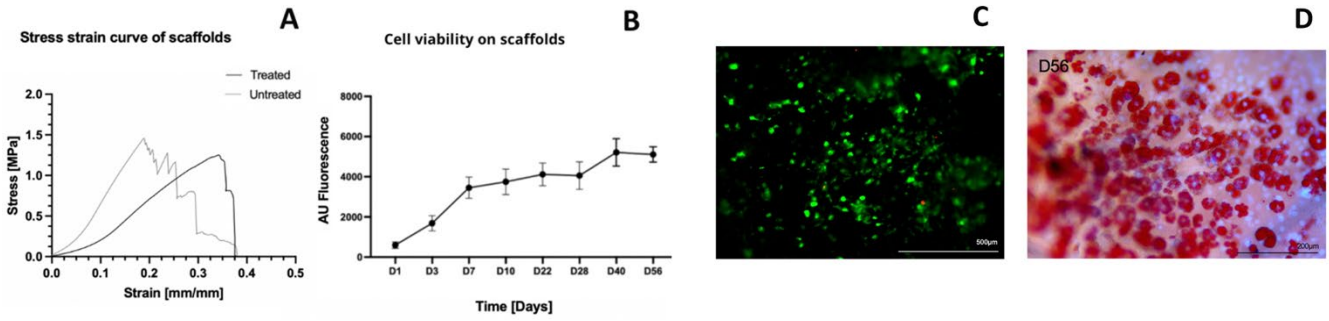
Research on cultured meat has intensified, with 3D scaffolds for muscle and fat cell growth representing a major challenge. Cell seeding onto plant-based scaffolds requires tissue decellularization, but existing protocols have limitations in scalability, efficiency, and reagent consumption. This work investigates the decellularization of savoy cabbage using reduced time and SDS concentrations. A microwave-assisted decellularization was performed by immersing samples in low concentrated SDS solution at 80°C for 3 hours. Scaffolds were then washed and sterilized. Decellularization efficiency was shown by DAPI staining, and mechanical tests confirmed that scaffold structural integrity was preserved. Cytocompatibility was assessed by culturing 3T3-L1 preadipocytes on 8 mm scaffold samples. Metabolic activity and viability were analyzed up to 56 days using Alamar Blue and LIVE/DEAD assays. Adipocyte differentiation was verified during the cell colture through Oil Red O and Nile Red staining. The results demonstrate that plant-based scaffolds for cultured meat can be generated via microwave-assisted decellularization with reduced time and low SDS consumption. Cytotoxicity studies confirmed scaffold biocompatibility, and savoy cabbage scaffolds successfully supported preadipocyte differentiation, highlighting their potential for developing adipose tissue components in cultured meat applications.

This work was supported by "Food for Future: 3D plant-derived structures to produce adipose tissue as innovative food ingredient for cultured meat" PRIN 2022, 2022APBX8X.



Overall, there are no changes in mechanical properties befor and after the decellularization treatment (a). Cell viability increases in 56 days (b); the result of LIVE/DEAD and Oil Red O staining are positive (c, d).

S1-10 |

PREPARATION AND CHARACTERIZATION OF ACID-FREE CHITOSAN HYDROGELS AS SCAFFOLD FOR FAT CULTURED INGREDIENTS

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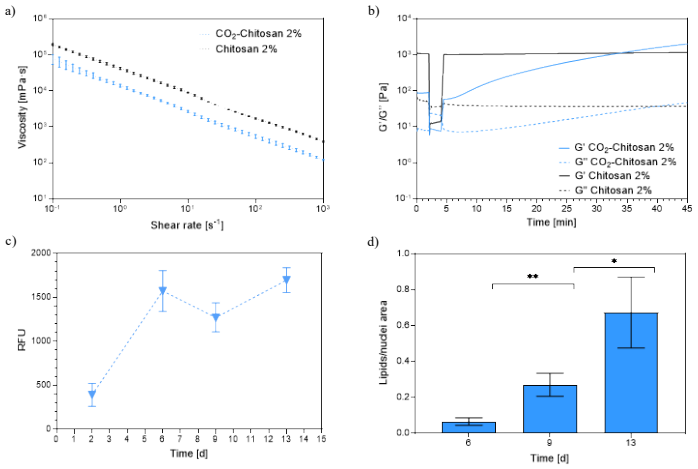
Replicating the fat component of meat is a critical challenge in the cultured food industry. Chitosan hydrogels are widely used in food industry and as scaffold for fat tissue mimicry, with some limitations in terms of the residuals of organic acids commonly used for wet processing compromising cell viability, organoleptic properties, and product safety. This work investigates a novel approach to fabricate cell-loaded acid-free chitosan hydrogels for cultured fat ingredients, by exploiting water carbonation reversibility. Acid-free chitosan hydrogels were prepared by means of an initial dissolution of chitosan in aqueous organic acid, subsequent neutralization, and re-dissolved in water by introducing carbon dioxide (CO_2). Upon CO_2 evaporation, acid-free hydrogels (CO_2-chitosan) were obtained, effectively eliminating residual acids and resulting in homogeneous materials. The obtained hydrogels remained stable in cell culture conditions for over 9 days, with a moderate weight loss (~35%). Rheological characterization revealed reduced viscosity and storage modulus compared to conventional hydrogels, indicating improved water interaction and extrudability due to carbonic acid-induced protonation. Hydrogels showed shear thinning behavior, making them suitable for the standard cell seeding protocol, and a potential (bio)ink. A three-step oscillation test confirmed that post-printing CO_2 evaporation restored the mechanical properties to levels comparable with conventional chitosan hydrogels, potentially minimizing shear-induced cell damage (Fig. 1a-b). Biological characterization revealed cell viability exceeding 70% in indirect cytotoxicity test, confirming the absence of acidic residues in the hydrogel. 3T3-L1 preadipocytes have been homogeneously seeded within the hydrogels by standard mixing with syringes, and showed good cell viability. A second innovative approach involving the encapsulation of pre-differentiated adipocytes pellets, was explored to overcome current limitation in functional adipose tissue production: metabolic activity, assessed via the Alamar Blue assay, increased over time, indicating good cell viability (Fig 1c). To confirm the maintenance of the adipocyte phenotype, Oil Red O staining was performed, and a semiquantitative test indicated sustained lipid droplet formation increasing over time (Fig. 1d). This study presents an efficient method for producing cultured fat ingredients, using acid-free chitosan hydrogels, overcoming current limitations and improving biofabrication properties. Future research will focus on the integration of animal-derived stem cells and incorporation of additives into chitosan to improve cell adhesion and consumer-relevant attributes.

Authors acknowledge "Food for future: 3D plant-derived structures to produce adipose tissue as innovative food ingredients for cultured meat" PRIN 2022, 2022APBX8X.



a) Viscosity vs shear rate curves; b) Three step oscillation test as simulation of printing process; c) Cell viability of adipocytes pellets encapsulated into CO_2 chitosan hydrogels; d) Lipid formation over time through semiquantitative evaluation.

S1-11 |

FIRST 3D VIRTUAL HISTOLOGY OF PRIMATE BACULUM VIA NANO-CT

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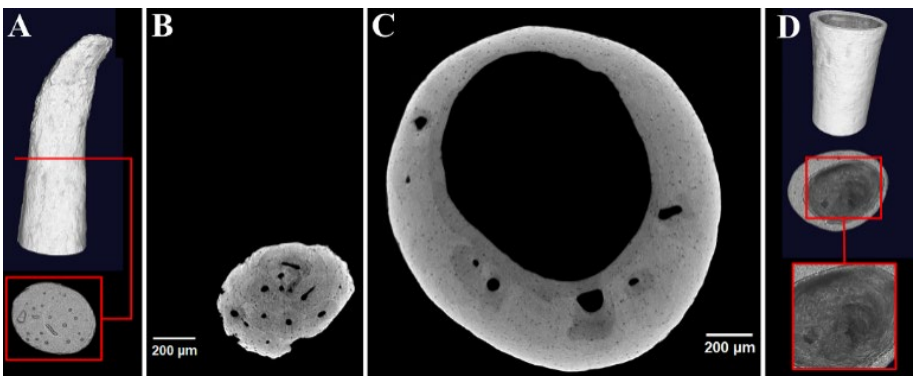
The *baculum*, or os penis, is a fascinating and highly variable skeletal structure found in many mammalian species, including primates. Despite its evolutionary and functional significance, its internal histological organization remains largely undocumented - particularly at high resolution and through non-destructive approaches. In this study, we present the first nanometric-scale virtual histological description of the *baculum* in two adult male primates belonging to distinct evolutionary lineages: *Lemur catta* (a strepsirrhine primate specimen of 6 years old) and *Sapajus apella* (a New World monkey specimen of 7 years old). These two species not only differ phylogenetically, but also anatomically in terms of *baculum* positioning. In *L. catta*, the *baculum* extends beyond half the length of the penis, whereas in *S. apella* it is restricted to the distal portion. High-resolution 3D scans were acquired using nano-computed tomography (nano-CT) at CNR-IPCB, with an optical setup providing a spatial resolution of 1.3 µm/pixel. The scanning sessions lasted between 6 and 12 hours, depending on the number of projections set for each acquisition, in order to ensure optimal contrast and image quality while preserving the integrity of the samples. The imaging clearly revealed a compact lamellar structure in both *bacula*. Key histological features such as secondary osteons, external circumferential lamellae, Haversian and Volkmann's canals, and bone lacunae - interpretable as osteocyte imprints - were clearly visible, enabling a virtual histological analysis comparable to conventional microscopy. A notable difference emerged in the internal organization of the two specimens. In *L. catta*, osteons densely filled the entire cross-section of the bone, forming a uniform and mature cortical structure. In contrast, in *S. apella*, osteons were fewer and arranged around a large central cavity. The nature of this cavity remains speculative; possible explanations include the presence of bone marrow, vascular or erectile tissue, or a remodeling process. However, age-related resorption appears unlikely, as both individuals were young adults. This study demonstrates the potential of nano-CT as a powerful non-destructive tool for investigating skeletal microstructures in rare or valuable biological samples. The findings provide new insights into primate genital bone morphology and highlight the broader applicability of advanced imaging in evolutionary, functional, and reproductive anatomy.



3D reconstruction (A, D) and transverse virtual histological sections (B, C) of the baculum in Lemur catta (A, B) and Sapajus apella (C,D).

S1-12 |

STRUCTURAL DYNAMICS OF LIGHT RESPONSIVE LIPID NANOPARTICLES REVEALED BY TIME-RESOLVED SMALL ANGLE XRAY SCATTERING

Talarico L[1,2], Clemente, I[1,2], Gabbricci G[1,2], Mavromatidou E[1], Cataldini S[1], Chen J.L.[1], Sutinen S. A.[3], Blanchet C[3], Magnani A[1,2]

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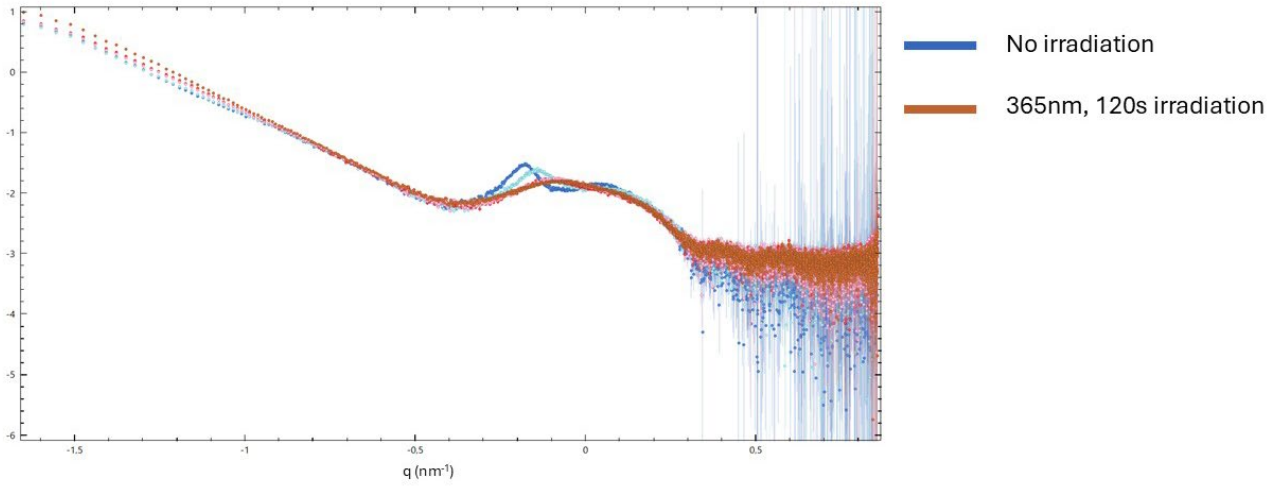
PEG-functionalized lipid nanocarriers are conventionally employed to obtain stealth delivery systems to avoid recognition from the immune system, thus reaching safely the target tissue. However, PEG surface coating also results in hindered fusogenicity with cell membranes and/or endocytic processes, as in, the so-called PEG dilemma. A strategy to overcome this challenge is to synthetically design stimuli-responsive PEGylated amphiphiles, that can remove the PEG moieties by selective cleavage under monochromatic light. In this work, time-resolved SAXS was used to investigate the kinetics and yield of PEG cleavage and possible nanocarrier structural transitions following the removal of the surface stabilizer. In comparison, a photo-switchable nanosystem, where a reversible cis-trans amphiphilic switch intercalated in the lipid membrane was used to provoke alterations and pore formation, eventually leading to drug release. This allowed us to investigate the extent of responsiveness of the proposed system, proving the effectiveness of the cleaving process and the nanocarrier stability to progressive coating loss. Information on the millisecond timescale of the kinetics of responsiveness to light-triggered shedding of PEG coating was obtained, as well as the temporal yield of surface modification and structural rearrangements to maintain stability. The pre-formed lipid-based samples with the intercalated photo-responsive PEGylated amphiphiles were triggered with with a near-UV monochromatic light source at 365 nm to irradiate during time-resolved scans acquisition. Complementary UV-Vis and fluorescence measurements of stimuli-responsive molecules were used to assess their process kinetics.



Structural modification on LNP following irradiation with 365 nm laser (from blue to brown curve)

S1-13 |

DRUG RELEASE IN GRADED POLYCAPROLACTONE FOAMS FOR ORAL DELIVERY

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Tablet-shaped polycaprolactone (PCL) foams were manufactured via physical foaming with compressed carbon dioxide used as blowing agent. Gas-induced melting point depression of PCL was exploited to process the polymer at 37 °C. This allowed the production of highly porous carriers under mild thermal conditions, thus preserving the entrapment of temperature-sensitive compounds. Tablet foams were designed with radial gradients in pore size and density, enabling tunable drug release. Curcumin was selected as a model molecule for its high thermal stability and poor aqueous solubility under gastric pH conditions. Entrapment efficiency of about 95% across all tested loadings was achieved, confirming negligible drug loss due to the foaming process. Graded foams were produced by first saturating the polymer at 100 bar and then creating non-equilibrium pressure zones along the spacial direction of the polymer. Scanning electron microscopy revealed pore size gradients in cell structure. This characteristic was responsible of an initial drug diffusion from outermost pores, followed by acid-induced polymer erosion and subsequent delayed drug release from the inner core. A five-parameter mathematical model was developed to describe this double behavior. The erosion onset delay time (τ) varied between 50 and 70 h depending on foaming layer length and theoretical drug loading, offering a tunable control of the release kinetics. Graded foamed tablets represented a good alternative to conventional oral delivery systems, often used as passive reservoirs and responsible for burst release and not-negligible side effects. Io. This work opens the way for future developments, including PCL-based blends for simultaneous entrapment of multiple drugs and pulsed release applications.

S1-14 |

MOLECULAR DOCKING STUDY OF SPOILAGE ENZYME LIPASE: EVALUATING PROBIOTIC METABOLITES AS NATURAL INHIBITORS OF ENZYMATICDEGRADATION

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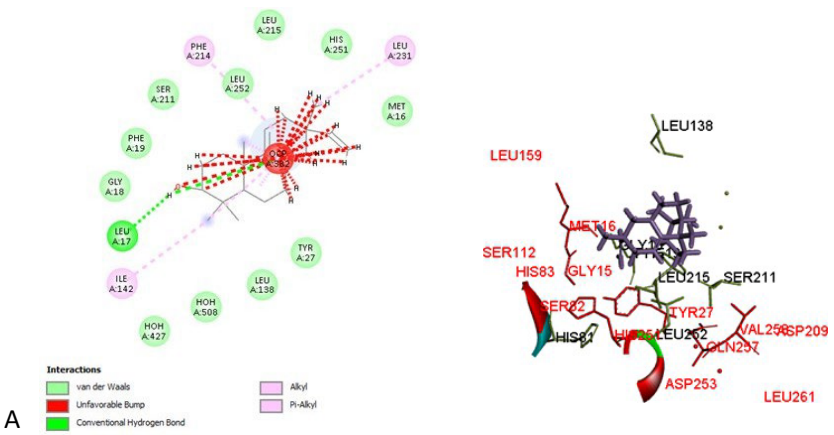
Yogurt spoilage is a persistent challenge in the dairy industry, primarily due to microbial contamination and the enzymatic degradation of lipids. Lipases—especially those produced by psychrotrophic bacteria such as Pseudomonas aeruginosa—are thermostable and remain active under refrigeration, significantly compromising product quality and shelf life. In the context of rising demand for clean-label and sustainable food preservation strategies, probiotic-derived bioactive compounds offer a promising natural alternative to synthetic preservatives. This study evaluates the potential of Lactobacillus reuteri to produce metabolites capable of inhibiting lipase activity. An *in silico* workflow combining genomic mining, molecular docking, and structural analysis was employed. The 3D structure of P. aeruginosa lipase (PDB ID: 1EX9) was retrieved from the RCSB Protein Data Bank. Biosynthetic gene cluster analysis of L. reuteri using AntiSMASH v8.0 identified four predicted secondary metabolites: bacilysin, citreohybridinol, trehangelin A, and viguiepinol. All ligands were energy-minimized using Avogadro (MMFF94 force field), and file conversions were carried out using Open Babel. Blind molecular docking was performed using AutoDock Vina via PyRx, with a maximized grid to ensure broad binding site coverage. Results were validated through re-docking on the DockThor platform. Visualization and interaction analysis were conducted using ChimeraX and BIOVIA Discovery Studio. Among the tested metabolites, viguiepinol exhibited the strongest binding affinity (–8.514 kcal/mol), docking at the lipase active site with Root Mean Square Deviation (RMSD) equal to 1 Å. It formed a hydrogen bond with residue Leu A:17, and a steric clash with RC-(RP,SP)-1,2-Dioctylcarbamoyl-Glycero-3-O-Octylphosphonate (OCP A:382) was observed—suggesting potential interference with enzymatic function. While these in silico findings are promising, further in vitro validation is necessary to confirm biological activity. This work highlights the potential of L. reuteri-derived metabolites as natural lipase inhibitors and proposes their application in smart delivery systems. Probiotic-loaded biodegradable polymers could enable localized, responsive release of inhibitory agents in the presence of spoilage molecules. Such systems may offer innovative solutions for extending yogurt shelf life, enhancing food safety, reducing waste, and supporting sustainable practices in the dairy industry.

This research was funded by PNRR-MISSION 4 COMPONENT 2 INVESTMENT 1.4 CENTRE "National Centre for HPC, Big Data and Quantum Computing (CN1)", (Project code CN00000013, CUP I53C22000690001) by the Italian Ministry of University and Research through NextGenerationEU.



(A) 2D interaction map of Viguiepinol within the active site of 1EX9. (B) 3D representation of Viguiepinol (in purple) bound at the active site of 1EX9.

S1-15 |

SMART AND SUSTAINABLE PACKAGING MATERIALS FOR POST-HARVEST AROMA PRESERVATION IN RASPBERRIES

Zhang J[1,2,5], Khomenko I[3], Pedrotti M[3], Betta E[3], Aprea E[4], Cliceri D[4], Mattina G[4], Endrizzi I[3], Gasperi F[4], Biasioli F[3], Tonezzer M[5]

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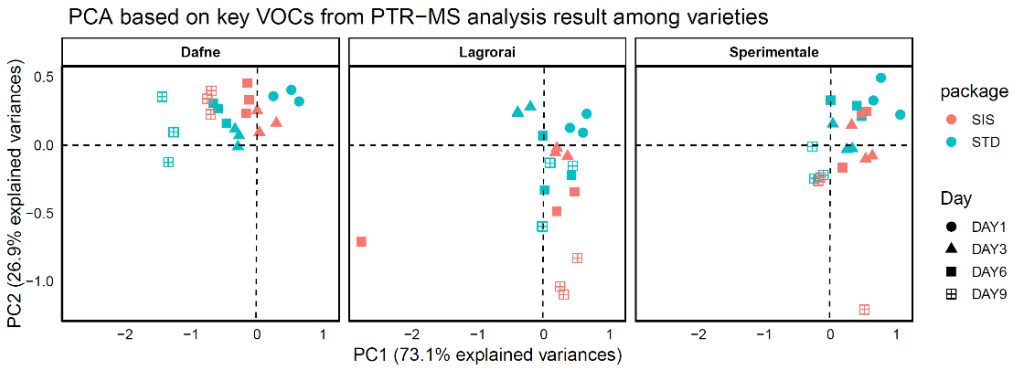
Innovative materials and packaging technologies are essential tools in extending shelf life and reducing post-harvest losses of fresh produce. This study, conducted within the EU Horizon 2020 SISTERS project (GA №101037796), investigates the role of biodegradable and smart packaging in preserving the chemical integrity of raspberries—one of the most perishable fruits in the market. Three raspberry cultivars (Dafne, Lagorai, Experimental) were stored under two packaging conditions: (i) a standard plastic clamshell (STD) and (ii) a novel biodegradable clamshell developed within the SISTERS project (SIS). Volatile organic compounds (VOCs), which are critical to aroma and consumer perception, were analyzed using Gas Chromatography–Mass Spectrometry (GC-MS) and Proton Transfer Reaction–Time-of-Flight–Mass Spectrometry (PTR-ToF-MS) on days 1, 3, 6, and 9 of storage. Multivariate statistical analysis (PCA) revealed that packaging type significantly influences the evolution of raspberry VOC profiles both from PTR-ToF-MS and GC-MS. The SIS packaging preserved a more stable chemical fingerprint over time, while the STD packaging was associated with accelerated oxidative degradation. Key compounds—such as limonene, acetic acid, (E)-2-hexenal, 2-nonanone, and nonanal—served as markers of freshness and indicators of senescence and microbial activity. Importantly, significant differences were also observed among the three raspberry cultivars, indicating varietal influence on volatiles stability and packaging response. Furthermore, the application of PTR-ToF-MS enabled rapid, non-destructive VOC profiling, demonstrating potential for real-time quality monitoring. This work highlights how advanced packaging materials—particularly those that are biodegradable or sensor-ready—can actively contribute to maintaining aroma, reducing waste, and improving the overall quality of soft fruits. The results offer valuable insights for industry stakeholders aiming to implement sustainable and effective preservation solutions, positioning packaging innovation as a key enabler in future food systems.



PCA based on key VOCs from the PTR-MS analysis result among varieties

S1-16 |

INSIGHTS INTO THE STRUCTURE AND SELF-ASSEMBLY KINETICS OF SOLID LIPID BASED NANOPARTICLES

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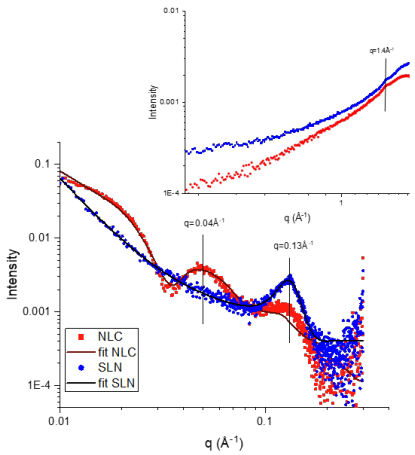
Lipid nanoparticles have emerged as a promising tecnhology for the delivery of both hydrophobic and hydrophilic therapeutics, demostrating an outstanding biocombatibility, biodegradability and entrapment efficiency. Among lipid based nanoparticles, solid lipid nanoparticles (SLNs) posses a crystalline inner struture that offers several advantages as an improved long-term stability, drug protection and controlled, tunable release. However, during storage, the lipid matrix may undergo polymorphic transitions, leading to the expulsion of the encapsulated molecule. To address this limitation, nanostructured lipid carrier (NLCs) have been developed by substuting a fraction of the solid lipid with a liquid lipid, which enhance the storage stability. Despite the benefits offered by SLNs and NLCs, their broad application remains restricted due to the current bulk production methods which lack reproducibility, as well as insufficient knowledge regarding their supramolecular structure and assembly kinetics. Indeed, the organization of lipids, surfactants, and active molecules along with their assembly process directly impact the system's stability, loading capacity and drug release behavior. A deeper understanding of these factors is essential for designing efficient, stable, and tailored drug delivery systems. In this work, an innovative microfluidic apparatus was employed, offering high reproducibility and direct scalability of the synthetical process. It was combined with a design of experiment approach, which allows a systematic study on the influence of independent synthetical and formulation factors on critical attributes of nanoparticles. SLNs and NLCs loaded with a model hydrophobic, and a model hydrophilic molecule were optimized in term of size, PDI and encapsulation efficiency by developing four independent experimental designs varying the lipid and surfactant concentrations and the flow rate ratio. The four optimized formulations exhibited ideal dimensions for interaction with biological membranes, monodispersity and were further characterized using multiple complementary techniques. Differential scanning calorimetry (DSC) was employed to assess the crystallinity of the lipid core, a critical factor that affects drug incorporation and release. The supramolecular structure was investigated with static SAXS measurements, which highlighted the effect of the cargo loading on the lipid organization. Additionally, time resolved SAXS provided direct insight into the kinetics of nanoparticle assembly and the timing modification caused by that the addition of the liquid lipid in NLCs core.



Static SAXS-WAXS of unloaded SLNs and NLCs.

SESSION 2

S2-1|

COMBINATION OF A MESOPOROUS COMPOUND (SBA-15) WITH BCZT TO OBTAIN A MESOPOROUS PIEZOCERAMIC

Caggiu L[1], Cau C[1,2], Pardo L[3], Mulas G[1,4], Orrù R[4,5], Garroni S[1,4]

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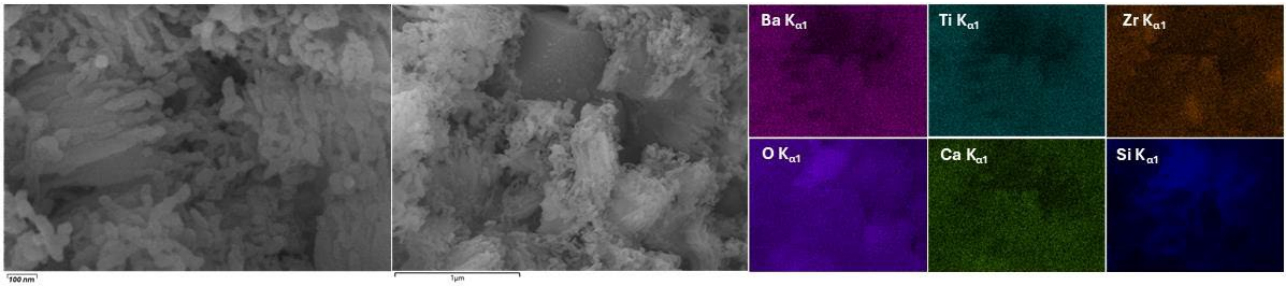
This study explores the integration of the mesoporous silica SBA-15 with the lead-free piezoceramic $(Ba_{0.85}Ca_{0.15})(Zr_{0.10}Ti_{0.90})O_3$ (BCZT) to develop a novel mesoporous piezoceramic material suitable for ultrasound transducer applications. SBA-15, characterized by its highly ordered unidirectional mesopores and large surface area, was used as a sacrificial template to introduce porosity into BCZT via sol-gel process. The BCZT precursor gel underwent thermal treatments at 650 °C and 900 °C, followed by NaOH etching to remove the SBA-15, leaving behind a porous BCZT structure that partially replicates the template's morphology. Structural analysis via X-ray diffraction (XRD) and nitrogen physisorption confirmed the preservation of mesoporous features and revealed changes in surface area and pore volume across synthesis stages. Scanning Electron Microscopy (SEM) analysis reveals that synthesizing at 650 °C with the addition of SBA-15 powder to the BCZT precursor gel prior to calcination results in the formation of ordered, tube- shaped BCZT particles (Fig. 1). Furthermore, Energy Dispersive X-ray (EDX) analysis confirms that these tubular structures possess the BCZT composition. The porous BCZT material shows promise for improved piezoelectric sensitivity in pressure-sensing applications, offering controlled porosity without compromising strength.



SEM anlysis and EDX elemental maps of the synthesis of the mesoporous BCZT treated at 650 °C after the NaOH treatment.

S2-2 |

SUSTAINABLE ENERGY-EFFICIENT ADSORBENTS FOR EFFICIENT WATER REMEDIATION

Cerbone A[1,2], Maglione A[1], Olivieri F[1], Avolio R[1], Cocca M[1], Errico ME[1], Lasala P[3,4], Tahla K[3], Tancredi M[3], Curri ML[3,4,5], Fanizza E[3,4,5], Castaldo R[1], Gentile G[1]

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Water remediation is a global and critical issue due to the increasing presence of contaminants and water scarcity. Adsorption is an efficient and cost-effective method for water treatment. Among many different adsorbent materials such as MOF, clay and activated carbons, micro/mesoporous polymers stand out for their spontaneous uptake, easy regeneration and tailorable porosity and functionality. Specifically, hyper-crosslinked (HCL) resins have gained growing attention because of their advantages such as easy preparation methods, versatile functionalization, high specific surface area (SSA), large microporosity, high chemical and thermal stability and cost-effective precursors. HCL polymers are typically synthetized starting from fossil-based monomers and recently some efforts have been made to replace them with bio-based monomers. In this work, ligno-cellulosic precursors were subjected to extensive crosslinking employing eco-friendly solvents and mild reaction conditions, resulting in high SSA resins (Langmuir SSA ~ 1500 m^2/g) characterized by large micro/mesoporosity. These features are particularly interesting for the capture of persistent organic pollutants. To endow the micro/mesoporous adsorbents of a sustainable regeneration mechanism, doped CeO_2 nanoparticles (NPs) were embedded into the resins porous structure, synergistically combining the adsorption capacity of the bio-based HCL resins with solar light-driven degradation of the pollutants by the CeO_2 NPs. Finally, the nanocomposite HCL resins/CeO_2 NPs were included in cellulose-based light transparent films able to absorb large amounts of water.
Morphological, structural and textural properties of the developed multifunctional adsorbents were analyzed. Adsorption capacity towards ionic organic contaminants like dyes and neutral compounds (i.e. 2,4-dichlorophenol) were tested. Equilibrium adsorption isotherms and kinetics of adsorption towards the model contaminants were assessed, as well as their reusability through repeated adsorption/regeneration cycles. The proposed innovative adsorbents result in easy-to-handle and energy-efficient regenerable systems for water treatment.

The authors acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 1409 published on 14.09.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title "Photocatalytically-regenerable hierarchically porous adsorbents for efficient water treatment" (PHOTOPAD, code P2022FP2W4, 2023-2025), CUP B53D23027540001, Grant Assignment Decree No. 1389 adopted on 01.09.2023 by the Italian MUR.

S2-3 |

AESO-BASED POLYMER COMPOSITES CONTAINING BIOCHAR OBTAINED BY VAT-PHOTOPOLYMERIZATION TECHNOLOGY

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Additive manufacturing (AM) technologies have been emerging as greener alternatives to production technologies for polymeric and polymer composite materials. 3D printing is considered a rapid prototyping tool due to its high printing accuracy, low raw material uses and low wastes production, and the ability to realize objects with complex geometry and good dimensional stability for many application fields, such as automotive, packaging and biomedical. Among the different AM technologies, vat-photopolymerization (VP), represents an easy method for obtaining well-defined objects by 3D printing. It is a light-based technology, which allows to obtain high printing resolution and good level of shape complexity of the printed parts. During the process, the build platform is completely immersed within the photocurable resin and, thanks to the UV light, the liquid resin in the vat can be photocured and transformed in a uniform layer of solid material. The process goes on until the desired object is complete, according to the previously designed CAD model. The present research work highlights to develop novel bio-based composites containing biochar (BC) as biofiller by using the Liquid Crystal Display (LCD) as 3D printing technology. Acrylate epoxidized soybean oil (AESO) resin was used as photocurable polymer matrix, isorbornyl methacrylate (IBOMA) was used as reactive diluent, and phenyl bis (2,4,6-trimethylbenzoyl) phosphine oxide (BAPO) was employed as radical photoinitiator. Biochar coming from cellulose pyrolysis was used to prepare the final composites by dispersing different amounts of filler within the AESO-based matrix. The printed specimens were fully characterized from thermal, morphological, and mechanical point of view. Several 3D printed parts were successfully realized showing very complex structures and improved final properties in terms of elastic modulus, ultimate tensile strength, and glass transition temperature due to the reinforcing effect induced to the presence of the filler's particles, without significant effects on the thermal stability. Cell viability and cytocompatibility tests were also carried out to study their possible applications into the biomedical sector.

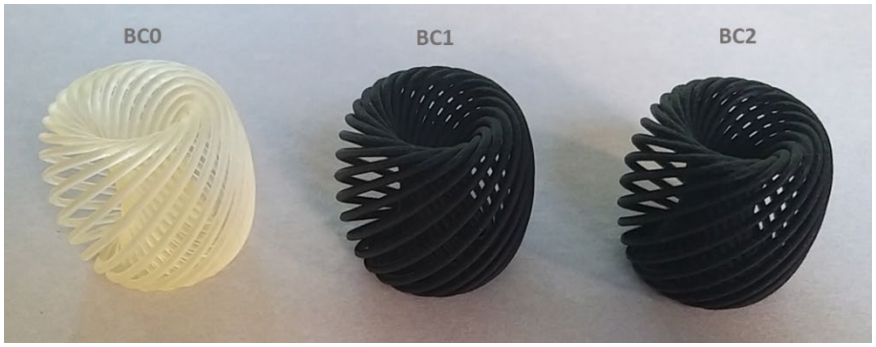

Fig. 3D printed AESO-based objects unfilled and filled with different amounts of BC.

S2-4 |

CHARACTERISATION OF ADDITIVELY MANUFACTURED ALUMINIUM ALLOYS FOR HEAT EXCHANGERS APPLICATIONS

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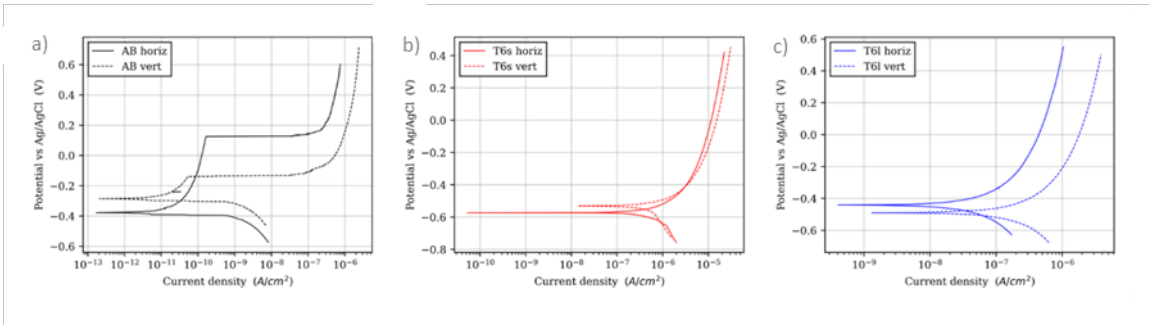
Laser Powder Bed Fusion (LPBF) is an Additive Manufacturing technique that builds complex near-net shape parts layer by layer, such as heat exchangers, used for heat transfer between two media. Commonly, ethylene glycol/water mixtures serve as coolants in these systems, because they are cost-effective and provide good protection against freezing and high temperatures. However, corrosion poses a significant risk of failure in heat exchangers, prompting increased industrial attention on maintenance and repair strategies. In the present study, an innovative A20X aluminum alloy has been selected due to its high strength and thermal conductivity, which makes it an ideal choice for use in a heat exchanger. A20X samples have been built using an EOS M270 Xtended system. Some of the samples underwent post-processing heat treatments needed for the achievement of the desired mechanical properties. Two T6 heat treatments have been considered: the conventional long T6 ($T6_L$), suggested by the powder provider and optimised on cast components of the same composition, and a short T6 ($T6_S$) specifically developed by our research group for LPBF components. Corrosion potentiodynamic polarisation tests have been performed in an ethylene glycol/water solution, and results are shown in Fig. 1. Samples were tested in the as-built (AB) (Fig. 1a), $T6_S$ (Fig. 1b) and $T6_L$ (Fig. 1c) states, maintaining the surface finish typical of LPBF production. Given the geometric complexity of internal channels in LPBF-fabricated heat exchangers, post-processing surface treatments are often impractical and therefore undesirable. The results indicate that the as-built samples are characterised by the highest corrosion resistance, probably due to the intrinsic oxide layer. Heat-treated samples showed reduced corrosion resistance, potentially as a result of oxide layer disruption during water quenching.



Potentiodynamic polarisation curves of A20X samples with rough surfaces in a) the AB, b) $T6_S$, c) $T6_L$ states

This study was carried out within the MOST – Sustainable Mobility National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1033 17/06/2022, CN00000023). This presentation reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

S2-5 |

DESIGN AND DEVELOPMENT OF CU-BASED ALLOYS FOR ADDITIVE MANUFACTURING IN AEROSPACE APPLICATIONS

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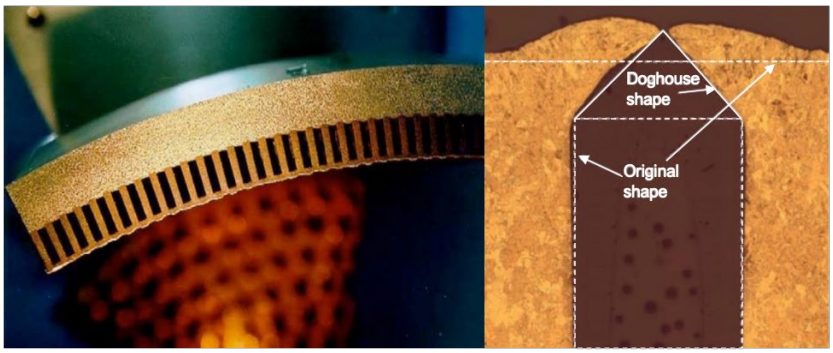
In the pursuit of advancing aerospace technology, one of the most enduring challenges remains the high cost of space exploration. The Space Shuttle era demonstrated the potential of reusable launch systems to reduce expenses, but technological constraints have consistently impeded their widespread adoption. A critical component is the rocket nozzle, which is subjected to extreme thermal and mechanical stresses due to intense heat and pressure, leading to substantial material degradation over time. When conventional heat management strategies fall short, materials with ultra-high melting points, such as molybdenum and Ni-based super alloys, are typically employed. However, their high density makes them less desirable for aerospace applications, where minimizing mass is paramount. In response, copper-based alloys have emerged as promising alternatives, offering a favourable balance between strength and thermoelectrical performances. Early developments included alloys like NARloy-Z (Cu-Ag-Zr) and GlidCop-A115 (Cu-0.03% Al_2O_3). More recent research has focused on copper-chromium systems, particularly those alloyed with elements such as niobium, zirconium, or silver. These additions improve mechanical performance through precipitation strengthening, leveraging the low solubility of the alloying elements to form stable intermetallic precipitates. This approach maintains a high-purity copper matrix, preserving its excellent thermal and electrical conductivity over a wide temperature range. To further enhance the solubility and distribution of these elements, rapid solidification techniques are essential. These approaches are directed in forming a supersaturated solid solution that promote uniform precipitation during subsequent thermal treatments. In this context, metal Additive Manufacturing (AM) technologies such as Direct Energy Deposition (DED) and Laser Powder Bed Fusion (L-PBF) offer a transformative pathway for future alloy development. Their ability to achieve localized cooling rates on the order of 10^5–10^6 K/s enables microstructural control that was previously unattainable using conventional techniques. By integrating advanced alloy design with cutting-edge additive manufacturing, this approach holds significant promise for producing high-performance rocket nozzle materials that meet the rigorous demands of modern aerospace propulsion, paving the way for more sustainable space exploration.



Cut through a Cu-based combustion chamber wall with representative micrograph of the cross setion after failure.

This study was conducted as part of the "BIG – Blue is Green" project, under the framework of the "Agreement for Innovation – Initiative of the Sustainable Growth Fund in support of research and development projects"– MISE 12-2021.

S2-6 |

CROSSLINK DENSITY CHARACTERIZATION IN HNBR: COMPARATIVE ANALYSIS BETWEEN RESULTS OBTAINED BY SWELLING TESTS AND DQ-NMR

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A comparison between the crosslink density values determined by different methods on hydrogenated nitrile butadiene rubbers (HNBR) with varying acrylonitrile (ACN) content, cured by adding different amounts of sulfur, is presented. The mechanical and physical properties of elastomers strongly depend on network characteristics, including average crosslink density, spatial heterogeneity, entanglements, and defect content. An accurate assessment of these features is essential for predicting elastomer behavior. It is shown that coupling two independent techniques for the characterization of network properties —equilibrium swelling tests and double-quantum nuclear magnetic resonance (DQ-NMR)— allows for reaching relevant information. Swelling experiments were performed following the Flory-Rehner theory, considering both affine and phantom network models. These tests account for chemical crosslinks and trapped entanglements, yet their accuracy depends on the validity of thermodynamic assumptions, such as polymer-solvent interactions and the entropy change associated with stretching polymer chains. In contrast, DQ-NMR provides a direct probe of molecular constraints without relying on thermodynamic models. This technique measures the residual dipolar coupling constant (D_{res}), which is directly proportional to crosslink density, and also provides insights into network heterogeneity and defect distribution. The comparison between swelling-based crosslink density (ν_e) and D_{res} revealed notable discrepancies. While both methods showed a general increase in crosslink density with sulfur content, swelling tests overestimated ν_e at low sulfur concentrations and underestimated it at higher crosslink densities. These differences are attributed to the inability of swelling tests to capture temporary entanglements and network heterogeneity, which are instead detected via DQ-NMR. Additionally, swelling tests failed to account for variations in crosslink functionality, while DQ-NMR highlighted the presence of defects such as dangling chains and sol fractions. The study also examined the influence of ACN content on crosslink density. Increase of ACN content led to a decrease of swelling ratio, suggesting reduced solvent compatibility, which affected the accuracy of thermodynamic-based crosslink density estimates. However, DQ-NMR confirmed that network rigidity increased as the ACN content increases, supporting the hypothesis of stronger intermolecular interactions and reduced chain mobility.
Overall, this work demonstrates the limitations of traditional swelling methods in accurately assessing crosslink density, particularly in heterogeneous networks. The integration of DQ-NMR with swelling tests provides a more complete understanding of rubber elasticity and network architecture. It is shown how these findings may contribute to the refinement of predictive models for vulcanized elastomers, providing significant implications for the optimization of HNBR-based materials in industrial applications.

S2-7 |

INTERACTIONS BETWEEN HYDROXYAPATITE SURFACES AND SMALL REACTIVE MOLECULES OF ENVIRONMENTAL INTEREST: A COMPUTATIONAL APPROACH

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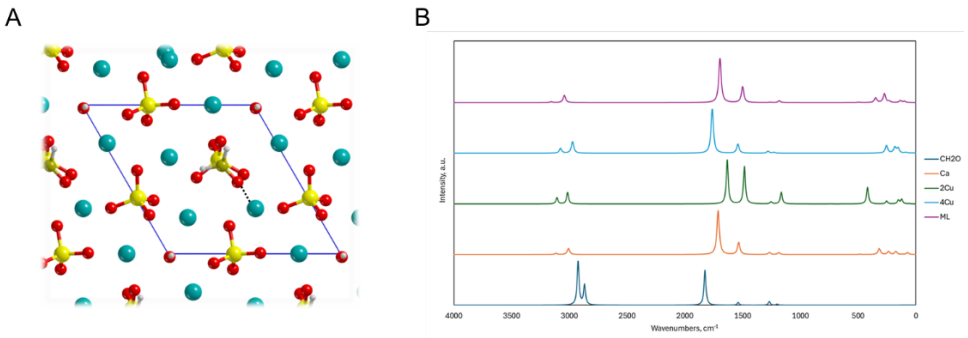
In recent years, hydroxyapatite (HA, $Ca_{10}(PO_4)_6(OH)_2$) has emerged as a highly promising mineral in green chemistry due to its feasible synthesis from waste materials. Its key properties, such as thermal and chemical stability, tunable acid-base characteristics, non-toxicity, great adsorption capacities, and ion-exchange capability, make it an attractive support for eco-friendly catalysts in heterogeneous catalysis aimed at the abatement of various classes of pollutants. Therefore, the nature and strength of the interactions between molecules and the catalyst surface, in terms of energy, are crucial to determining the reaction outcome. In this regard, computational methods have become increasingly accurate in studying such interactions, enabling guided approaches to catalyst design and development. This process has been further accelerated over the past decades due to the rapid advancement in computing power. In this contribution, a periodic quantum mechanical (QM) approach has been employed to characterize the interactions between small reactive molecules and the most stable hydroxyapatite surfaces. Besides HA in its pure form, metal-substituted models will also be considered (with a deep focus on Cu-HA). In fact, it is known that calcium ions can be replaced by various metal ions, including transition metals, to enhance HA's catalytic activity and performance while maintaining its overall structure. More specifically, results will be presented on the interaction of carbon monoxide, as probe molecule able to interact with sites of interest, and simple aldehydes (formaldehyde and acetaldehyde), as benchmark of volatile organic compound class, with the HA (001), (010) (both stoichiometric and non-stoichiometric), (002) and (101) facets, in both pure and metal-substituted hydroxyapatite. Changes in geometrical parameters, energetic properties (i.e., binding energy and enthalpy), and vibrational features will be analysed to establish a preliminary framework for computational investigations on the oxidative decomposition of pollutants in environmental remediation and on their potential conversion into useful materials.



Top view of first atomic layers of HA (002) facet in interaction with a molecule of formaldehyde; B: calculated IR spectrum of formaldehyde on surfaces with different Cu loadings compared with the IR spectrum of the gas phase molecule.

S2-8 |

THIOL-BASED PHOTOPOLYMERS: UNRAVELING MECHANISMS FOR NEXT-GENERATION DIFFRACTIVE OPTICAL ELEMENTS

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Diffractive Optical Elements (DOEs) are extensively employed in technologies such as laser manipulation, spectroscopy and augmented reality thanks to their ability to shape light via internal periodic structures. In this study, we introduce a novel photopolymer-based holographic material distinguished by a "free-monomer" formulation, which removes the need for pre-polymerized monomers and thus significantly reduces production costs. All components are commercially available, and the simple formulation enhances both scalability and reproducibility. Over the past two decades, holographic photopolymers have attracted growing attention for their versatility: they are used in augmented-reality visors, optical waveguides, biomedical devices and even as diffraction gratings in telescopes. In particular, Volume Phase Holographic Gratings (VPHGs) which store a refractive-index pattern up to 0.045, offering high efficiency and customization for astronomical instrumentation. These gratings, with fringe densities ranging from 100 to 2 000 lines per millimeter, diffract light at precise angles according to wavelength, making them a standard choice for ground- and space-based spectrographs. Hologram writing can be performed either via Direct Laser Writing (DLW) or classical holographic interference, each method offering specific advantages in resolution and speed. Many photopolymer formulations rely on photo-induced radical polymerization, and some incorporate nanoparticles to enhance stability, refractive-index contrast and targeted reactivity. Uniform film deposition across thicknesses from a few microns to tens of microns remains a critical challenge. The PhD research at Politecnico di Milano and the National Institute for Astrophysics aims to develop a high-performance, highly stable photopolymer with a simplified chemical recipe and cost-effective production. We will employ ultrasonic spray depositions to achieve precisely controlled, patterned films on various substrates. This innovative material could also serve as a diffractive element within a microfluidic lab-on-a-chip for space-based biomedical applications, combining compactness, efficiency and minimal footprint. A deeper understanding of the material's internal chemistry will enable the design of custom photonic structures responsive to environmental stimuli, opening avenues for real-time, compact, selective detection platforms with potential impact in medical diagnostics, environmental monitoring and wearable technologies. Films were recorded and a comprehensive suite of characterizations was conducted. To elucidate the chemical reactions underlying crosslinking and to assess the crosslinker's specific role, we performed spectroscopic analyses that revealed the kinetics of polymerization and light-induced structural changes.

S2-9 |

METAL OXIDE DECORATED ADSORBENTS FOR PHOTOCATALYTIC WATER REMEDIATION

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The development of efficient and sustainable strategies for water purification is a pressing global need. Water contamination represents a critical environmental concern, adsorption, recently greatly stimulated by availability of high specific surface area materials, has grabbed the attention of scientists as a versatile, cost-effective option for relatively effortless large-scale water treatment. However, adsorbent disposing may have an adverse environmental impact that should be mitigated through regeneration and reuse processes, usually employing high-cost procedures. Various strategies have been explored to overcome poor adsorbent lifetimes, and economic and environmental cost of regeneration treatments, including heterogeneous photocatalysis.
In this work, we propose a new concept of smart adsorbents by coupling a purposely synthesized hyper-crosslinked microporous adsorbent with metal oxide nanoparticles, such as TiO_2 and CeO_2, designed to integrate the photocatalytic properties of the nanoparticles with the high adsorption capacity of the microporous support. Particular attention has been paid to maintaining the structural stability of the adsorbent, ensuring effective nanoparticle loading, and optimizing photocatalytic performance. The combination of large specific surface area adsorbents, characterized by hyper-crosslinked structure that provide good chemical and thermal stability, and photocatalysts at the nanoscale enables a synergistic effect: on one hand, the adsorbent promotes contaminant capture and enhances local concentration at the photocatalyst interface; on the other, the anchored nanoparticles ensure efficient light-driven degradation of pollutants, thereby enabling *in situ* regeneration of the adsorbent. Structural, morphological, chemical and optical characterizations of the photocatalysts have been exploited and their photocatalytic activity investigated using different dyes as model contaminants, monitoring adsorption and photocatalysis, activated by UV-irradiation or solar-simulator irradiation, under different pH conditions. Among different hyper-crosslinked adsorbents, the best performing ones has been impregnated with the nanoparticles increasing their loading while preserving adsorbents textural properties. Finally, adsorption isotherm and kinetic of the photocatalysts-modified adsorbent towards the model contaminants have been investigated to validate the regeneration process.

This work has been funded by European Union through Next Generation EU, Mission 4 Component 1, for the financial support to MUR within PRIN call 2022 PNRR, project title: Photocatalytically-regenerable hierarchically porous adsorbents for efficient water treatment PHOTOPAD, P2022FP2W4, 2023-2025CUP B53D23027540001

S2-10 |

STUDY OF THE COMPATIBILIZING CAPACITY OF OLEFIN GRAFT COPOLYMES IN iPP/HDPE BLENDS

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Polyethylene (PE) and isotactic polypropylene (iPP) account for over 50% of global plastics production, thanks to their excellent thermal, physical and mechanical properties, low costs and ease of processing. However, the thermodynamic immiscibility of iPP and PE presents a significant challenge in developing an effective and industrially sustainable mechanical recycling methodology. Consequently, recent research has focused on the use of compatibilizers to enhance the miscibility of iPP and PE. Studies have shown that olefin graft copolymers (OGCs) with a linear PE main chain and iPP grafts (HDPE-*g*-iPP), serve as effective compatibilizers for PE-rich iPP/HDPE (30/70) blends at 1–5 wt% loading. Higher tensile strength has been observed with an increased number of blocks and longer graft lengths. More recently, OGCs with an iPP backbone and HDPE side chains (iPP-*g*-HDPE) have been proposed as compatibilizers for iPP-rich iPP/HDPE (70/30) blends. Notably, in both studies, the backbone, representing the major component of the graft copolymers, matches the major component of the blends, while the grafts, being the minor component, correspond to the minor blend component. Whether this structural arrangement is a necessary prerequisite for OGCs to function as effective compatibilizers in iPP/PE mixtures remains unclear. Additionally, both HDPE-*g*-iPP and iPP-*g*-HDPE copolymers contain a significant amount of unreacted macromonomer (40–60 wt%), whose role in the compatibilization mechanism has yet to be fully elucidated. This study aims to investigate the relationship between graft architecture and compatibilization ability, as well as the role of unreacted macromonomer in the compatibilizing properties of iPP/PE blends with varying compositions. It is shown that the presence of HDPE macromonomer, in addition to the graft copolymer, not only enhances elongation at break values of the blends but also exhibits superior compatibilizing capacity compared to the copolymer alone. This effect is attributed to the "glue" mechanism, wherein PE macromonomers positioned at the interface between phase-separated iPP- and HDPE-rich domains contribute to improved blend miscibility.

S2-11 |

MEASUREMENT AND CHARACTERISATION OF BRAKE-PAD AND ROTOR PARTICULATE EMISSION USING A CUSTOM TRIBOMETER

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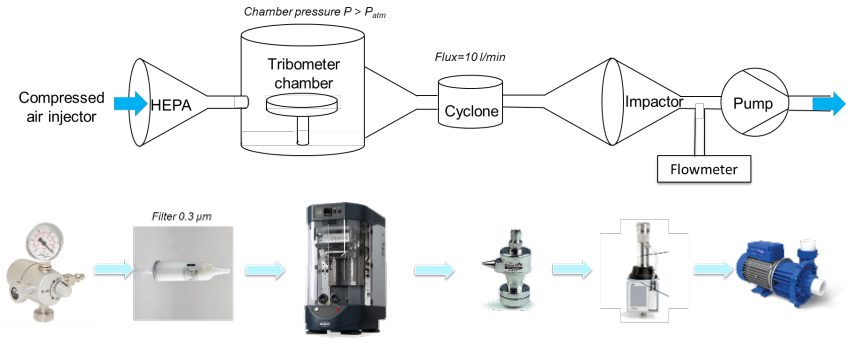
Brake pad wear is a significant source of particulate emissions from vehicles. These particles pose risks to both the environment and human health. In response, the European Commission has enacted regulations to limit braking system fine-dust emissions by 2027 under the forthcoming Euro 7 standard. This study aims to quantify and understand brake-related particle emissions and to develop strategies for their reduction. Several tools and techniques are used to characterise friction materials and discs. The equipment employed in this study is a custom tribometer specifically developed to investigate the pad-disc interface by removing all other sources of interference. We use the Worldwide Harmonized Light-Duty Vehicles Test Procedure (WLTP) to evaluate the friction materials. This procedure was originally created for an instrument called bench dynamometer (dyno) which is the reference tool in the braking system analysis. The procedure consists of repeating 3 cycles of 303 braking events. Data analysis is performed considering particulate emissions and the energy dissipated by the interface. To measure and characterise dust from the disc-brake pad contact it was necessary to develop an apparatus entirely dedicated to collect the tribological couple emissions (Figure). The rotor and the sample holder are housed in an airtight chamber. After the chamber, a Teflon filter is inserted in an eFilter, which assesses real-time emission, and its weight is measured before and after the procedure: the difference is the particulate emitted. The first part of this work was dedicated to the validation of the measurement procedure, the materials were tested both on the dyno and on the tribometer. The value of particle mass is obtained by normalising the filter weight by energy and surface area of the samples. The eFilter analysis highlighted the particle generation mechanism and a correlation between emissions and energy. The correlation found was satisfactory and indicated a strong correlation between the procedure developed and the dyno original procedure. The particle collection system is now a powerful instrument to investigate tribological emissions. The results obtained in this study allow the implementation of the procedure as screening method to develop new and improved materials with emission values according to the EU7 limits. Future work will focus on integrating machine-learning models to predict particulate emissions directly from brake-pad formulation parameters.



Schematic of the custom tribometer-based setup for brake pad-rotor particulate emission measurements.

S2-12 |

IRON-OXYHYDROXIDE-BASED MATERIALS AS NANOSORBENTS FOR As (III) AND As(V) REMOVAL FROM CONTAMINATED WATER

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Arsenic pollution in surface water and groundwater represents a worldwide problem originated by the dissolution of arsenic from soil, mainly due to anthropogenic activities. Among the various technologies, adsorption seems to be the most promising method for the removal of As(III)/As(V) species from waters due to its low cost, high efficiency, the possibility of regeneration and the flexibility of operation. In particular, iron oxyhydroxide nanopowders exhibit remarkable adsorption capabilities, due to their high density of surface hydroxyl groups, strong tendency to form inner-sphere complexes, and high surfaceto-volume ratio. These properties, combined with their low toxicity and ease of synthesis, make them ideal candidates for sustainable arsenic remediation technologies. In this study, three iron-oxyhydroxides - akaganeite, ferrihydrite and feroxyhyte - were synthesized via eco-friendly precipitation methods and characterized using a multi-technique approach (XRD, TGA, N_2 physisorption, ELS, TEM, FTIR, ^{57}Fe Mössbaeur Spectroscopy and DC magnetometry). Their adsorption performances were compared under identical experimental conditions, with key parameters including initial pH (2–8), arsenic concentration (10–500 mg L^{-1}), contact time (10–960 min), and the presence of competing ions. Total arsenic concentrations before and after adsorption were determined by ICP-OES. The results show that akaganeite achieves nearly 100% As(V) removal (C^0= 100 mg L^{-1}) across the entire pH range, while ferrihydrite exhibits high removal efficiencies at pH 2 and 3 (100% and 94%, respectively), but its performance drops significantly to 23% at pH 8. Feroxyhyte shows excellent removal at pH 2 (99%) and maintains good efficiency (77–80%) up to pH 6, but its performance decreases sharply, reaching a 50% at pH 7 and 38% at pH 8. For As(III)(C^0 = 100 mg L^{-1}), akaganeite shows limited removal at pH 2 (64%) but performs better (around 80%) between pH 3 and 8. Ferrihydrite maintains high As(III) removal (~96%) across this range, while feroxyhyte shows similarly strong performance (90–93%). When considering the adsorbed amount of As per unit surface area (q_e, mg/m^2), feroxyhyte displays the highest As(III) uptake, followed by ferrihydrite and akaganeite. In contrast, for As(V), akaganeite is the most active sorbent, followed by feroxyhyte and ferrihydrite. Given the higher toxicity and mobility of As(III) compared to As(V), a promising strategy is its in situ oxidation to As(V), followed by adsorption. To this end, manganese-doped iron oxyhydroxides were synthesized to combine oxidation and adsorption properties, and adsorption tests are currently underway to evaluate their performance. Following these promising results, preliminary studies are now focusing on the development of functional hybrid materials based on Fe-oxyhydroxides and Mn-doped Fe-oxyhydroxides for their potential application in real-world scenarios.

S2-13 |

ENANTIOSELECTIVE CO_2/CYCLOHEXENE OXIDE COPOLYMERIZATION: A DFT INVESTIGATION OF MECHANISMS PROMOTED BY CHIRAL ZN β-DIIMINATE CATALYSTS

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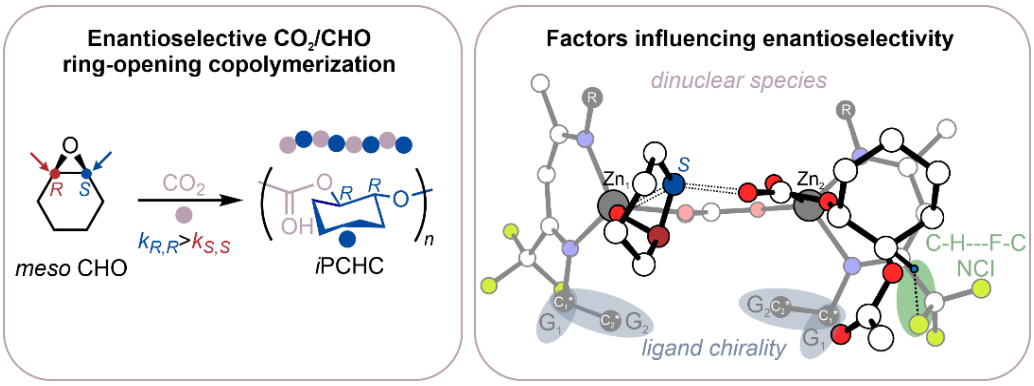
The valorization of carbon dioxide (CO_2) - a nontoxic, inexpensive, and Earth-abundant feedstock - has gained significant interest in recent years. One promising application is its copolymerization with *meso* epoxides to produce polycarbonates, materials that are potentially recyclable and biodegradable. Among these, cyclohexene oxide (CHO) stands out as a benchmark monomer. Its enantioselective copolymerization with CO_2 *via* ring-opening copolymerization (ROCOP) enables the synthesis of isotactic poly(cyclohexene carbonate) (*i*PCHC), a semicrystalline material with desirable properties. Several enantioselective catalytic systems have been developed for ROCOP. Notably, Coates and co-workers introduced a family of C_1-symmetric β-diiminate Zn catalysts with high activity and selectivity. These catalysts are classified into two generations (G_1 and G_2), differing on the number of stereocenters (one or two on adjacent carbons). We performed a detailed mechanistic investigation of the first-generation (G_1) catalyst, using Density Functional Theory (DFT). Our study reveals that polymerization proceeds *via* a dinuclear complex, with mononuclear intermediates being energetically unfavorable. Remarkably, both *anti* and *syn* conformations of the catalyst can be involved - an unprecedented result, as only the *anti* form had been structurally characterized *via* X-ray crystallography. Our computational results explain the experimental preference for *R,R*-configured polymer chains, identifying CHO insertion as the rate and enantioselectivity determining step (Fig. 1). We demonstrate that the enantioselectivity of ROCOP arises primarily from the steric deformation of the incoming monomer, as a result of the hindrance of the ligand. The study underscores the critical interplay of structural and steric effects in governing the copolymerization mechanism and stereochemical outcome, as well as the presence of a noncovalent interaction (NCI) between the ligand and the growing chain in the propagation.



Meso desymmetrization through CO_2/CHO ROCOP at Zn β-diiminate complexes.

S2-14 |

PROTECTIVE NANOSTRUCTURED FLAME RETARDANT COATINGS CONTAINING LDHs

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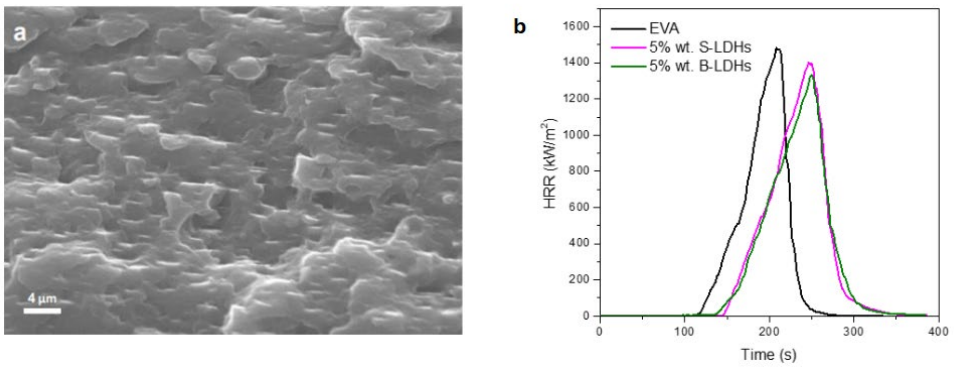
This study focuses on the development of nanocomposite films based on Ethylene Vinyl Acetate (EVA) and Ethylene Butyl Acrylate (EBA) copolymers, incorporating magnesium-aluminum layered double hydroxides (LDHs) with different aspect ratios. These films were applied as surface coatings on pristine EVA and EBA samples, showing significant improvements in flame-retardant properties.
Surface coating as a flame-retardant strategy is gaining attention due to its effectiveness in concentrating the protective action at the combustion interface. This method minimizes the required amount of additive compared to traditional bulk incorporation, while preserving the mechanical integrity of the polymer matrix. Two types of LDHs with identical chemical composition (magnesium-aluminum with oleate as intercalated species) but different particle sizes (S-LDHs: D50 = 5.60 µm, B-LDHs: D50 = 18.67 µm) were used. The nanocomposite films were produced through melt compounding using a twin-screw extruder and formed into 300 µm thick sheets, which were then applied to unfilled polymer samples via compression molding. Rheological analysis of the films revealed the presence of a yield stress behavior at low frequencies, attributed to the well-dispersed LDH nanoparticles disrupting polymer chain relaxation. This behavior was modeled using a modified Cross model accounting for yield stress. Scanning Electron Microscopy (SEM) images confirmed the alignment of nanofillers along the stretching direction and showed a mostly homogeneous dispersion, with some micron-scale aggregates. The morphology observed indicated intercalated/exfoliated structures, supporting the rheological findings. Cone calorimetry tests, conducted under heat fluxes of 25–30 kW/m^2, demonstrated that the coated samples exhibited delayed ignition times compared to uncoated counterparts. This improvement is due to the surface-localized LDHs forming a physical barrier that reduces heat and oxygen transfer to the underlying polymer. The enhanced flame retardancy is thus attributed to both the structural properties of the nanocomposite films and the barrier effect of the LDH particles. In conclusion, surface coatings based on EVA and EBA nanocomposites with LDHs provide an efficient and effective method for improving flame resistance, offering a promising alternative to bulk additive incorporation strategies.



a) SEM micrograph of EVA+5%MgAl F film and b) HRR curves of pristine EVA and EVA-based samples

S2-15 |

NOVEL FUNCTIONAL ELASTOMERS DERIVED FROM SYNDIOTACTIC POLYPROPYLENE AND α,ω-NON-CONJUGATED DIENE COPOLYMERS

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Syndiotactic polypropylene (sPP) is a semicrystalline polymer that uniquely combines mechanical strength, stiffness and elastic behavior, making it an excellent candidate for advanced elastomeric materials. By introducing α,ω-non-conjugated dienes through copolymerization, it is possible to further tailor the structure of sPP by incorporating terminal vinyl groups, which act as reactive sites for subsequent chemical modifications. In this work, we report the synthesis of sPP-based copolymers with 1,5-hexadiene (sPPHD) and 1,7-octadiene (sPPOD), using a highly syndiospecific metallocene catalyst. The successful insertion of diene units into the polymer backbone was confirmed by NMR spectroscopy and the resulting copolymers exhibited reduced crystallinity and melting temperatures compared to the sPP homopolymer. These structural changes translate into enhanced ductility and elasticity, with significant improvements in elongation at break and elastic recovery, suggesting their suitability for elastomeric applications. Importantly, the pendant unsaturations introduced by the dienes were efficiently employed in post-polymerization functionalization reactions, including peroxide-induced cross-linking and click chemistry reactions. These chemical transformations broaden the application landscape of the materials enabling the incorporation of polar groups or the development of new properties, such as shape memory behavior or enhanced molecular flexibility. The resulting materials represent a novel class of functional elastomers, combining the mechanical stiffness typical of semicrystalline polymers with with the customizable properties enabled by post-functionalization. The strategic use of α,ω-non-conjugated dienes as functional comonomers proves to be an effective route for diversifying the properties and enhancing the utility of syndiotactic polypropylene-based elastomers.

SESSION 3

S3-1|

POST-INDUSTRIAL AND POST-CONSUMER WASTE POLYPROPYLENE FOR THE AUTOMOTIVE SECTOR: INVESTIGATION OF MECHANICAL AND THERMAL PROPERTIES AFTER AGEING

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The transport sector's impact on climate change and energy-related greenhouse gas (GHG) emissions has become a significant concern in recent years. In response, the automotive industry is moving towards a green transition by producing lighter vehicles with more sustainable materials. A key focus is on using recycled plastic instead of fossil-based plastics. In July 2023 the European Commission proposed a new regulation within the framework of the automotive industry, which is expected to have substantial environmental benefits, including an annual reduction of 12.3 million tons of CO2 emissions by 2035. The cited regulation focuses the attention on enhancing the circularity of the automotive sector, covering the design, production and end-of-life treatment of vehicles beyond setting a target about the recycled content: 25% of the plastic used to build a new vehicle will be required to come from recycling, of which 25% must be recycled from end-of-life vehicles. In this context, my research aligns with the goal of utilizing innovative recycled-based polymer blends and developing mono-material trims to enhance vehicle end-of-life treatment. In this context, my research over the years has focused on gaining a deeper understanding of the properties of recycled polypropylene (rPP) used in the automotive sector, with a particular focus on its behaviour under accelerated ageing conditions. The study began with an investigation of rPP sourced from post-industrial waste and was later extended to rPP derived from post-consumer waste. The former was subjected to thermal accelerated ageing, while the latter underwent solar ageing. Thermal and mechanical properties were evaluated before and after aging using thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), Fourier-transform infrared spectroscopy (FT-IR), Raman spectroscopy, tensile test, flexural test, IZOD impact test, and multiaxial impact test. The investigation was carried out both on industrial compounds and on specifically designed formulations, in order to assess the individual contribution of different components of the compound (fillers, carbon black, elastomeric phase) to the ageing behavior. The results show that all tested materials demonstrate good resistance to ageing conditions. FTIR spectra before and after ageing revealed no significant signs of oxidative degradation. Thermogravimetric analysis (DSC) confirmed that melting and crystallization temperatures, as well as the degree of crystallinity, remained largely unchanged. Also no evident change were noted from TGA. However, some limitations were observed in the mechanical properties, particularly after UV ageing.

S3-2 |

FIRST-PRINCIPLES STUDY OF PEROVSKITE OXIDE FOR SOLID OXIDE ELECTROCHEMICAL CELLS: EFFECTS OF CATION SUBSTITUTION ON OXYGEN ION DIFFUSION IN $Sr_2Fe_{2-x}Mo_xO_{6-\delta}$

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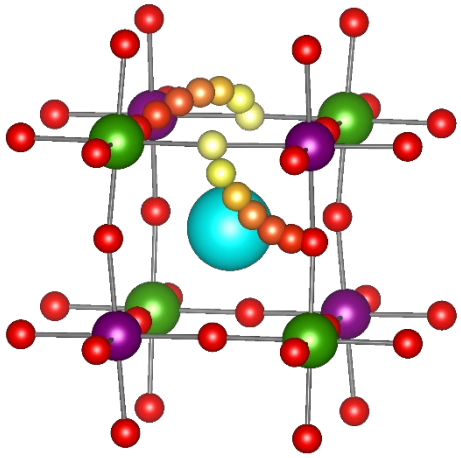
Solid oxide fuel cells (SOFCs) and their reversible counterparts, solid oxide electrolyzer cells (SOECs), offer efficient routes for clean energy conversion water splitting and hydrogen storage. However, efficient transport of oxygen ions and electrons in state-of-the-art solid-state electrolytes and electrodes typically requires high temperatures, which limit device durability and slow start-up times. Lowering the operating temperature necessitates advanced electrode materials, particularly mixed ionic-electronic conductors (MIECs). Among these, perovskite oxides have emerged as promising electrodes for both the oxygen evolution and reduction reactions (OER/ORR), though the efficiency of the two opposite reactions being usually largely different. $Sr_2Fe_{2-x}Mo_xO_{6-\delta}$ (SFMO) has attracted attention as a potentially bifunctional system due to its high electronic conductivity, redox-active B-site cations (Fe/Mo), and capacity to accommodate oxygen vacancies. Following previous works, in this study, we investigate the impact of cationic substitution on oxygen vacancy formation and migration in SFMO via first-principles calculations, targeting improved oxygen ion transport. Two Fe:Mo ratios (1:1 and Fe-rich 3:1) are considered to assess the effect of B-site composition, while partial substitution of A-site cation (Sr) with smaller (Ca) and larger (Ba) cations at two Sr:Ca:Ba ratio (6:1:1 and 4:2:2) allowed us to probe the role of lattice strain. Structural, electronic and energetic properties are investigated using Density Functional Theory (DFT+U), revealing trends relevant to the optimization of SFMO as a bifunctional electrode material for low-temperature solid oxide technologies.



Pictorial representation of V_O-mediated migration in $Sr_2Fe_{2-x}Mo_xO_{6-\delta}$

S3-3 |

DESIGN AND CHARACTERIZATION OF A NEW, SUSTAINABLE, BIOINSPIRED, ANTIFOULING SILICON-BASED COATING FOR MARINE HULLS

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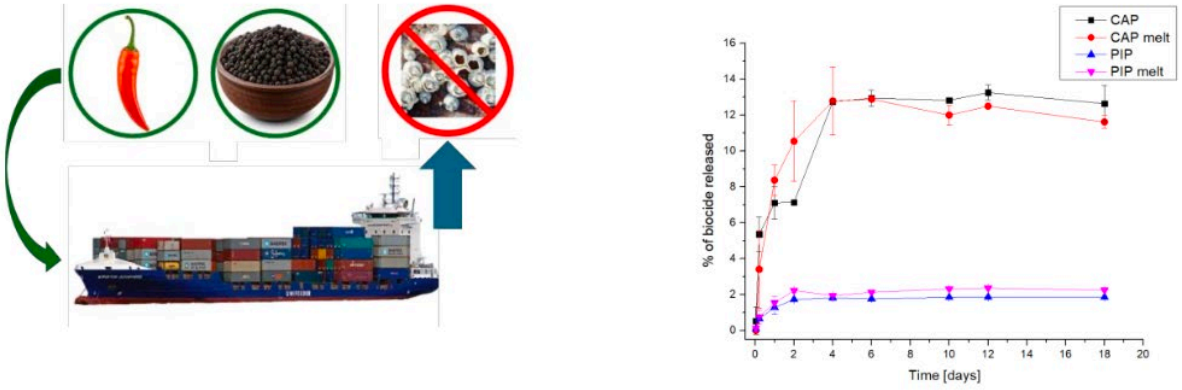
One of the most persistent challenges in marine navigation is biofouling — the accumulation of marine organisms such as bacteria, algae, and barnacles on the submerged parts of vessels, especially the hull. This natural process occurs when ships remain in the water for extended periods and can lead to serious consequences. Among the most notable issues are the reduction in hydrodynamic efficiency, which increases fuel consumption, the risk of biocorrosion that damages the vessel's structure, and the need for frequent, expensive maintenance and cleaning interventions. To mitigate biofouling, traditional antifouling coatings containing biocides, typically based on metal oxides such as copper or zinc, have been widely employed. While these coatings can be effective, they pose significant environmental risks due to the gradual leaching of toxic substances into marine ecosystems, harming non-target species and disrupting biodiversity. As a result, the scientific community is increasingly focused on developing safer, more sustainable alternatives. In this context, we present preliminary findings on a new, eco-friendly antifouling coating inspired by natural defense mechanisms. The formulation is based on a siloxane matrix, known for its hydrophobic and low-adhesion properties, and is enhanced with natural biocides such as capsaicin and piperine (as is and melted), compounds extracted from chili peppers and black pepper, respectively. These substances are recognized for their irritating effects and have shown potential to deter marine organisms from settling on submerged surfaces. To assess the performance of these coatings, solubility studies and UV-Vis spectroscopy were conducted to analyze the release kinetics of the active compounds from the polymeric matrix, a critical factor in ensuring prolonged antifouling action. Surface properties were further evaluated through wettability tests, surface free energy measurements, and contact angle analysis. Finally, biological assays, adhesion tests with marine organisms, and in situ trials in marine environments were carried out to simulate real-life conditions, targeting both microfouling (early-stage biofilm formation) and macrofouling (larger organism attachment).



Implementation of red chili and black peppers' molecule into the marine hull coating to avoid the formation of macrofouling (on the left) and release kinetics analysis of the active compounds from the polymeric matrix (on the right)

S3-4 |

BEYOND NAFION®: FUNCTIONALIZED GRAPHENE OXIDE AS A POTENTIAL SELF-ASSEMBLING PROTON-CONDUCTING MEMBRANE FOR PEM FUEL CELLS

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The core of proton exchange membrane fuel cells (PEMFCs), and one of the components in which they can be extensively improved, is their proton-conducting electrolyte. Nowadays, Nafion® is the most widely used material and allowed PEMFCs to establish themselves as the leading commercial-scale fuel cell technology. Nonetheless, it requires completely humidified reactant gases and temperatures in the 60–80 °C range to work properly. Additionally, the release of toxic and environmentally persistent per-and polyfluoroalkyl substances (PFASs) during both its production and disposal makes Nafion® at risk of being banned in the coming future. Therefore, the progress of PEMFCs technology inevitably goes through the pursuit of alternative PFASs-free proton conductors, which must also overcome the performance of Nafion® in conditions suffered by this material, but which would increase both water management and kinetics of the redox reaction, i.e., gas humidification lower than 60% and temperatures higher than 60 °C. Thus, this work focused on the preparation of novel self-standing proton-conducting membranes based on functionalized graphene oxide (GO), whose oxygen-bearing moieties provide well-known hydrophilic and self-assembling properties, as well as the possibility of introducing suitable groups that can enhance proton transport. Thus, sulfuric acid and naphthalene sulfonate (NS) molecules were investigated as functionalizing agents, with the aim to insert proton-carrying sulfonic acid groups and obtain either sulfonated graphene oxide (SGO) or graphene oxide-naphthalene sulfonate (GONS) membranes. Moreover, a potential crosslinking additive, i.e., sodium tetraborate decahydrate (SBD), was exploited to try to enhance the structural stability of the most promising SGO specimen and produce a crosslinked SGO-B membrane. Samples with six acid-to-GO, two GO-to-SBD, and three GO-to-NS molar ratios were prepared and analyzed via ATR-FTIR, SEM-EDX, Raman, TGA, XPS, XRD, and by the evaluation of their mechanical behavior, ion exchange capacity (IEC), water uptake, and in-plane proton conductivity (σ_{ip}). The last two features were explored at 42%, 53%, and 95% humidification in the 20–100 °C range. These tests allowed the identification of three most promising membranes, i.e., SGO-10, GONS-5-T100, and SGO-B80 A, which exhibited 4.2, 2.9, and 4.7 meq/g, respectively, of IEC, and 1.15, 1.71, and 0.19 S/cm, respectively, of σ_{ip} (at 80 °C, 95% relative humidity), compared to 0.7 meq/g and 0.60 S/cm, respectively, for Nafion® 212. Their production processes were finally analyzed via life cycle assessment and SGO-10 stood out among all GO-based membranes, due to its remarkable proton transport along with the best mechanical properties and carbon footprint.

S3-5 |

AMINE-FUNCTIONALIZED MESOSTRUCTURED SILICAS FOR CO_2 CAPTURE: INSIGHTS AND COMPARISON WITH METAL–ORGANIC FRAMEWORKS

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Carbon Capture, Utilization, and Storage (CCUS) technologies represent one of the most effective strategies to reduce atmospheric CO_2 concentrations and mitigate their environmental impact. Within the scope of CCUS, CO_2 capture using porous solid materials—such as Ordered Mesostructured Silicas (OMSs) and Metal-Organic Frameworks (MOFs)—has gained increasing attention due to their high CO_2 adsorption capacities, low regeneration temperatures, ease of handling, and good material stability. This work focuses on a comparison between two classes of hybrid organic-inorganic adsorbents for CO_2 capture: amino-modified OMSs, derived from both commercial and waste precursors, and MOFs. Among the OMSs, MCM-41 was selected as a platform for anchoring amine groups, thanks to its high surface area, narrow and tunable pore size distribution, high pore volume, ordered structure, and abundant surface silanol groups. Two MCM-41 samples were synthesized using different silicon sources: (i) TEOS (tetraethyl orthosilicate) as a commercial precursor, (ii) FSA (fluorosilicic acid) derived from industrial waste. Both were functionalized with (3-aminopropyl)triethoxysilane (APTES) via a dry-grafting method (NH2@TEOS_MCM-41 and NH2@FSA_MCM-41). For comparison a 3D ultramicroporous MOF based on a benzoquinone derivative—3,6-N-ditriazolyl-2,5-dihydroxy-1,4-benzoquinone (trz_2An)—coordinated with cobalt(II) (CoMOF) was proposed. All materials were characterized using powder X-ray diffraction (PXRD), nitrogen physisorption (BET surface area analysis), and thermogravimetric analysis (TGA). CO_2 capture performance was assessed through dynamic adsorption tests (Breakthrough Curves) under dry conditions using gas streams containing 5–10% CO_2 in N2. Additionally, in situ FTIR spectroscopy and microcalorimetry using CO_2 as a probe molecule were employed to elucidate the adsorption mechanisms. At 10% CO_2 and 30 °C, NH2@TEOS_MCM-41 showed higher uptake (~1000 µmol/g) than CoMOF (~700 µmol/g). Under 5% CO_2, the difference was even more pronounced: NH2@TEOS_MCM-41 adsorbed ~829 µmol/g, compared to ~317 µmol/g for CoMOF. Conversely, CoMOF is more easily regenerable, requiring only room temperature under N2 flow, whereas NH2@TEOS_MCM-41 needs treatment at 120 °C in N2. Nevertheless, both classes of materials were subjected to 13 adsorption–desorption cycles and proved to be fully regenerable. The different performances of the two classes of materials arise mainly from their distinct CO_2 adsorption mechanisms: NH2@TMCM-41 adsorbs CO_2 primarily through a chemisorption process, where the amine groups grafted onto the surface interact with CO_2 molecules forming ammonium carbamates, resulting in strong and specific chemical interactions, whereas CoMOF relies on physisorption, driven by weak intermolecular forces between CO_2 molecules and the MOF's porous surface. The adsorption heats derived from microcalorimetry data and the FTIR studies confirm the mentioned mechanisms. Additionally, NH2@FSA_MCM-41, synthesized from waste-derived FSA with similar amine loading, showed even better performance: about 1000 µmol/g (5% CO_2) and about 1200 µmol/g (10% CO_2).

S3-6 |

EXPLORING PHOTOCATALYTIC AND ELECTROCATALYTIC CO_2 CONVERSION *VIA* IR CHARACTERIZATION

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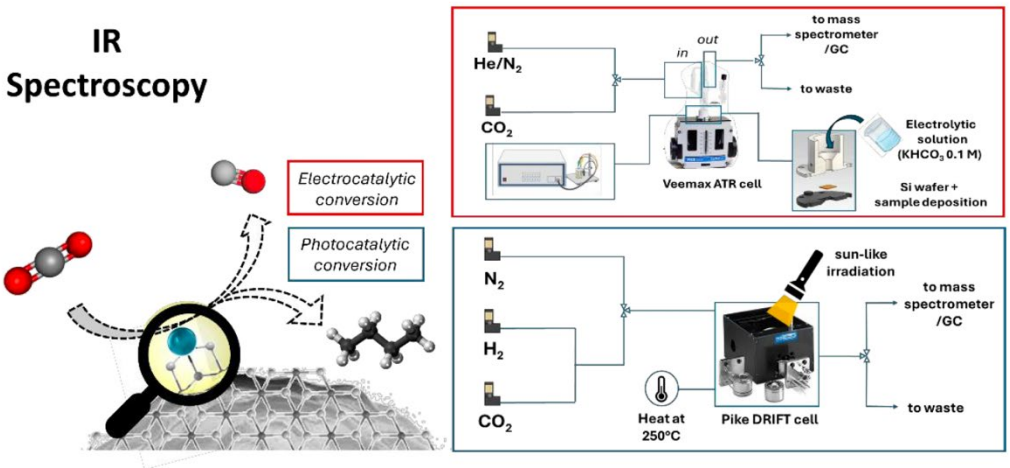
Among the possible strategies to reduce the level of CO_2 in the atmosphere, Carbon Capture and Utilization (CCU) stategies began to attract increasing attention because of its involvement not only in the permanent storage, but also in its utilization and conversion into new sources and products, such as chemicals or renewable fuels. In this regard, electrocatalytic and photocatalytic CO_2 reduction offer a more sustainable alternative to conventional thermocatalytic methods. A powerful tool for improving catalytic performance is to study active sites and reaction mechanisms by conducting in-depth characterization. This presentation discusses two distinct examples of characterization: one focused on electrocatalysts for the CO_2 reduction reaction to CO (CO2RR), and the other on photocatalysts for the conversion of CO_2 into C_4–C_9 renewable fuels. Regarding electrocatalysts, three Zn-Al LDHs with Zn^{2+}/Al^{3+} ratios of 2, 1, and 0.5 were synthesized, characterized, and tested for CO_2RR. Preliminary in situ ATR-IR spectroscopy in the absence of potential simulating electrocatalytic environments was performed to study interaction with CO_2-saturated liquid. The results showed different carbonate formations on catalysts with different electrocatalytic activities, suggesting their influence on the overall reaction. To confirm this hypothesis, preliminary tests were performed using a spectro-electrochemical cell under an applied potential (Figure 1). In case of photocatalysts, two different metal oxides based on Fe and Cu were synthesized and tested under photothermal conditions (200-250 °C, atmospheric pressure, under sun-like irradiation). The catalysts in powder form were characterized by coupling basic characterization (such as X-ray diffraction and volumetry) with *in situ* IR spectroscopy to study the nature of the interactions occurring between the reagent/products and the catalyst surface (Figure).



Schematic representation of the set-up used for the spectroscopic IR measurement to study the electrocatalytic and the photocatalytic conversion of CO_2.

S3-7 |

STRUCTURED CATALYST DEVELOPMENT FOR BIOGAS-FED SOLID OXIDE FUEL CELLS

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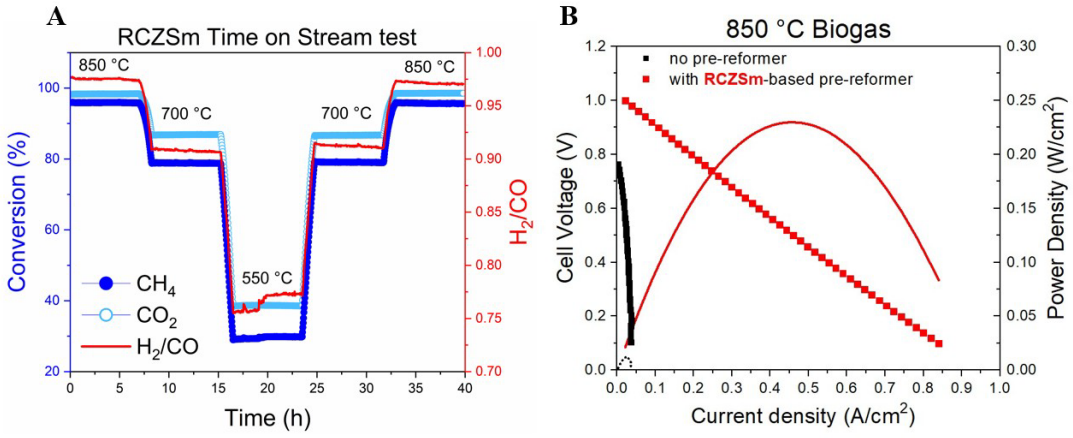
Dry reforming of methane has industrially appealing advantages over other routes towards syngas production: CH_4 and CO_2 DRM conversion simultaneously tackles two main greenhouse gases to obtain an H_2/CO ratio close to unity. Ni-supported systems are by far the most used, owing to their outstanding activity and cost-effectiveness. Nevertheless, Ni promotes carbon deposition, which results in severe deactivation. Here, 3.0 wt% ruthenium was strategically loaded onto a calcium zirconate perovskite oxide ($CaZr_{0.85}Sm_{0.15}O_{3-\delta}$, CZSm). The substrate was chosen due to its remarkable stability and 15 mol% samarium was substituted at the B-site to increase the extent of oxygen vacancies, favoring reactant adsorption on a highly basic surface. Ruthenium was added during the perovskite synthesis to obtain RCZSm, that displayed uniformly distributed fine Ru nanoparticles in DRM operation. The catalyst was characterized via structural (XRD) textural (N_2 adsorption/desorption), morphological (FE-SEM) and chemical (XPS) analyses. RCZSm revealed high activity for DRM, with a CH_4 an CO_2 conversions of 96% and 98% respectively and a H_2/CO ratio of 0.97 at 850 °C. RCZSm proved also to be stable for over 40 h of operation in a Time-on-Stream endurance test at different temperatures (Figure 1A). The catalyst was finally supported onto a NiCrAl foam substrate and used as an indirect biogas reformer coupled to a state-of-the-art SOFC. The cell was able to provide 230 mW/cm^2 at 850 °C when fed with a 50% CH_4 and 50% CO_2 gas mixture (Figure B). Low Ru loading on a tailored oxide substrate is an effective strategy to develop highly active and durable DRM catalysts.



A) – DRM activity Time-on-Stream endurance test of RCZSm catalyst; B) I-V and power density curves of state-of-the-art SOFC systems with (red) and without (black) the RCZSm-based pre-reformer system.

S3-8 |

WATER-BASED BINDERS FOR HIGH-VOLTAGE LNMO CATHODES: A SUSTAINABLE APPROACH

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A significant challenge in the energy sector is simultaneously developing high-performance electrochemical energy storage systems and ensuring their sustainable production, particularly through the use of green materials. To achieve high specific and volumetric performance, high-voltage cathodes are essential. Concurrently, enhancing sustainability means reducing or eliminating cobalt from cathode compositions and substituting traditional organic binders with water-based alternatives. While water-based binders are standard for graphite anodes in industrial settings, their application to cathodes is difficult due to the aluminum current collector and the risk of metal ion leaching during slurry processing. This work focuses on using naturally derived binders for high-voltage, cobalt-free cathodes. The goal is to formulate binders that balance sustainability with electrochemical performance in high mass-loading electrodes. Specifically, we investigated commercial $LiNi_{0.5}Mn_{1.5}O_4$ (LNMO) cathodes prepared with chitosan-based binders. Electrochemical performance was assessed using standard techniques, and further insights into electrode stability and degradation mechanisms will be obtained through advanced analytical techniques. The leaching of metals such as Mn and Ni in the electrolyte were investigated by Microwave Plasma-Atomic Emission Spectroscopy, while SEM, EDS and X-Ray diffraction were employed for cathodes characterization.

S3-9 |

FIRST-PRINCIPLES INSIGHTS INTO INTERFACIAL STRUCTURE AND CHARGE TRANSFER DYNAMICS IN DYE-SENSITIZED PHOTOELECTROCHEMICAL CELLS

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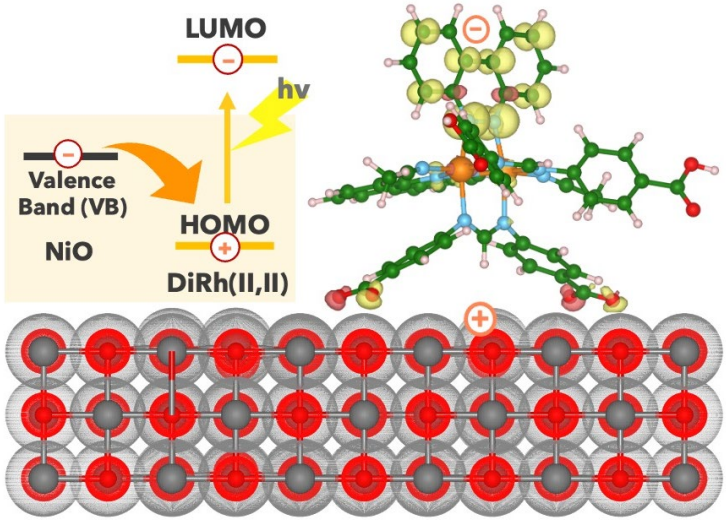
Single-chromophore single-molecule photocatalysts have emerged as promising agents for the conversion and storage of solar energy into chemical bonds. Recently, Turro and co-workers reported a single-molecule dirhodium photocatalyst (DiRh(II,II)) bound to nickel oxide (NiO) photocathode able to generate hydrogen from acidic solutions with red light. Its unique design makes this complex also a highly promising sensitizer for Dye-sensitized photoelectrochemical cells (DSPECs) when coupled with p-type semiconductors such as NiO. The efficient development of DSPECs calls for a thorough understanding of all properties and processes occurring at the molecule/solid interface, only partially achievable by experimental techniques. In this context, this contribution presents new insights into structural and electronic features of the DiRh(II,II)/NiO interfaces from state-of-the art Density Functional Theory (DFT)-based calculations. Besides, we also compute molecule/surface electron injection rates and identify preferential charge transfer channels via the projection-operator diabatization (POD) approach. Our analyses reveal stable mono- and bi-anchored configurations of DiRh(II,II) on NiO, with strong interactions between ligands and the surface. Anchoring enhances charge separation efficiency without significantly altering the intrinsic electronic features of the DiRh complexes. Beyond these specific systems, this work provides a comprehensive atomic-scale perspective on interfacial CT processes, offering valuable insights for improving the performance, stability, and design of renewable energy conversion technologies.



Schematic representation of charge transfer at NiO/DiRh(II,II) interface

S3-10 |

COORDINATION POLYMERS AS COUNTER ELECTRODES IN DYE SENSITIZED SOLAR CELLS: EFFICIENT CATALYSTS FOR CHARGE TRANSFER AT ELECTRODE INTERFACES

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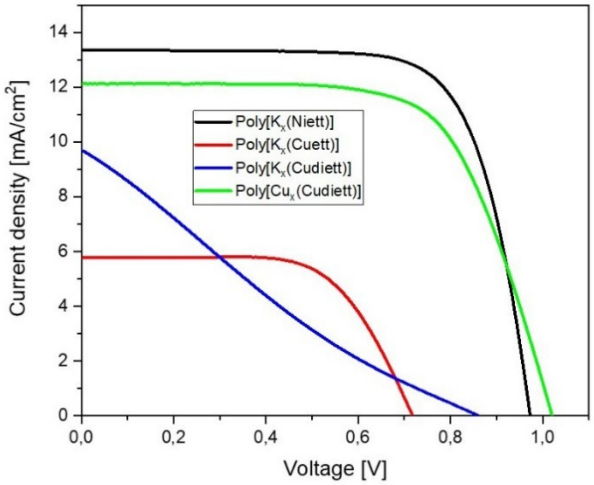
In recent years, renewable energy has undergone rapid advancement, with photovoltaic technologies accounting for the majority of new capacity additions. While silicon-based solar cells remain the market leader, they are hindered by limitations such as dependency on specific raw materials and diminished efficiency under low or scattered light conditions. As a viable alternative, dye-sensitized solar cells (DSSCs) present several advantages, including low production costs, straightforward fabrication, and adaptability for flexible or transparent applications. DSSCs work through a photoelectrochemical system involving a photoanode, a dye, a redox electrolyte, and a counter-electrode (CE). Currently, the most effective CEs are based on platinum, PEDOT, or carbon materials. Despite their performance, these systems are constrained by issues of cost, limited availability, and poor long-term stability. Diversifying the types of CEs available is crucial for enhancing DSSC efficiency and facilitating the integration of redox couples and dyes. In this contribution, we report the successful employment of coordination polymers (CPs) as counter electrodes in DSSCs. Both Cu- and Ni-ethenetetrathiolate-based systems have been developed, and when used as CEs, yielded remarkable performance and efficiencies exceeding 10% at 1 sun. When paired with various copper-, cobalt-, and iodine-based redox electrolytes, the polymer-based CEs achieved power conversion efficiencies close to 10%, comparable to benchmark platinum and PEDOT electrodes. To our knowledge, this is the first demonstration of a series of CPs, being directly deposited on bare FTO, serving as efficient and stable CEs in DSSCs. This work establishes a foundation for further advancements and optimization of this promising class of materials.

Authors acknowledges support from the Project CH4.0 under the MUR program "Dipartimenti di Eccellenza 2023-2027" (CUP: D13C22003520001).



J-V curves of DSSCs based on the synthesized CPs.

S3-11 |

SILICON NANOPILLARS FOR THERMOELECTRIC COOLING IN DATA CENTERS

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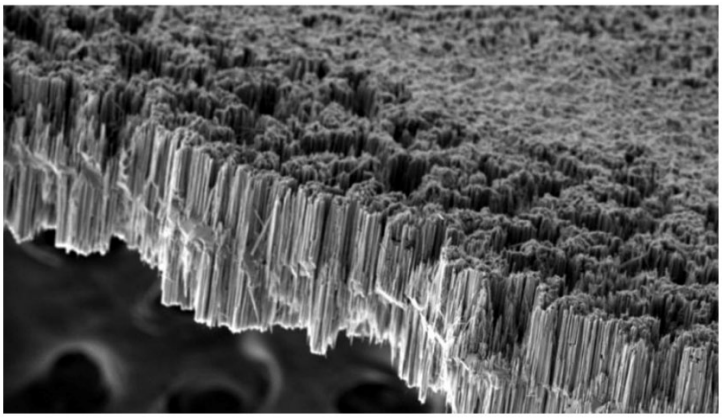
The rapid growth of artificial intelligence is expected to drive a substantial increase in energy consumption in data centers (DCs), due to the growing computational demand. In addition, the energy required for computational tasks generates a significant quantity of heat that must be effectively dissipated to prevent the failure of the electronic components. The current cooling solutions account for the 40% of a DC total energy consumption. This not only limits computational efficiency but also raises serious concerns about environmental sustainability. In this scenario we propose to implement thermoelectric coolers (TECs) to manage the thermal load in DCs. Indeed, TECs offer several advantages over conventional cooling methods (air and liquid cooling) since they are compact, noiseless, have no moving parts, require virtually no maintenance, and can operate reliably for over 25 years. Our aim is to develop TECs based on silicon nanopillars (SiNPs), providing a sustainable alternative to current commercial thermoelectric materials, which are typically based on telluride alloys which are rare, expensive, and could not allow large-scale deployment. SiNPs exhibit higher thermoelectric properties compared to bulk silicon, as quantum confinement effects reduce thermal conductivity and thereby improve the thermoelectric figure of merit ($ZT = \alpha 2\sigma T/\kappa$, where α is the Seebeck coefficient, σ and κ are the electrical and thermal conductivity respectively while T is the absolute temperature). This resulted in enhanced cooling efficiency. SiNPs are produced using a low cost and scalable technique called Metal-Assisted Chemical Etching (MACE). This technique, based on the local silicon oxidation catalyzed by metal nanoparticles, allows the formation of high-aspect ratio and crystalline SiNPs in a wide silicon doping range and for both p- and n-type. Moreover, we demonstrate that MACE enables the production of a self-supporting and mechanically stable structure entirely made of SiNPs with millimetric lengths. Due to the absence of a residual silicon membrane, such unique structure fully qualifies for the making of macroscopic thermoelectric legs, bringing all the advantages of nanotechnology to the macroscale. Indeed, this strategy combines the benefits of silicon with its geo-abundancy and non-toxicity, while dimensional constraints enhance silicon thermoelectric performance by reducing its thermal conductivity. This approach paves the way for scalable, and sustainable cooling tech for DCs, enabling a theoretical increase of the computational efficiency by the 30% and a power consumption reduction by the 20%.



SEM micrograph of the self-supporting structure made of SiNPs obtained via MACE and suitable for thermoelectric applications.

S3-12 |

Zr-DOPING OF P2-$NA_XMn_{0.625}Ni_{0.375}O_2$-LAYERED OXIDES FOR HIGH-ENERGY NA-ION BATTERY CATHODES: NEW INSIGHTS FROM FIRST-PRINCIPLES

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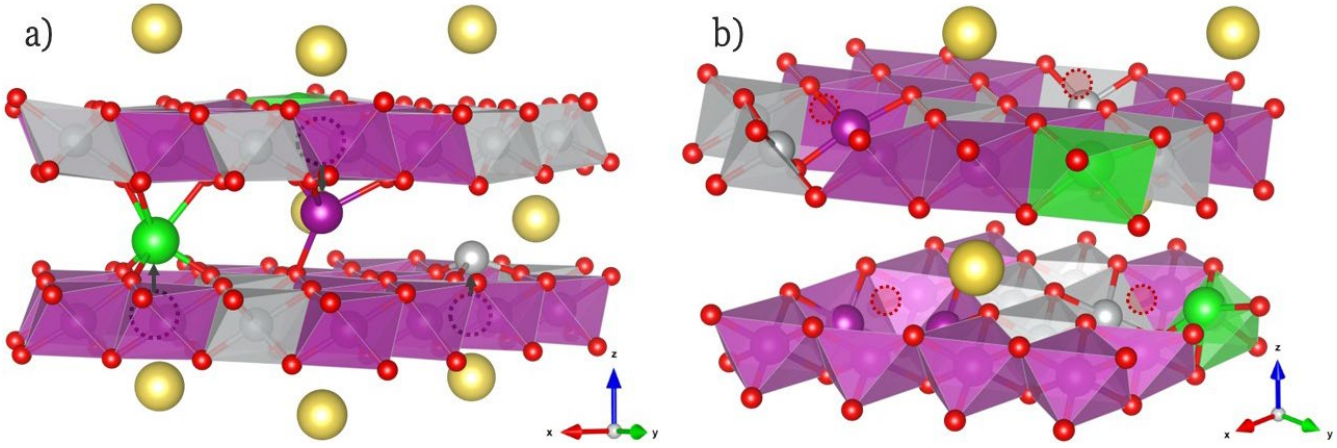
Na-ion batteries (NIBs) are at the forefront of energy storage technologies due to larger abundance of raw materials and enhanced cost-effectiveness compared to Li-ion counterparts. Despite the great advances achieved in last decades, identification of efficient, stable and cheap component materials still hinders a convenient NIB commercialization. Following the route paved by different TM combinations in P2-cathode materials, we present a first-principles investigation at the PBE+U(-D3BJ) level of theory on Zr-containing Na_xTMO_2 (TM = Zr, Ni, and Mn), chosen for its potential to enhance structural stability and electronic properties. We dissect the specific roles of different element sublattices during sodiation/desodiation processes. In addition, the formation of oxygen vacancies and TM anti-sites defects is explored (see Fig. 1) in the high-voltage range (%Na = 25% -> 12.5%) to address the related effect on the structural and electronic features. Experimental analysis (*e.g.*, Cyclic Voltammetry, X-ray diffraction) provide key validation for computational results demonstrating the cathode stability and efficiency. The theoretical insights and the experimental outcomes can be useful for an optimal design for next-generation efficient and high-energy NIB cathodes with enhanced structural stability at high voltage and improved sustainability.



Pictorial representation of punctual defects investigated in the present work: a) TM anti-site defects; b) O-vacancies.

S3-13 |

BIOSOURCED FURAN-DERIVED POLYIMINES AS SUPPORTS FOR METAL CATALYST FOR FORMIC ACID DEHYDROGENATION TO H_2

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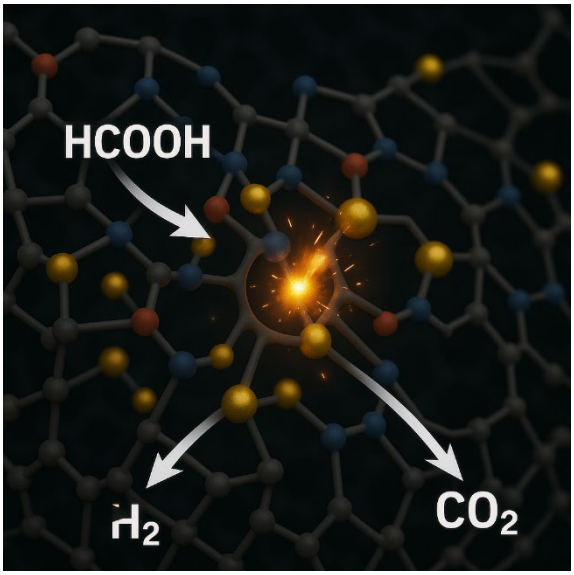
The synthesis of chemicals from renewable, biomass-derived feedstocks has garnered significant attention in recent years, driven by the urgent need to reduce reliance on nonrenewable fossil resources and promote sustainable material development. Among various bio-based building blocks, 5-hydroxymethylfurfural (HMF), 2,5-furandicarboxylic acid (FDCA), and 2,5-diformylfuran (DFF) are particularly valuable platform molecules. These furanoid compounds, typically obtained through acid-catalyzed dehydration of carbohydrates, serve as precursors for a wide range of fine chemicals and high-performance polymers. The resulting furan-based polymers exhibit interesting chemical properties conferred by the furan moiety. They can be reversibly cross-linked with bis-maleimides via the Diels-Alder reaction, obtaining covalent adaptative networks with self-healing properties. This contribution focuses on DFF-based polyimines, synthesized through Schiff-base condensation between DFF and various diamine or polyamine spacers. The resulting polymers feature imine linkages (–C=N–) that are thermally robust and offer coordination sites for metal ions and particles. The lone pair on the imine nitrogen, in conjunction with the oxygen atoms on the furan ring, acts synergistically to chelate metal species, resulting in stable metal–polymer composites. These DFF-derived polyimines typically exhibit high thermal stability, insolubility in a wide range of organic solvents, and adjustable morphologies depending on the chosen amine monomer. Overall, DFF-derived polyimines represent a versatile class of entirely biosourced polymers that combine robust mechanical and thermal properties with functional sites for metal coordination. Such attributes make them highly suitable candidates for next-generation heterogeneous catalysts, especially in energy-related transformations. In this context, we present preliminary work on incorporating gold nanoparticles (AuNPs) as a catalytic species within DFF-polyimine matrices; these hybrid materials demonstrate promising activity in formic acid dehydrogenation (FAD), a process of considerable interest for hydrogen storage and release.



S3-14 |

GRAPHENE DERIVATIVES AS FILLERS FOR NANOCOMPOSITE HOLE TRANSPORTING LAYERS IN PEROVSKITE SOLAR CELLS

Longo C[1,2], Brun LM[1,2], Lazzarin L[1,2], Iannibelli E[3], Vesce L[2,3], Di Carlo A[2,3], Menna E[1,2]

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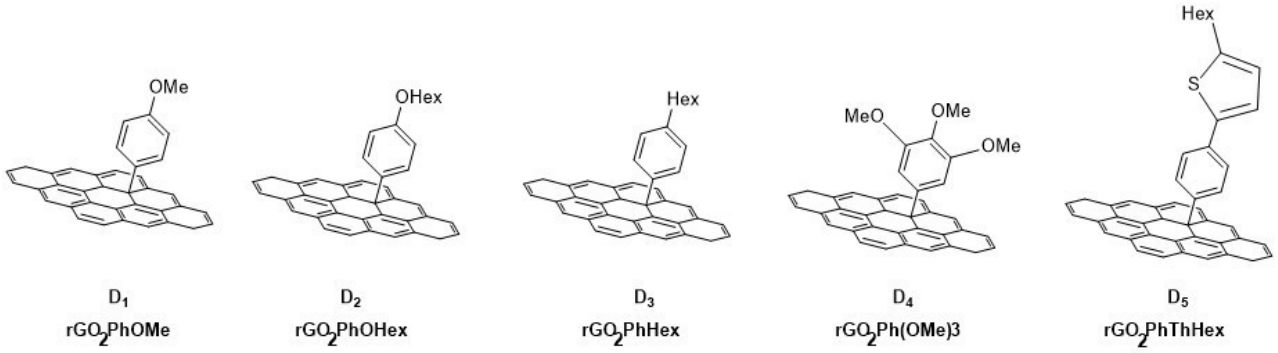
Perovskite Solar Cells (PSCs), are a type of photovoltaic device which stand out for of their high power conversion efficiencies and broad absorption spectrum. However, this technology lacks long-term stability due to degradation of the perovskite layer when it is exposed to environmental factors.
In this work, we make use of the electrical properties of graphene materials, by exploring the potential of a composite hole transporting layer (HTL) with reduced graphene oxide (rGO) and poly(3-hexylthiophene)(P3HT), combination that has been already shown to improve the stability of the cells.
To address the tendency of graphene derivatives to aggregate, we covalently functionalized different types of graphene-based materials with various functional groups, to improve their dispersibility in the P3HT matrix. The derivatives were synthesized through diazotization chemistry and characterized through Raman, TGA and dispersibility measurements.



f-rGO derivatives

The blends of functionalized graphene derivatives and P3HT were obtained through a sedimentation-based separation and was characterized by dispersibility measurements, UV-Vis, SEM and TEM, showing that, among all, functionalized rGO (f-rGO) derivatives (Figure 1) were more homogeneously dispersed in the polymeric matrix. Further studies will highlight the stability advantages of depositing f- rGO/P3HT composite material as HTL in PSCs.

S3-15 |

NANOCRYSTALLINE SILICON AS THERMOELECTRIC MATERIAL FOR WASTE HEAT RECOVERY

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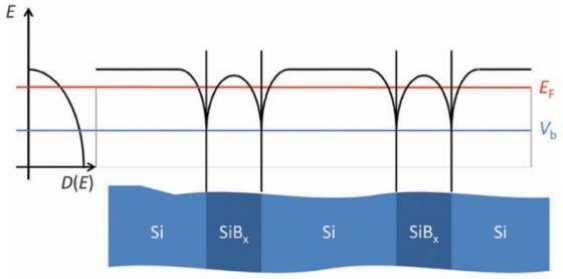
Thermoelectricity is a branch of physics which studies transport phenomena that lead to the conversion of a heat flux into electric power and vice-versa. The main parameters to evaluate thermoelectric materials are the dimensionless Figure of Merit $zT = S^2\sigma T/\kappa$ (where S is the Seebeck coefficient, σ is the electrical conductivity, κ is the thermal conductivity and T is the absolute temperature) and the Power Factor ($PF = S^2\sigma$). Nowadays, the main thermoelectric material is Bi_2Te_3 with a zT ~1 at 300K. Despite its good performance, Bi and Te are expensive both for their abundance and for geopolitical reasons. This motivates the search for competitive and cheaper thermoelectric materials. Silicon is a poor thermoelectric material due to its high thermal conductivity (~150 W/mK) which lowers its zT to 0.01 at 300K. In nanocrystalline silicon κ decreases down to ≈10 W/mK due to phonon scattering at grain boundaries (GBs). Moreover, under well defined conditions, it is possible to activate Energy Filtering (EF), a charge carrier energy-dependent scattering mechanism, which leads to higher PF values compared to the bulk material. We reported how this can be achieved in CVD-grown heavily boron-doped nanocrystalline Si thin films. After high temperature annealing, Boron precipitates at GBs. The SiBx second phase forms potential barriers with height of ~50 meV. These barriers can filter out low-energy carriers without affecting the transport of high-energy carriers (Fig.1), leading to a significant increase of PF (~33 mW/K^2m) compared to that of bulk Silicon. However, it was observed how the presence of H dissolved into Si (as a by-product of silane decomposition) complexes boron, decreasing the amount of dopant available to precipitate at GBs.

In this flash contribution, we will discuss how H-free PVD techniques may be used to enhance energy filtering in nanocrystalline Si (nc-Si) thin films. Both electron-beam-assisted (E-beam) evaporation and sputtering have been considered. Moreover, in-situ boron doping strategies have been analyzed. In both cases, substrate type, deposition temperature and post-deposition processing were found to be critical parameters. Regarding E-beam evaporation, low-temperature deposition was employed. The possibility to obtain post-deposition crystallization of the material on various substrates (Si/SiO_2, Al_2O_3, Intrinsic_Si) was investigated with XRD and TEM analyses, confirming the formation of nano-grains after RTA and annealing processes. The doping was attempted via co-deposition with a Silicon-Boron (SiB) alloy followed by high-temperature annealing. Atomic Probe Tomography (APT) provided elemental distribution inside the sample, confirming boron incorporation and diffusion. Sputtering, instead, was employed to study high-temperature deposition resulting in the formation of polycrystalline silicon films on quartz and Si/SiO_2 at deposition temperature ≥ 550°C. Boron concentration exceeding its solubility threshold was achieved by co-sputtering from Si:B and B targets. The thermoelectric properties of CVD-grown, evaporated and sputtered films will be compared to evaluate if PVD techniques may be competitive with the CVD process.



Formation of potential barrier at the Si-SiB_x interface

S3-16 |

Eu^{3+}-DOPED PMMA: ADVANCED OPTICAL WINDOWS FOR BUILDING INTEGRATION

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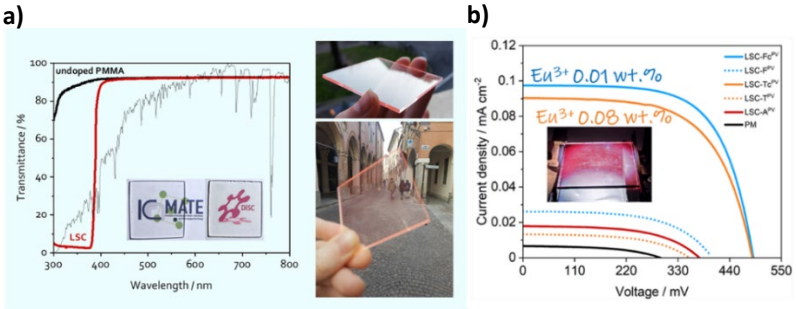
The luminescence properties of β-diketone lanthanide complexes make them attractive to design multifunctional advanced materials, with applications spanning diversified fields, such as laser materials, devices for energy harvesting, probes and sensors. In the presented work, a family of supramolecular Eu^{3+} bis-β-diketones has been used as dopant for PMMA to produce highly transparent, luminescent polymeric slates. These systems, exhibiting very high molar brightness, have been first investigated as Luminescent Solar Concentrators (LSCs). In building-integrated photovoltaics (BIPVs), LSCs are deployed as energy-producing windows capable of absorbing a portion of the incident solar spectrum and re-emitting it at higher wavelengths. The emitted light is then converted into electricity by thin strips of photovoltaic material placed at the slate's edges. The synthesized luminophores have been used to realize a series of PMMA/Eu^{3+} slates by cast polymerization, having a 50 × 50 mm^2 active area and thickness of 3 mm. The prepared materials strictly absorb UV radiation, showing transparency and absence of coloration comparable to those of window glass (AVT = 92%, CRI > 98, Fig. 1a). The LSCs also show excellent UV blocking properties, as they fully absorb AM1.5G radiation between 300 and 400 nm. Such wavelengths are known to be harmful to human health, and to accelerate the degradation of indoor furniture and flooring, shortening their service lifetimes. LSC-PV devices have been obtained by coupling the PMMA/Eu^{3+} slates to Si solar cells. Electrical characterizations (JV curves, EQE spectra, Fig. 1b) have been conducted in compliance with widely recognized guidelines for correct measuring and reporting of LSC devices. Results demonstrate that, by employing the proposed super-bright luminophores, it is possible to achieve classic Eu^{3+}-based concentrators performances by using a 1/100 of Eu weight content in respect, denoting a most efficient use of such valuable material. Owing to their selectivity to UV photons, the PMMA/Eu^{3+} slates also show potential application as self-powered photodetectors for UV radiation. A brief overview of preliminary results will be presented as well.



a) Absorption spectra of the investigated LSCs, demonstrating UV-blocking capabilities. Photographs of the LSCs under daylight. The observed visible color originates from the emission of Eu^{3+} complexes within the polymer matrix. b) Electrical output of the LSC-PV devices under 1 sun AM1.5G illumination. Optimized ligand design enables high performance with a two-order-of-magnitude reduction in Eu^{3+} content.

S3-17 |

LITHIUM-ION BATTERY CATHODE MORPHOLOGY AND MECHANICAL BEHAVIOR: FOCUS ON NMC MATERIALS

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Nickel-rich lithium nickel manganese cobalt oxide (NMC) cathodes are among the most promising materials for next- generation lithium-ion batteries due to their high specific capacity and energy density. However, these cathodes suffer from mechanical and structural degradation during electrochemical cycling, which limits their long-term stability and commercial viability. Microstructural features such as particle morphology and internal stress distribution play a critical role in determining degradation pathways. This study investigates the effect of morphological characteristics on the mechanical and electrochemical degradation behavior of NMC cathodes synthesized via coprecipitation. Samples were prepared by Centro Ricerche Fiat (CRF) and embedded in resin under high pressure for mechanical stability. Microstructural and morphological characterization was conducted by the University of Roma Tre using focused ion beam–scanning electron microscopy (FIB-SEM), enabling high-resolution imaging and 3D reconstruction of cathode architectures. A serial slicing approach (Slice & View™) was employed to generate a stack of nanoscale images, which were processed using Avizo3D software for volume rendering, segmentation, and particle-matrix discrimination. The resulting morphology showed predominantly spherical secondary particles with distinct radial cracking patterns, along with visible pores and voids. These features are attributed to synthesis-induced stresses, cationic disorder, and repeated volume changes during lithiation/delithiation. The observed microcracks—both intergranular and intragranular—facilitate electrolyte infiltration, accelerating structural deterioration and electrochemical fading. Surface reconstruction and particle pulverization were evident, leading to mechanical decoupling of active particles from the conductive matrix and binder. High Speed Nanoindentation measurements confirmed a substantial loss in mechanical stiffness and hardness in cycled samples. Furthermore, phase transitions from the layered structure to a disordered rock-salt phase were detected near the particle surface, promoting the formation of a Cathode Electrolyte Interphase (CEI). This interphase is associated with parasitic side reactions, further exacerbating performance loss. The combined effects of microstructural damage and surface phase transformation significantly impact on the capacity retention and cycling stability of nickel-rich NMC cathodes. Overall, this study highlights the critical influence of particle morphology on both mechanical integrity and electrochemical performance.

S3-18 |

FIRST-PRINCIPLES STUDY OF OPTOELECTRONIC AND TRANSPORT PROPERTIES IN MAPI AND TRIPLE-CATION PEROVSKITES

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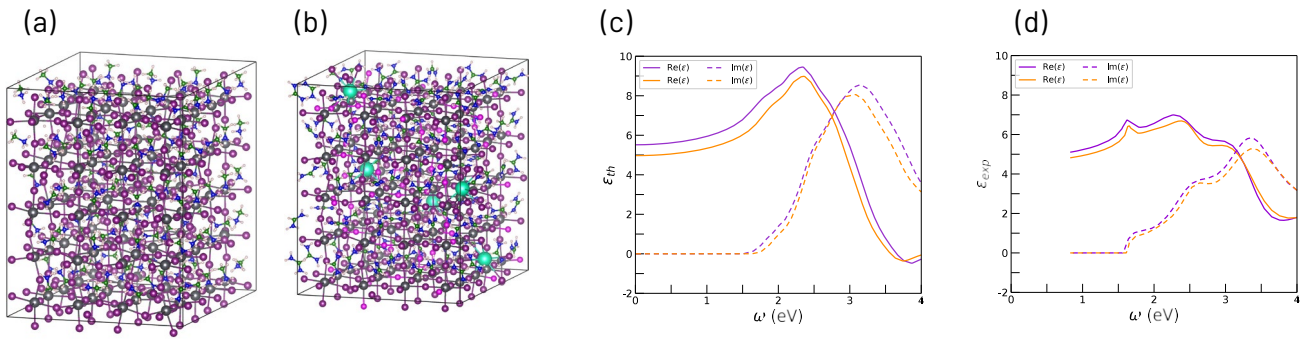
Metal halide perovskites have emerged as leading candidates for next-generation photovoltaic (PV) technologies due to their exceptional optoelectronic properties, including high absorption coefficients, optimal bandgaps, defect tolerance, and long charge carrier lifetimes. Among these, methylammonium lead iodide (MAPI) and mixed-halide, triple-cation perovskites (TriLHP) are two of the most extensively studied compositions. The interplay between organic and inorganic components in these materials plays a key role in determining their structural stability, dielectric behavior, and charge transport properties factors that critically impact their PV performance. In this work, we investigate the optical and transport properties of MAPI and TriLHP using density functional theory (DFT) and validate the theoretical predictions with experimental ellipsometry measurements on TriLHP. Using first-principles calculations, we compute the dielectric functions and analyze how the material composition affects dielectric screening and electronic structure. Our results show that MAPI exhibits stronger dielectric screening, which can enhance defect tolerance and reduce charge carrier recombination. In contrast, TriLHP displays a lighter electron effective mass, likely due to halogen mixing and octahedral distortions, suggesting enhanced charge transport capabilities.
We also estimate the exciton binding energy and radius for both materials, confirming the presence of Wannier-Mott excitons with binding energies on the order of the thermal energy at room temperature. This supports efficient exciton dissociation into free carriers, a key factor for high photovoltaic efficiency. Our comparative study reveals how compositional tuning can be used to modulate the optoelectronic properties of perovskite materials, providing valuable insights for the rational design of efficient and stable solar absorbers. The integration of theoretical modeling with experimental validation underscores the importance of a synergistic approach to understanding and optimizing the performance of perovskite- based PV devices.



Computational models of MAPI (a) and Triple-cation (b). Theoretical (c) and experimental (d) dielectric functions.

S3-19 |

PASSIVE COOLING OF SILICON PHOTOVOLTAIC CELLS BY USING PHASE CHANGE MATERIALS AND EXPANDED GRAPHITE COMPOSITES

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Passive cooling strategies have been designed to reduce the temperature of silicon photovoltaic (PV) cells, as their power conversion efficiency declines with increasing temperature. Organic Phase Change Materials (PCMs) are commonly employed in passive thermal management systems due to their capacity to absorb and store heat at a nearly constant temperature during their solid-to-liquid phase transition. However, two primary challenges limit their application: the need for shape stabilization to prevent leakage when the material is in a molten state, and the enhancement of thermal conductivity to ensure efficient heat transfer. In this study, expanded graphite (EG) is investigated as a highly conductive supporting matrix for phase change materials (PCMs) in the development of heat-absorbing panels. The EG was vacuum- impregnated with PCMs having melting points between 30–55 °C, and the resulting stabilized powders were compacted at room temperature to form the panels. The composites exhibited high melting enthalpies (150–220 J/g), significantly enhanced thermal conductivity, up to 5000% higher than that of the neat PCM, reaching values around 10 W/m·K, and satisfactory leakage resistance, particularly when fatty acids were used as the PCM. The compacted panels can be placed in direct contact with photovoltaic (PV) cells by utilizing the unused space typically found on the rear side of PV modules, making them suitable for both new installations and the retrofitting of existing systems. Various encapsulation solutions were explored to prevent PCM leakage while preserving effective heat transfer, including custom-designed 3D-printed housings that positioned the panels in contact with the solar cells. Field tests were carried out in Trento, Italy (46° N, 11° E) during the spring and summer of 2025, monitoring cell temperatures under sunlight exposure with and without thermal management. Panels incorporating single and multilayer PCM composites were tested. Efficiency improvements were estimated based on temperature reductions, which were correlated with different temperature coefficients to generalize the results across a wider range of scenarios. Temperature reductions between 15 °C and 30 °C were sustained for several hours, in some cases completely mitigating daily temperature peaks. These reductions led to energy output gains of up to 11%.

S3-20 |

1INTERFACIAL PASSIVATION BETWEEN $CsPbI_3$ AND HOLE TRANSPORT LAYERS: EXPERIMENTAL AND THEORETICAL INSIGHTS

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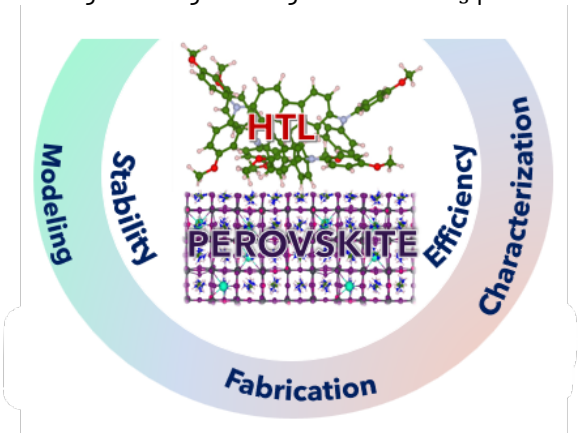
Lead halide perovskites (LHPs) are promising materials for solar cells, offering outstanding optoelectronic properties, low-cost fabrication, and power conversion efficiencies. Among them, caesium lead triiodide ($CsPbI_3$) stands out for its superior thermal stability. However, it remains prone to phase instability, moisture sensitivity, surface defects, and interfacial recombination, which limit performance. Addressing these limitations requires effective interface engineering strategies to optimize charge transport, suppress non-radiative recombination, and enhance material stability. We investigated $CsPbI_3$ interfaces with hole transport layers (HTLs) and passivants using both computational and experimental approaches. Through Density Functional Theory (DFT) calculations we provided insights into interfacial adhesion and electronic structure modifications, which are critical for optimizing device design. Experimentally, we explored interface passivation using P3HT, OABr, and OAI to enhance interfacial quality and improve optoelectronic properties. We analyzed the interaction of $CsPbI_3$ with HTLs such as 2-PACz, PTAA, and Spiro-OMeTAD, as well as the passivant P3HT. Preliminary DFT results indicate that $CsPbI_3$ exhibits stronger interaction with SPIRO, as reflected in its lower adhesion energy. Experimentally, we find that passivants such as OABr and OAI enhance photoluminescence, suggesting a reduction in non-radiative recombination, consistent with previous studies on similar perovskite compositions. This combined computational and experimental approach provides insights into interface engineering strategies for $CsPbI_3$ perovskite solar cells.



Holistic Design Strategy for Perovskite Interfaces

S3-21|

HIGH POROSITY CARBONS DERIVED BY THERMOSETTING RESIN WASTE FOR HYDROGEN STORAGE: THE ECOSTORE-H_2 PROJECT

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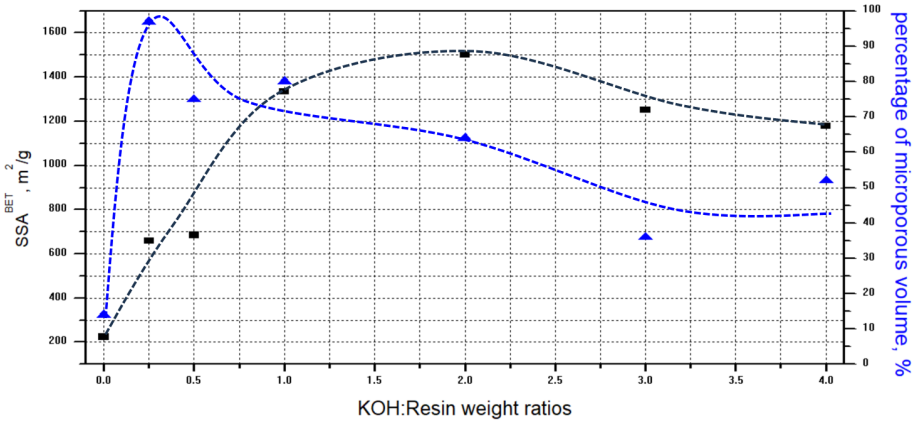
Hydrogen (H_2) is commonly considered a promising energy carrier, thanks to its high gravimetric energy density and zero emissions in its use. Unfortunately, its low volumetric energy density requires high pressures and low temperatures for its storage and transport. Materials for solid-state storage at low pressures and temperatures close to ambient are still being studied and designed. Among these, highly porous carbon materials, easy to prepare and with excellent adsorption properties, are of particular interest especially if obtained from recycled materials or biomass. The ECOSTORE-H_2 project aims to transform waste materials into highly porous carbons for energy storage applications, in particular for H_2. As part of this project, a study was conducted on the influence that a specific activator, KOH, added in the single-stage carbonization process, has on the porosity of carbon materials obtained using waste thermosetting resins. In detail, the influence of the amount of KOH on the pore formation and on the final structure of the materials has been analyzed. The porosity of the carbonaceous materials, obtained by pyrolysis under reducing conditions and at controlled temperature, has been analyzed by evaluating the specific surface area, the pore distribution and the adsorption capacities with respect to a target molecule (dichloromethane). Morphological and structural analyses have also been performed. The results obtained are crucial for the definition of sustainable and efficient materials for hydrogen storage, while promoting a circular economy.



Influence of KOH ratio on the precursor on the specific surface area and microporous percentage of synthesized activated carbons.

S3-22 |

TUNING STRUCTURE AND ELECTRONIC BEHAVIOR IN PEROVSKITE-INSPIRED MATERIALS VIA MIXED HALIDE CHEMISTRY

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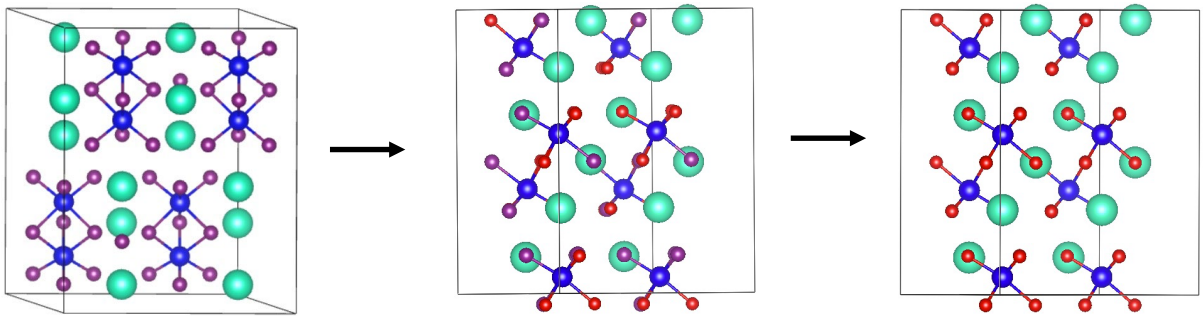
Lead halide perovskites have attracted considerable interest in optoelectronics due to their exceptional properties, including high absorption coefficients, tunable bandgaps, long carrier lifetimes, and excellent defect tolerance. Nevertheless, their practical deployment is limited by the toxicity of lead, motivating the search for more environmentally friendly alternatives. Among the lead-free candidates, bismuth-based perovskite-inspired materials have shown promise, offering similar electronic features along with improved stability. In this work, we employ density functional theory (DFT) to systematically explore the structural, electronic, and carrier transport properties of the mixed-halide series $Cs_3Bi_2(I_{1-X}Br_X)_9$, covering a broad range of compositions ($0 < x < 1$). Our results predict a composition-dependent phase transition from the iodine-rich $P6_3/mmc$ structure to the bromine-rich P-3m1 structure, occurring around 42% Br content. The bandgap is found to increase with rising Br concentration, aligning with reported experimental trends. Calculated effective masses show that electrons consistently possess lower masses than holes across the composition range, suggesting superior electron mobility. Moreover, we observe higher hole masses with increasing Br content, potentially due to self-trapping effects associated with Br atoms, which may influence charge transport behaviour. Overall, this study underscores the critical influence of halide composition on phase stability, electronic properties, and transport characteristics in Bi-based perovskite-inspired materials. The insights gained here can guide the design and optimization of lead-free materials for future photovoltaic and photocatalytic technologies.



Optimized structures for $Cs_3Bi_2I_9$ (P63/mmc, left), $Cs_3Bi_2(I_{0.58}Br_{0.42})_9$ (transition state, P-3m1, center) and $Cs_3Bi_2Br_9$ (P-3m1, right).

S3-23 |

A NOVEL Li-DOPED HIGH-ENTROPY BIXBYITE AS A POSSIBLE Li-ION BATTERIES CATHODE: PRELIMINARY CHARACTERIZATION AND CELL TESTING

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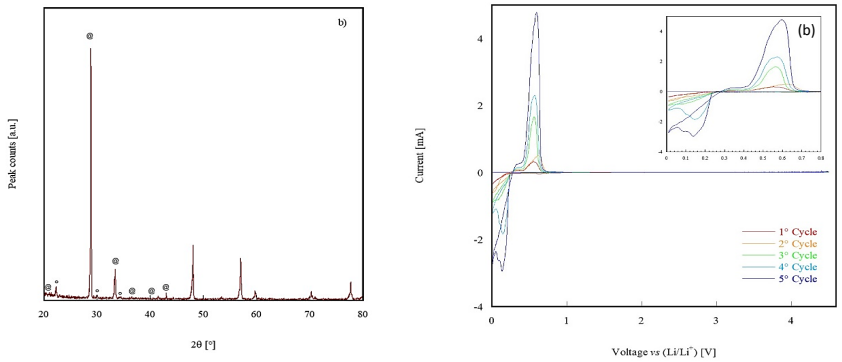
High entropy oxides (HEOs) have been attracting increasing interest in the field of lithium-ion batteries (LiB) for several years. When used as cathode or anode materials, they can combine stability and high electrochemical performance in a highly flexible composite structure. This study proposes the use of HEO owning bixbyite structure (M_2O_3) as an alternative active material for the cathode of lithium-ion batteries (LIB). The composition of this new HEO is $(Zr_{0.67}Yb_{0.33}Gd_{0.33}Sm_{0.33}La_{0.33})O_{3+d}$ which was designed using the cluster plus glue atom method and successfully synthesized by solid-state process (starting from the oxides of all the cations and employing using ball-milling). The material was then impregnated with $LiNO_3$ solution and finally calcined at 1500°C for 6 h. The formation of the single phase was confirmed by X-ray diffraction analysis (see Fig. 1(a)) with minor impurities attributed to interaction with the alumina crucible. The electrochemical performances of this novel cathode were evaluated in CR2032-type coin cells by cyclic voltammetry (CV), see Fig. 1(b), and galvanostatic charge-discharge test (GCD). CV results revealed that Yb^{3+}/ Yb^{2+} and Sm^{3+}/ Sm^{2+} likely, act as reducing couples, characterized by stable RedOx reactions, in Li-doped HEO facilitating delithiation/lithiation processes. Furthermore, charge-discharge profiles demonstrated high cyclic stability, although the tests were limited to four cycles. These results strongly indicate that the newly developed bixbyite-structured HEO holds potential as a highly effective cathode material for low-power, low-current battery applications. Its promising electrochemical performance could pave the way for more efficient and durable energy storage solutions. However, to fully realize and validate this potential, further comprehensive investigations are essential-particularly by extending the number of charge-discharge cycles to thoroughly assess long-term stability and durability.



Diffraction patterns of the Li-doped HEO calcined at 1500 °C for 6 h (a), Cyclic voltammetric (CV) profile of Li-doped HEO calcined at 1500 °C for 6h (b).

SESSION 4

S4-1|

VITRIMERIZATION: INFLUENCES OF PROCESSING CONDITIONS ON MECHANICAL PROPERTIES AND VITRIMERIC BEHAVIOR

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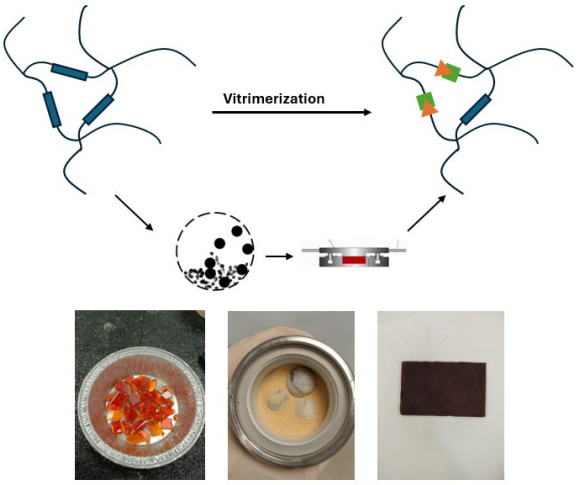
Epoxy resins represent 70% of the commercial thermoset market. They offer high mechanical and chemical resistance, but their crosslinked structure prevents reprocessing and recycling. Vitrimers are polymers with a similar three-dimensional structure to thermosets, but they include dynamic covalent bonds that, through exchange reactions, provide reprocessability and recyclability. These materials can be obtained through the synthesis of intrinsically recyclable epoxy resins or by converting non-recyclable thermoset waste via processes like vitrimerization. The latter is a cost-effective and eco-friendly method that involves functionalization in ball milling with a catalyst, followed by recycling in a hot press. A significant advancement in this field is the development of vitrimeric composites by adding fillers as sources of functional groups during ball milling, enhancing exchange reaction rates and thermomechanical properties. This project builds on existing research by introducing biobased fillers produced through simpler, scalable, and eco-friendly methods. Potential fillers include pine needles, fumed silica, lyophilized potato peel, recycled paper, and silica glass. Another improvement we aim to introduce, addressing the limitations found in the literature, is optimizing process parameters to enhance powder compaction. This optimization aims to improve the mechanical properties of the final product, reducing brittleness and increasing the elastic modulus, ultimate tensile strength and breaking strain, thus expanding the potential applications of these materials. This project highlights the importance of sustainable approaches in material development and waste management, offering eco-friendly, scalable solutions to the challenge of epoxy thermoset waste.



S4-2 |

PILOT PLANT SILANE FUNCTIONALIZATION OF BIOFILLERS FROM AGRO-INDUSTRIAL WASTE TO ENHANCE BIOCOMPOSITE

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Agro-industrial bio-waste, such as maize, wineseed, and sunflower residues, offers a viable alternative to conventional petroleum-based additives and mined fillers. These materials are abundant, naturally occurring, non-edible, and renewable. Their powdered form makes them ideally suited for incorporation into polymer matrices. Numerous studies have investigated the use of lignocellulosic fillers in biocomposite preparation, demonstrating promising results. A major challenge in utilizing biofillers for biocomposite production is their compatibility with the polymer matrix. Poor compatibility leads to weak interfacial adhesion, resulting in compromised mechanical properties. To address this issue, the use of silanes to functionalize biofillers has emerged as a promising solution. Silanes can enhance filler-matrix compatibility due to their ability to form chemical bonds with both the filler surface and the polymer matrix, effectively acting as molecular bridges between the two phases. This work introduces an innovative silanization technique developed at the pilot scale using a turbomixer. The process is optimized for minimal solvent usage, enabling its potential translation to large-scale production. In addition to investigating silane concentration and reaction conditions, we selected and evaluated the most suitable silanes for each biofiller and matrix combination to optimize the final biocomposite properties. Notably, the inherent hydrophilicity of polyesters is often insufficient to ensure optimal compatibility with lignocellulosic biofillers. In this work, we prepared composites with PLA, PBAT, and PBS matrices compatibilized with aminosilanes, while polyolefin matrices like PP and PE were paired with alkylsilanes. The processed materials were injection molded to produce standard "dog-bone" tensile test specimens. Silane functionalization of the biofiller was characterized using FT-IR spectroscopy. Improvements in interfacial adhesion and biocomposite compatibility were assessed through mechanical testing and SEM analysis of the fracture surfaces of mechanically tested specimens.

S4-3 |

OPTIMIZED ENZYMATIC DEGRADATION OF PLA/PBSA COMPOSITES REINFORCED WITH NATURAL FIBERS

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The increase in plastic pollution on a global scale has led to a need for the development of sustainable alternatives and effective end-of-life solutions. Biodegradable polymers such as poly(butylene succinate-co-butylene adipate) (PBSA) and poly(lactic acid) (PLA) present environmentally friendly options. In this study, a blend composed of 60wt.% PLA and 40wt.% PBSA was developed to combine the beneficial properties of both polymers. However, the degradation efficiency of the blend must be optimized to ensure effective disposal and reduce environmental impact. Enzyme-based degradation strategies offer a promising solution to accelerate polymer breakdown, making them crucial for sustainable material management. Various lipase and cutinase enzymes were evaluated for their effectiveness in degrading polymeric substrates. The findings revealed that Lipase *Pseudomonas sp.*, Lipase B from *Candida antarctica* (CalB), and Lipase from *Alcaligenes sp.* demonstrated high efficiency in degrading PBSA. However, these enzymes did not exhibit any significant effect on pure PLA. Conversely, Proteinase K has been identified as an effective enzyme for PLA degradation, demonstrating its specificity toward this polymer. Given these insights, the development of an enzyme mixture tailored for polymer blend matrices is essential. To achieve effective degradation of PLA-PBSA blends, a sequential enzymatic system is proposed, leveraging the specificity of individual enzymes. To assess the degradation process, weight loss measurements were conducted using a precision balance to quantify polymer reduction over time, providing direct insight into enzymatic activity. Additionally, high-performance liquid chromatography (HPLC) was employed to analyze the degradation products, allowing identification of specific soluble degradation fragments and ensuring that enzymatic hydrolysis proceeded effectively. Gel permeation chromatography (GPC) was also performed to examine molecular weight distribution before and after enzymatic treatment, verifying polymer chain breakdown and confirming the extent of depolymerization. These complementary analytical techniques provided a comprehensive evaluation of the enzymatic degradation of the PLA-PBSA blend, ensuring accuracy in assessing polymer stability and degradation efficiency.

S4-4 |

RECYCLABILITY STUDY OF MDOPE FLEXIBLE FILMS WITH ALOX BARRIER LAYER FOR FOOD PACKAGING

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This work was carried out as part of the RE.MO.PACK (REcyclable MOnomaterial PACKaging) project, which aims to develop innovative structures for single-material flexible packaging, such as polyolefins, that can be easily integrated into recycling processes already used at the industrial level. The barrier performance of the film, i.e. the oxygen transmission rate (OTR) and water vapour transmission rate (WVTR), is guaranteed through the vacuum deposition of aluminium oxides (AlOx) and lacquers, while maintaining the classification as a monomaterial according to European regulations. The current study focuses on evaluating the recyclability of an intermediate material step i.e. flexible MDOPE (Machine Direction Oriented Polyethylene) films with ān AlOx barrier layer, used in food packaging as a sustainable alternative to traditional aluminium or EVOH (Ethylene Vinyl Alcohol) barrier films. The main objective is to analyse the performance of these innovative materials during the recycling process to evaluate possible solutions to reduce their environmental impact, thus aligning with the principles of the circular economy. The project envisaged the analysis of two film samples, the control film (MDOPE25 - CF) and the innovative film (MDOPE25+AlOx - IF), following the Recyclass guidelines 'Recyclability Evaluation Protocol for PE films'. Specifically, the materials were initially ground by means of a cutting mill equipped with a V-shaped rotor, obtaining flakes that were mixed in different proportions (100% CF, 75% CF + 25% IF, 50% CF + 50% IF, 100% IF). Subsequently, the flakes were dried in an oven at 60 °C for 24 h to reduce the surface moisture to below 1%. Finally, the blends were processed using a twin-screw extruder at temperatures between 197 and 235 °C to produce pellets for the subsequent characterisation steps. The results of the analyses, which include differential scanning calorimetry (DSC), Fourier transform Infrared spectroscopy (FTIR), melt flow rate (MFR) and tensile tests, will be reported since they provide critical data on the recyclability of MDOPE films with an AlOx barrier, helping to evaluate their potential as a more environmentally friendly and high-performance alternative for the food packaging industry.

The authors wish to acknowledge the funding from "Risorse del Piano nazionale per gli investimenti complementari al PNRR" Ministero dell Imprese e del Made in Italy within the project "RE.MO.PACK - Study and development of an innovative REcyclable MOnomaterial film and its introduction into the food PACKaging processes" (n° F/310061/01-02/X56).

S4-5 |

DESIGN AND CHARACTERIZATION OF 1K WATERBORNE NON-ISOCYANATE POLYURETHANES FROM BIO-BASED CARBONATES

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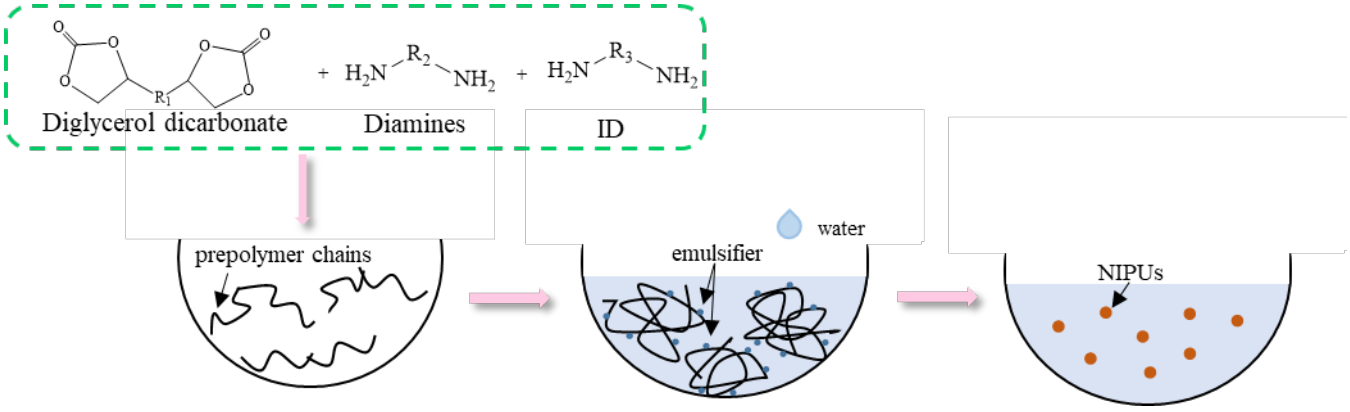
Since their introduction in the late 1930s by Otto Bayer, polyurethanes have become essential materials across multiple industrial fields, largely due to the high reactivity of isocyanates with polyols. These compounds continue to be key components in the production of foams, coatings, adhesives, and elastomers. However, the inherent toxicity of isocyanates raises serious health concerns, as even brief exposure can result in respiratory problems and skin irritation. Growing awareness of these risks has led to tighter safety regulations and has driven research efforts toward the development of safer, more sustainable alternatives-most notably, non-isocyanate polyurethanes (NIPUs). In this work we present the development of novel cationic NIPU dispersions in water, achieved through a polyaddition process involving bio-based cyclic carbonates, diamines, and a tertiary amine functioning as an internal emulsifying agent (ID). Waterborne NIPUs are highly attractive materials with reduced environmental impact and potential applications such as adhesives and coatings, however the preparation of these formulations directly in water involves challenges due to the lack of water-soluble carbonated precursors and the occurrence of side-reactions. A structural, thermal and mechanical characterization of all the synthesized water-soluble non-isocyanate polyurethanes was carried out to study how the chain composition and the formulation step influences the material properties. Overall, the results demonstrate that these 1K waterborne materials represent a sustainable and competitive alternative to conventional isocyanate-based systems.



Synthesis of the waterborne non-isocyanate polyurethanes coatings.

S4-6 |

REDUCED GRAPHENE OXIDE AND TiO_2-COATED POLYURETHANE FOAMS: INTEGRATED PHOTOCATALYTIC ADSORBENTS FOR WATER DECONTAMINATION

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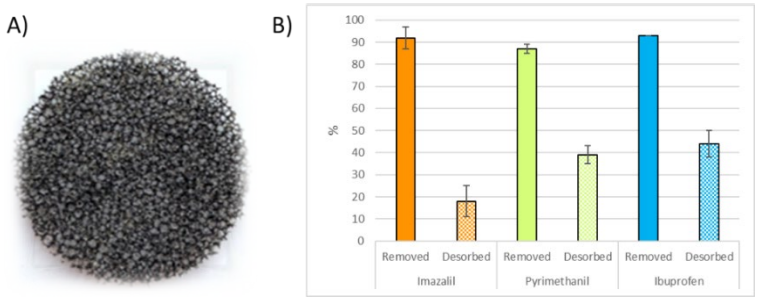
Water decontamination is one of the main challenges of our time, calling for innovative solutions. Compared to traditional sorbent materials, integrated photocatalytic adsorbents represent a sustainable innovative alternative. Their double functionality allows not only to capture contaminants, but also to mineralize the organic pollutants through photodegradation. In this context, research on composite materials of TiO_2 and reduced graphene oxide (rGO) has already provided encouraging results. TiO_2 is the most known photocatalyst, while rGO is studied for its noticeable adsorption capacity toward inorganic and organic pollutants. Moreover, according to the literature, their combination can succeed in overcoming some of the typical TiO_2 limitations, such as fast recombination of photogenerated carriers and high energy gap in the UV region. Nevertheless, rGO/TiO_2 composites are mainly studied in the form of nanopowders, which are hardly applicable in real systems. In this research, by exploiting the self-assembling properties of rGO, we formulated a binder-free coating containing only non-toxic components, i.e., a commercial aqueous dispersion of GO, L-ascorbic acid as reducing agent, and TiO_2 P25. To deposit the coating, we adopted a low-tech strategy involving dip coating, blowing of compressed air, and drying at 40 °C. As substrate, we used a polyurethane (PU) commercial flexible foam. The resulting rGO/TiO_2-coated sample is reported in Figure A.



A) rGO/TiO_2-coated PU foam, B) removal and desorption efficiencies toward different pollutant after 3 h exposure to UV light.

Samples of 2.5 cm diameter and 0.5 cm thickness were employed for the decontamination of 21 mL of monocontaminated $5x10^{-5}$ M aqueous solutions of imazalil, pyrimethanil and ibuprofen. Tests were carried out both in dark and UV light conditions for 3 h. Then, pollutants desorption was achieved by immersing used foams in ethanol. After UV-light irradiation, foams were able to remove ~90% of all the molecules considered, as a result of the combination of adsorption and photodegradation. Considering the difference between the amount of contaminant removed and desorbed, a photodegradation efficiency can be estimated, resulting to be higher (~70%) for imazalil. Foams reusability, in the same conditions, was confirmed up to five times. In the future, coated foams will be tested in continuous flow experiments.

S4-7 |

EUTECTIC SYSTEMS OF TBA-SALTS AND IMIDAZOLE-BASED COMPOUNDS: HOW ANION AFFECTS THE EXPERIMENTAL PHASE DIAGRAM

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The climate and economic challenges of the past few years have led scientific research to explore systems that are environmentally friendly, non-toxic, cheap, and easy to synthesize. Among the most interesting compounds, Deep Eutectic Solvents (DESs) have gained great attention due to their tunable properties. In our recent research, we studied various eutectic systems composed by TBA-based salts and three similar aromatic compounds, namely imidazole, 2-methylimidazole and 2-ethylimidazole. We investigated the experimental phase diagram of each system to identify the effects of both the anion and the length of the lateral alkyl chain bonded to the aromatic ring.
Based on the calculated ideal phase diagram, we prepared and analyzed mixtures at various compositions using differential scanning calorimetry (DSC), to determine their melting points and melting enthalpies. Our results indicate that only the systems containing bromide and tetrafluoroborate anions exhibit negative deviations from thermodynamic ideal behavior, and, therefore, can be classified as DES. In contrast, when the TBA-salt contains a less symmetric anion, such as trifluoromethanesulfonate (TFO), the mixtures with the aromatic compounds melt at temperatures higher than those predicted by the ideal behavior. To clarify these results, we studied the microscopic arrangement of components in the mixtures using both experimental and computational approaches. From an experimental point of view, we studied the intermolecular interactions between the components by infrared spectroscopy (MIR and FIR). The spectra of the pure components and their mixtures, measured at different temperatures and compositions, suggest which chemical bonds are most affected by the mixing of the components. The hypotheses formulated from experimental observations were additionally rationalized by computational modelling involving both classic molecular dynamics (MD) and density functional theory (DFT).

S4-8 |

SCREENING AND OPTIMIZATION OF THE REACTION CONDITIONS OF CATALYTIC ALLYLIC PARTIAL OXIDATION OF CYCLOHEXENE OVER Ce-UiO-67 MOF THROUGH THE DESIGN OF EXPERIMENTS

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Light hydrocarbons can be converted into widely exploited and more valuable oxygenated chemicals via C–H bond activation, becoming more interesting feedstock for the chemical industry and offering a stepping-stone towards a more circular economy. Cyclohexene allylic partial oxidation is important for bulk and fine-chemicals production as adipic acid production both in organic solvents and halide-free conditions. Ce-UiO-67 metal-organic framework (MOF) was synthesised, characterized and tested as a catalyst for the allylic partial oxidation of cyclohexene, taking advantage of the good thermal and chemical stabilities that characterize this type of framework. The catalytic tests in liquid-phase were performed in dark conditions at 25 °C under stirring in dichloromethane (DCM) as a solvent, starting from 162 mmol/g of cyclohexene and 39 mmol/g of *tert*-butyl hydroperoxide, and monitoring the reaction for 24 h and detecting the products by gas chromatography (GC) with a flame ionization detector (FID). The spent catalysts were characterized again after the tests, and exhibited a good stability as evidenced by their crystallinity retainment. Under the adopted preliminary reaction conditions, the catalyst seems to convert cyclohexene into 2-cyclohexen-1-ol and 2-cyclohexen-1-one. By means of a Design of Experiments (DOE), our contribution was devoted to screening the radical initiator amount, the substrate amount, and the oxidant employed looking towards the use of O_2 as a greener one. Exploiting the DOE as a valuable tool, our goal was maximizing the responses productivity (mmol/$g_{catalyst}$). After optimizing the reaction conditions, we aim at investigating and exploiting the photocatalytic activity of Ce(IV)/Ce(III) species.

S4-9 |

COPPER RECOVERY BY WASTE DERIVED ALKALI-ACTIVATED SORBENT

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The global use of Electric and Electronic Equipment (EEE) is extensively increasing in our everyday life and over the years, across different sectors. This trend inevitably leads to a growing Waste from Electric and Electronic Equipment (WEEE), and if left untreated or mismanaged, it may represent a serious environmental concern due to its content of hazardous components. However, WEEE also represents a valuable secondary source of critical and strategic raw materials. Among them, Printed Circuit Boards (PCBs) are very rich in copper (Cu), a strategic element, representing the 40 %(w/w) of the selected e-waste. Through proper treatment and recovery processes, copper can be efficiently extracted from WEEE, offering both significant environmental advantages and substantial economic benefits by reducing the need for primary mining and supporting a more circular economy. Among the available treatments, hydrometallurgical recovery is a versatile technique, which often includes an adsorption step following leaching stages. Adsorption is particularly advantageous due to its high recovery efficiency, rapid extraction time, strong enrichment capability, operational simplicity, and low cost. Moreover, it can be performed using a wide range of sorbents with diverse properties, including silica- and carbon-based materials, green alternatives, and polymeric compounds. Accordingly, waste-derived alkali-activated based materials, obtained by mixing ladle steel slag (Calcetek) with selected retarding admixtures following a procedure developed by Opigeo srl (European Patent extension demand n°. 25179514.2.), was used in this study as adsorbent. The resulting material was used in powder form, maximizing in this way the surface to volume ratio, and was contacted with different initial copper concentrations, ranging from 1 mM to 300 mM to study the sorbent capacity and behaviour. The experiments were conducted in batch at room temperature for 90 minutes under stirring conditions (450 rpm), using 50 mL of solution and 2 grams of sorbent. The adsorption capacity showed very promising results also at high initial concentrations, reaching 5 mmol/g of adsorbed copper. The materials were also characterized using Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDX), and X-ray Diffraction (XRD).

S4-10 |

MULTIFUNCTIONAL FIBERS FOR PLA BIOCOMPOSITES: A NOVEL APPROACH TO REINFORCEMENT AND POST-USE PRODEGRADATION

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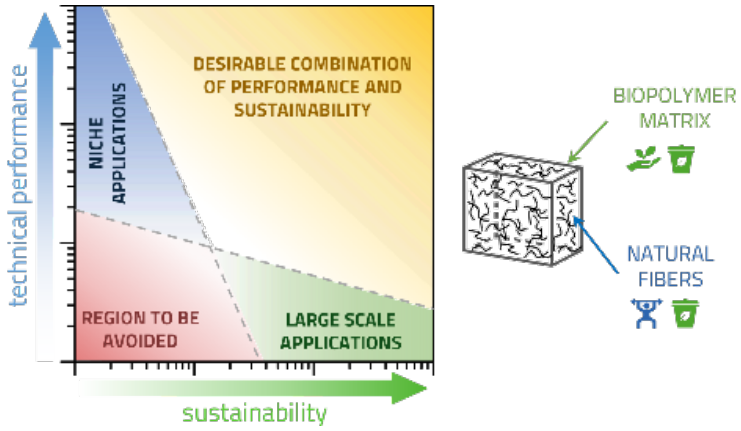
The addition of lignocellulosic fibers to biopolymers is expected to improve their mechanical performance during use. Furthermore, due to their hygroscopic nature, this class of fibers can also promote biodegradation of the hydrolyzable PLA matrix at the end of the biocomposite's life cycle, thereby contributing to a reduced overall carbon footprint for this family of materials. The key challenge is to find the optimal trade-off between the reinforcing action of lignocellulosic fibers, which is crucial for maximazing biocomposite performance during use, and their ability to accelerate degradation at the end of the lifecycle. How much pushing in these two directions, i.e., performance maximization or environmental impact minimization, depends on the specific application: large-scale products (e.g., fast-moving consumer goods) should prioritize environmental aspects, while niche applications should be primarily driven by property optimization. A new paradigm can hence be proposed when dealing with biocomposites. This is schematically shown in Figure.



The concept of sustainability-weighted performance

Moving towards the upper-right quadrant of the plot can be pursued in different ways. We are currently exploring two possible strategies in the case of PLA-based biocomposites reinforced with hemp fibers. First, we are considering the simultaneous use of two components of the hemp stalk: (i) bast fibers for promoting reinforcement and (ii) the highly hygroscopic shives particles for bringing water into the material for (bio)degradation purposes. Other pro-degradative fillers, such as pine needles, are also being considered. The second strategy involves the use of strictly reinforcing fibers (hemp bast) functionalized with pro-degradative agents. Here the challenge is to maxime the stress transfer at the fiber-matrix interface. This goal is being addresses by: (i) preserving fiber lengths greaters than the critical value necessary for optimal stress transfer throughout processing (extrusion), and (ii) improving fiber-matrix interfacial adhesion by environmentally friendly surface modifications (enzymatic treatment). A comprehensive characterization campaign is currently underway to evaluate both the technical properties of PLA-based biocomposites (vertical axis of Fig.1) and their environmental impacts via Life Cycle Assessment (horizontal axis of Fig.1). The objective is to quantitatively combine performance and sustainability indicators. Therefore, we propose a novel design principle based on the concept of sustainability-weighted performance, whereby multifunctional fibers allow PLA-based biocomposites to meet the mechanical requirements of technical applications while enhancing end-of-life biodegradability. These results align with circular economy goals and represent a significant step forward in the development of next-generation sustainable materials.

S4-11 |

MECHANICAL RECYCLING OF HDPE-BASED PACKAGING: INTERPLAY BETWEEN CROSS CONTAMINATION, AGING AND REPROCESSING

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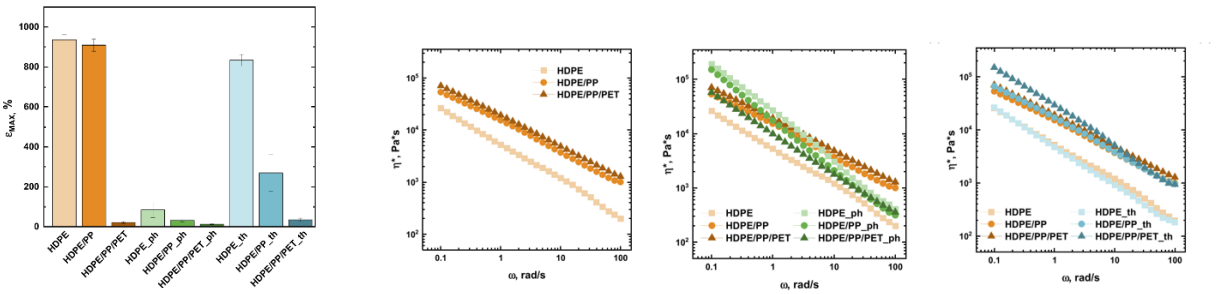
Developing efficient mechanical recycling strategies for polyolefins remains a significant challenge due to several factors. Firstly, the thermo-mechanical degradation that occurs during reprocessing, along with various forms of degradation experienced throughout their service life, leads to substantial alterations in the microstructure of polyolefins. This, in turn, causes a gradual decline in their performance. Additionally, limitations in sorting technologies often result in minor cross-contamination within recycled polyolefins. These factors contribute to the production of recyclates with a heterogeneous and complex morphology, which greatly influences their final properties and frequently restricts their potential applications. Our work aims at addressing these issues, evaluating the combined effect of cross-contamination and of the degradation undergone by the polymers during service life and reprocessing for high-density polyethylene (HDPE) containing low amounts of polypropylene (PP) and polyethylene terephthalate (PET) as contaminants. Starting from the typical composition of HDPE bottles, HDPE-based materials with cross-contaminations were formulated and exposed to photo-oxidative or thermo-oxidative aging treatments. The resulting systems were reprocessed and analysed to evaluate potential functional and microstructural modifications caused by the combined effects of cross-contamination and degradation, as well as their impact on the final mechanical properties of polymeric materials. Firstly, it was demonstrated that the presence of cross-contaminations significantly reduces the formation of oxygen-containing functional groups resulting from photo- and thermo-oxidative treatments, particularly in photo-oxidized materials. Furthermore, the addition of PP and PET led to the formation of immiscible blends, with their final microstructure being highly influenced by the impact of the specific aging treatment on the viscosity of the HDPE matrix phase. In particular, the photo-oxidised sample of HDPE with PP and PET showed significant morphological alterations, driven by both aging and reprocessing, leading to a more refined morphology compared to the non-aged counterpart. Finally, tensile characterization results highlighted the critical role of cross-contamination in causing severe embrittlement of HDPE, particularly in thermo-oxidized materials; in contrast, under photo-oxidative aging, PP and PET presence has a negligible impact on HDPE ductility, which is already significantly compromised by degradation.



Mechanical and rheological characterization of aged samples.

S4-12 |

BIOCHAR FOR THE ADSORPTION OF RARE EARTHS ELEMENTS (REEs) FROM WASTE OF ELECTRIC AND ELECTRONIC EQUIPMENT (WEEE)

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The use of Electrical and Electronic Equipment (EEE) is steadily increasing across various sectors, including transportation, healthcare, security, and energy generation. This increase is expected to result in a corresponding rise in Waste from Electrical and Electronic Equipment (WEEE). If not managed properly, WEEE can pose significant environmental concerns due to the presence of hazardous and toxic substances that can be released into the environment. Conversely, the proper treatment of WEEE can offer substantial economic benefits and reduce the demand for raw materials, such as Rare Earth Elements (REEs). In this context, the adsorption of metals onto solid sorbents is gaining significant attention due to its operational simplicity, low cost, and minimal use of organic solvents. Biochar, the by-product obtained from gasification and pyrolysis processes, represents an environmentally friendly and promising solution for the adsorption of metals found in WEEE and in wastewater. Indeed, this carbonaceous material, because of its physicochemical characteristics, such as high surface area, surface functional groups, and porosity, can efficiently adsorb REEs contained in WEEE. Moreover, biochar is gaining attention for its role in climate change mitigation, as well as in the management of agricultural and forestry wastes. Accordingly, in this study biochar was tested as a potential sorbent for simulated REE solutions containing Lanthanum (La), Neodymium (Nd), and Yttrium (Y), which are representative of the REEs. The comparison among commercial biochars derived from gasification and pyrolysis processes of residual biomass, such as woody-derived biomass and vine pruning waste was assessed. The materials were characterized using X-ray Diffraction (XRD), Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDX), and Brunauer-Emmett-Teller (BET) analyses. An initial metal solution of 100 mM was evaluated, resulting in a maximum capture efficiency in the range of 45-69%, depending on the specific REE.

S4-13 |

SUSTAINABLE DESALINATION OF OLIVE MILL WASTEWATER VIA ELECTRODIALYSIS

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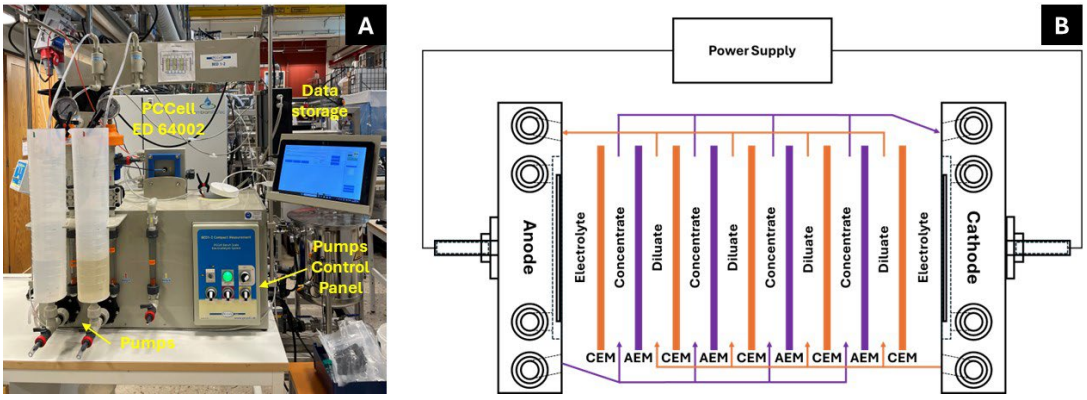
Electrodialysis (ED) is a membrane-based separation process that exploits the selective migration of ions under the influence of an electrical driving force. It removes ionized species from liquid solutions using alternating cation- and anion-exchange membranes, arranged between two electrodes. When a direct current is applied, cations move toward the cathode and pass through cation exchange membranes (CEM), while anions migrate toward the anode through anion exchange membranes (AEM). As a result, alternating compartments become either depleted of salts (diluate) or enriched (concentrate). ED is an environmentally friendly technology that competes with reverse osmosis for desalination of low-salinity streams. It shows advantages in fouling resistance and high sustainability due to its low chemical consumption. This study investigates the feasibility of using ED for demineralization of pretreated olive mill wastewater (OMW), with the goal of reducing salinity while preserving valuable phenolic compounds. Experiments were performed using a PCCell ED64 electrodialysis stack configured with five cell pairs and powered by a constant voltage (Fig. 1). The OMW was previously acidified, microfiltered, and nanofiltered to reduce organic load and suspended solids. A series of membrane combinations were tested in batch mode to evaluate their ionic removal efficiency and their impact on the retention of bioactive molecules. The tested membrane pairs included standard heterogeneous membranes (SK and SA), homogeneous monopolar pairs (MVK/MVA), and three specialty membranes (100D, 200D, 400D) coupled with SK. Among these, the standard SK/SA membranes and the 100D/SK configuration demonstrated the best trade-off between conductivity reduction and phenolic retention. Specifically, these two configurations minimized the migration of low molecular weight polyphenols (e.g., tyrosol and hydroxytyrosol) into the concentrate while achieving significant demineralization. In contrast, membranes such as 200D and 400D, characterized by looser structure and higher ion selectivity, led to increased phenolic losses. Although the present study focused on membrane screening under constant voltage conditions, the transition toward a semi-continuous process is planned in future work. This would aim to further enhance process control, energy efficiency, and scalability. This research is funded by Agritech Project (PNRR), National Center for Technology in Agriculture.



Laboratory scale of ED system a) ED pump unit, data storage, and PCCell ED 64002 and b) ED stack.

S4-14 |

MULTI-DIMENSIONAL APPROACH OF PAPER-BASED PACKAGING FUNCTIONALISATION: THE KEY DRIVER TO SUSTAINABILITY

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The development of barrier coatings for packaging substrates is key to ensuring proper shelf-life of the content. For paper and board substrates, the coating formulation needs to be managed to ensure performance and processing with conventional coating techniques. The formulation of the polymer, as well as possible filler content and morphology, can broadly affect the outcoming barrier performance to, e.g., water, water vapour, and grease to as low as 0 g/m2, 10 g/m2·day, and >24 h, respectively. However, it is mandatory to assess the processing ability of coated substrates. The coatings need to adapt to non-planar fibre surfaces while minimising the coating weight, possibly below 5 wt%. Folding, creasing, and press-forming can negatively affect coating integrity and its barrier performance (up to +120% in water vapour transmission rate for small cracks): there's evidence showing that higher latex Tg and filler content embrittle the coating, making it less attractive from an industrial perspective, besides providing a higher barrier. Aiming for a holistic approach, the research also needs to include the role of the consumer and the end-of-life of the packaging. This means that, on the one hand, wrong perception of the coated material (which is influenced by the coating smoothness and glossiness, with a Pearson correlation of 0.933 and 0.874, respectively; $p < 0.05$) can undermine proper packaging sorting, hence the chance to contribute to ensuring European recycling targets and circular economy. On the other hand, the recycling behaviour according to the most recent methodologies and standards is not fully explored yet. Indeed, besides thin coatings (5–10 μm) may not generate waste that is mechanically separated in the recycling facility, early-stage results in tracking small particles highlighted that thin coatings may generate tens of thousands of microplastics. Therefore, a multi-dimensional perspective for material design as coating for packaging applications can open discussions at early stages that help (re)consider factors bridging the gap between research and industry, pushing higher circularity in the sector.

S4-15 |

CHIRAL 3D HYBRID METAL HALIDES FOR NEXT-GENERATION SEMICONDUCTORS

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In the past few years, chiral hybrid organic-inorganic perovskites (HOIPs) have emerged as promising materials for applications in optoelectronics, spintronics, photodetection, energy harvesting and beyond, enabling the absorption and subsequent emission of polarized light with enhanced tunability across the electromagnetic spectrum. So far the research has largely focused on 2D and quasi-2D HOIPs, along with a few 1D and 0D ones, demonstrating remarkable chiroptoelectronic and spin-polarization properties. However, expanding the corner-sharing interconnection of the inorganic motif in the three dimensions is challenging due to steric constrains, as the bulky chiral cations prevent the accordance with the Goldschmidt tolerance factor, but highly demanded for isotropic charge transport since the organic layers usually act as dielectrics in low-dimensional systems.
In our work, we have engineered novel chiral HOIPs derivatives featuring a 3D corner-sharing octahedral architecture closely resembling that of prototypical perovskites. This structural motif is attained by incorporating the relatively small ditopic cation *R*/*S*-3-aminoquinuclidine (*R*/*S*-3AQ) leading to the (*R*/*S*-3AQ)Pb_2Br_6 materials, exhibiting a direct bandgap and an isotropic electronic band structure in agreement with a three-dimensionally delocalized excitation, in sharp contrast with the Ruddlesden-Popper counterpart (*R*/*S*-3AQ)$_2$PbBr$_4$·2Br presenting typical 2D features. The measured chiral anisotropy factor is in good agreement with values predicted from first-principles calculations for such a chiral inorganic framework, and a pronounced Rashba-type spin splitting is observed in the conduction band, expected for a non-centrosymmetric semiconductor and arising from the synergy between spin–orbit coupling and structural chirality. A lower exciton binding energy was found out in the 3D composition, indicating a more stable excitonic population and being beneficial for an enhanced charge transport. Conductivity measurements are currently ongoing to further assess the impact of these electronic properties on the material's potential performance in optoelectronic applications. The demonstrated 3D chiral HOIP derivatives, featuring a wide chemical tunability, represents a promising platform for developing next-generation nonlinear functional materials.

S4-16 |

ANALYSIS OF MATER-BI/PHBV BIODEGRADABLE SYSTEMS TO PRODUCE PACKAGING FILMS

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The environmentally friendly properties of biodegradable polymers have led to their immense scientific and industrial interest. In packaging, which makes up 60% of plastic items, biodegradable materials should be used more frequently to address the market economy and recurring environmental risks. Despite the growth of biodegradable polymers, their utilisation is constrained due to the heightened competitiveness of conventional plastics in terms of cost and performance. Biodegradable polymers exhibit technological constraints regarding processability and functionality, especially due to the inadequate gas/moisture barrier that severely limits their use in food packaging. In this study, films were produced by co-extruding two bioplastics that complement one another in terms of characteristics: Poly3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV) and MaterBi. PHBV is known for its strength as a good barrier against oxygen, but it is brittle and difficult to process; MaterBi, instead, has low stiffness and high ductility, but poor barrier properties. Research was done on the films' barrier effectiveness, optical characteristics, mechanical strength, and sealability, to determine how the processing parameters affected the films'characteristics.

S4-17 |

INFLUENCE OF GREEN AND ORGANIC SOLVENT IN THE FRACTIONATION ON PLA BIO-NANOCOMPOSITES

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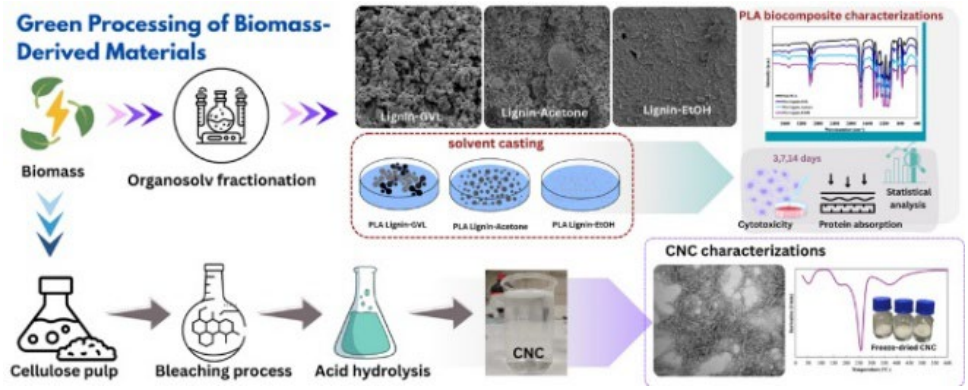
This study explores the use of biomass-derived materials to develop sustainable biocomposites based on polylactic acid (PLA). Lignin was extracted from cardoon using three solvents; gamma-valerolactone (GVL), acetone, and ethanol (EtOH), which were incorporated into PLA at 3 wt% via solvent casting. Cellulose nanocrystals (CNC) were synthesized through an acid hydrolysis with H_2SO_4 62 wt% and consequently treated via dialysis and ultrasounds to obtain CNC. Transmission electron microscopy (TEM) revealed that the CNC exhibited a rod-like morphology at the nanoscale, and thermogravimetric analysis (TGA) indicated a multi-step thermal degradation profile. In the case of lignin characterization, scanning electron microscopy (SEM) demonstrated distinct differences in particle morphology among the three solvents used for fractionation. Lignin obtained using GVL showed gradual coalescence and particle nucleation, acetone led to rapid solidification resulting in a mixture of large and small particles, while ethanol (EtOH) induced rapid supersaturation, producing smaller and more irregularly shaped particles. TEM analysis further provided insights into the internal structure, porosity, and aggregation behavior of the lignin fractions. For the PLA–lignin biocomposites, Fourier-transform infrared spectroscopy (FTIR) confirmed successful lignin incorporation into the PLA matrix. Variations in the intensities of hydroxyl and carbonyl absorption bands reflected different levels of interfacial interaction depending on the solvent used during lignin fractionation. Among the tested samples, EtOH-derived lignin exhibited the highest thermal stability based on TGA results. The biological performance of the composites was assessed through in vitro experiments using human adipose-derived stem cells (hASCs). All samples exhibited excellent cytocompatibility over a 14-day period with no observable cytotoxic effects. Furthermore, protein adsorption analysis revealed that composites containing EtOH-fractionated lignin showed the highest protein affinity, indicating enhanced biomolecular interaction that could support cell attachment and proliferation. These findings demonstrate the potential of cardoon-derived lignin as a sustainable reinforcement material for PLA and emphasize the critical influence of solvent selection on the thermal, morphological, and biological properties of the resulting biocomposites. In addition, the successful synthesis and characterization of CNC support their prospective use in future high-performance biocomposite systems.



The green processing of biomass-drived materials and charaterizations.

S4-18 |

TUBULAR BRAIDED PVDF MEMBRANES FOR BIOFILM GROWTH IN MEMBRANE AERATED BIOREACTOR

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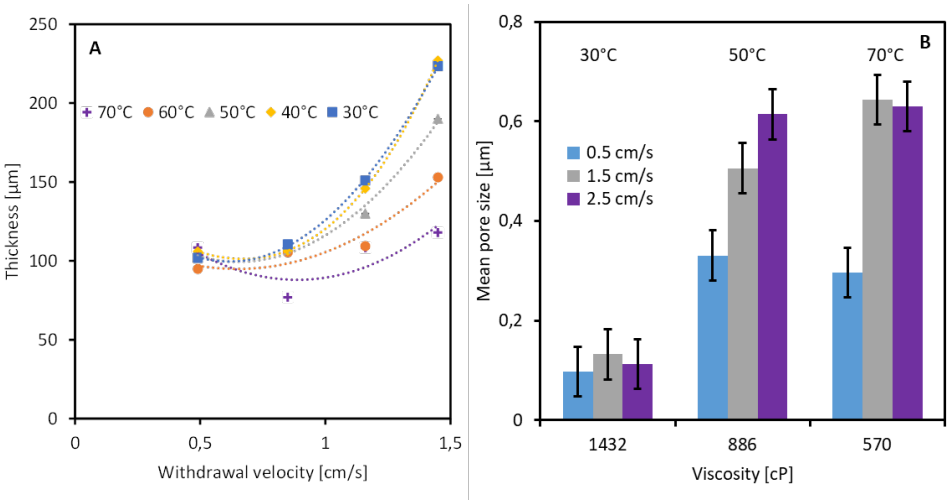
Polyvinylidene fluoride (PVDF) is a commonly exploited polymer for its chemical and thermal stability, and it can be employed, thanks to its hydrophobicity, as a membrane contactor to supply air to a growing biofilm in a membrane aerated biological reactor (MABR). In fact, supplying air to a biofilm allows the microorganisms in it to oxidize dissolved substances in a wastewater, to obtain a cleaner water with a reduced content of pollutants. In this work, some tubular PVDF membranes were prepared by dip-coating of a braided glass-fiber sleeve with a polymeric solution of PVDF and a green solvent, triethyl phosphate (TEP). Precipitation of the membrane was triggered via nonsolvent induced phase separation (NIPS), through immersion of the polymer covered support in a pure ethanol bath. Different membranes were prepared, by changing dip-coating withdrawal speed and the temperature of the polymeric solution. The resulting membranes were characterized in terms of thickness of the deposited polymeric layer, mean pore size with a liquid-liquid displacement porometry (LLDP), water contact angle to determine their hydrophobicity, and their cross section and surface were observed with a field-emission scanning electron microscope (FESEM).
It was found that the withdrawal speed in dip-coating was the main parameter modulating membrane thickness, in agreement with Landau-Levich model, while the solution temperature was determining for the pore size change (Fig.). A selected membrane was used in a MABR batch reactor, to grow a biofilm on the external surface, with air flowing in the lumen. After two months of biofilm growth, the performances of this reactor were evaluated monitoring the abatements of different pollutants (organic substances, ammoniacal nitrogen and total nitrogen). The MABR demonstrated to be effective in reducing the concentration of the pollutants considered, with specific removal rates of 3.8 g/(m^{2}day) for organic substances in terms of chemical oxygen demand (COD), 2.2 g/(m^{2}day) for ammoniacal nitrogen and 1.0 g/(m^{2}day) for total nitrogen.



A) Thickness of the polymeric layer deposited on the braided support at different temperature and withdrawal speed. B) Effect of temperature and withdrawal speed on mean pore size

S4-19 |

TEXTILE CARDING TECHNOLOGY: EVALUATION AND FIRST CHARACTERIZATION OF DIFFERENT HYBRID NON-WOVEN MATERIALS FROM RECYCLED FIBERS

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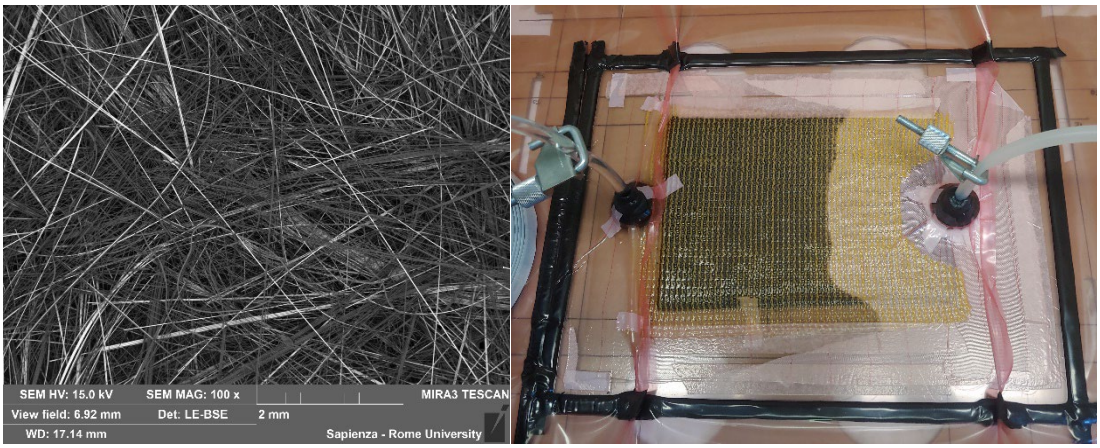
In a circular economy-based approach, fibers reclaimed from EoL composite parts or, more generally, waste fibers produced during textile fabrication could be upcycled into reinforcement for sustainable composite products. With the intent of exploiting at best the reinforcing effects of non-continuous recycled fibers, a possible solution would be the transformation into non-woven fabrics. Some of the most common dry-laid techniques for non-woven fabric preparation are carding and needle-punching. These methods allow the hybridization of reinforcement by simple calibration of the mix of fibers that are fed to the process. Hybrid non-wovens offer many advantages, as they make possible to tune mechanical properties, energy dissipation, thermal conductivity and costs of the final composite. To achieve fully sustainable composite materials, it is desirable to adopt thermoplastic matrices, and, to overcome impregnation issues related to their high melt viscosity, dedicated processing techniques should be used. In our work we investigated different hybrid non-wovens and different preparation methods. Recycled glass/carbon fiber composites were prepared by vacuum infusion with a reactive acrylic resin, suitable for in-situ polymerization (Elium®, Arkema). Recycled basalt/carbon and silk/carbon fiber composite were prepared with the same technique, using epoxy resin as preliminary study. Moreover, we prepared recycled carbon fiber/PA6 composites with hybrid reinforcement/matrix non-wovens. Thermo-compression was adopted as the final step, to promote matrix diffusion and form the final composite. In all cases, not only was the preparation of different hybrid non-wovens successful but the impregnation and the subsequent preparation of the composite gave positive results. A thorough morphological and mechanical characterization was carried out to investigate the different materials obtained. Although improvements in terms of fiber content and porosity should be sought, the results are promising for medium range applications in automotive, construction and transportation sectors.



Left: SEM-BSE micrograph of 50/50 basalt/carbon hybrid non-woven. Right: vacuum infusion process set-up (resin flows from left to right).

S4-20 |

UPCYCLING OF POST CONSUMER POLYPROPYLENE WITH SINGLE-POLYMER COMPOSITES: THE ROLE OF THE MATRIX'S MOLECULAR WEIGHT DISTRIBUTION IN TRANSCRYSTALLINITY AND MECHANICAL PROPERTIES

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Polyolefins are the most widely used plastics worldwide, and their end-of-life management remains a significant technological and environmental challenge. Upcycling polyolefins, indeed, is not an easy task: recycled polyolefins typically have a wide molecular weight distribution and many impurities and pollutants, which limit their applications to low-value products. Self-reinforced polymer composites (SRPCs) could be the answer to this challenge. Being constituted by the same polymer for both the matrix and the reinforcing phase, these materials exhibit ideal recyclability, as already has been proved in literature. This approach enables the reinforcement of low-grade recycled polyolefins by incorporating high-performance fibres of the same polymer. However, the manufacturing processes rely on the difference in melting temperature between the highly aligned and extended-chain structure in the reinforcing phase fibres and an isotropic bulk matrix, typically only a few degrees. Such small differences in melting temperature provide significant technical challenges for SRPC manufacture. Furthermore, achieving a substantial improvement in the mechanical properties of the matrix requires good interfacial adhesion with the fibres, through the formation of a crystallinity nucleated radially from the fibers called *transcrystallinity*—although the scientific community has not reached a consensus on this issue. Within this framework, the present study aims to explore the rooms for action of post-consumer recycled polypropylene in the SRPCs technology. Specifically, it investigates the influence of the molecular weight distributions and thermal history on the microstructure formation of polypropylene's self reinforced composites—factors that are still insufficiently explored in the literature—by correlating the morphological features of the matrix with the mechanical properties of the resulting composites. Understanding this correlation is essential for optimizing SRPC processing conditions and advancing the upcycling of recycled polyolefins.

S4-21 |

BIO-BASED AEROGELS FROM CITRUS WASTE AND POULTRY FEATHERS: MODULATION OF STRUCTURE AND FUNCTIONAL PROPERTIES THROUGH SYNTHESIS STRATEGY

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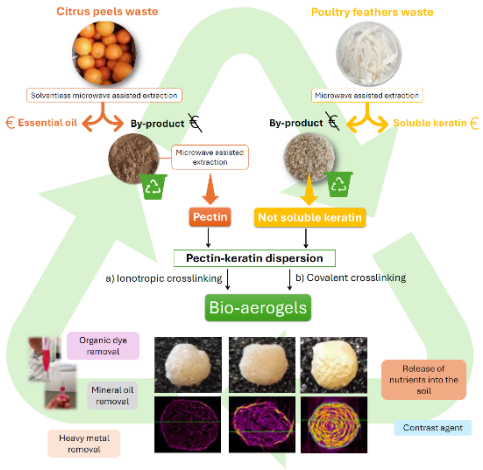
The global population growth and increased human activities have resulted in the yearly production of around 100 billion metric tonnes of biomass waste. Inadequate waste management have led to seriuos enviromental pollution and accumulation of waste in ecosystems. Addressing this, the European Green Deal emphasizes transforming biomass waste into sustainable, bio-based materials to replace fossil fuels. This study focuses on valorising agro-food industry waste, specifically poultry feathers and citrus peels. Keratin extracted from feathers and pectin from orange citrus peels, both processed via eco-friendly microwave-assisted methods, were used to produce advanced aerogels. These materials possess excellent properties, such as high porosity, low density, high surface area, excellent absorption capacity and good thermal and acoustic insulation, which make them suitable for a wide range of applications. We prepared aerogels through freeze-drying of pectin/keratin hydrogels cross-linked either ionically with calcium or barium ions or covalently with N-(2-Aminoethyl)-3-aminopropyltrimethoxysilane. Structural (FT-IR, solid-state NMR, Micro-CT) and thermal analysis (TGA) revealed that the synthesis method plays a fundamental role in determining the material structure, thermal and chemical behaviour. Moreover, Micro-CT highlighted that barium imparted radiopacity to aerogels, also indicating potential biomedical uses as contrast agents. This work demonstrates a sustainable approach to transforming agro-indutrial waste into high-performance materials, offering a viable alternative to fossil-based products.



Schematic illustration of the synthesis process for pectin/keratin aerogels derived from biomass waste.

The authors gratefully acknowledge ESSENTIA project (Elaboration and Development of Innovative Production and Extraction Systems for Essential Oils in Organic Farms - MASAF-DM di concessione n. 0639748 del 04/12/2024) for providing the biomass waste used in this study.

S4-22 |

LOW-TEMPERATURE PYROLYSIS OF WASTE BIOMASS AND BIOCHAR APPLICATION AS HETEROGENEOUS CATALYST FOR THE PRODUCTION OF SUSTAINABLE AVIATION FUEL PRECURSORS

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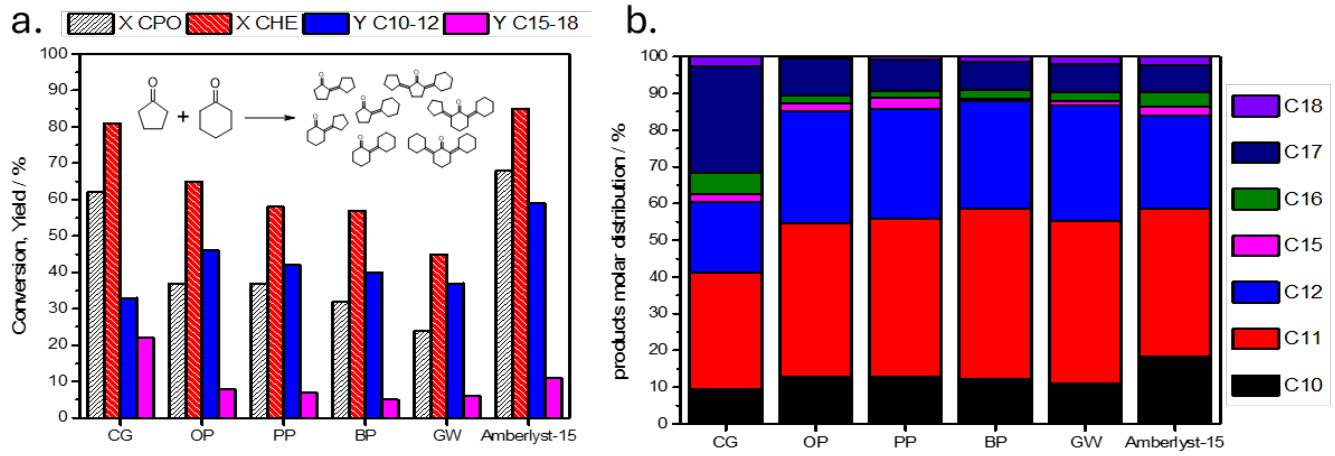
Common waste biomass such as fruit peels and coffee grounds was valorized through low-temperature pyrolysis (400°C) to produce valuable biochar and bio-oil for diverse downstream applications. Through detailed characterization of the resulting biochars, properties such as carbonization degree, morphology, surface acidity/basicity, and energy content were assessed to evaluate their potential use in various technological and environmental fields, based on the specific features developed during thermal conversion (Higher Heated Value, wettability, alkali content, etc..). The resulting bio-oils exhibited feedstock-specific chemical profiles, enriched in valuable platform chemicals (e.g. HMF, furfural, cyclic ketones), lipid-derived compounds (fatty acids and alcohols), or aromatics, supporting their targeted applications in energy, materials, and chemical synthesis. After functionalization through sulfonation, selected biochars exhibited promising properties as acidic heterogenous catalysts (1.65-1.75 mmol H^+/g), demonstrating activity in reactions of industrial relevance such as esterification and condensation. Their specific application in the cross-aldol condensation between bio-based cyclopentanone and cyclohexanone, targeting the production of sustainable aviation fuel (SAF) cyclic precursors (C10-C18), was explored in detail (Fig.). Among the tested samples, activated biochar derived from coffee ground and orange peel showed superior catalytic performance, achieving yields under optimized conditions (120°C, 4 h, atmopsheric pressure) that matched or exceeded those obtained with commercial Amberlyst-15 catalyst. The stability and recyclability of the samples were assessed over multiple reaction cycles. Deactivation was observed due to the deposition of heavy compounds on the catalytic active sites. However, after a regeneration treatment, these deposits could be removed, effectively restoring catalytic active sites and, consequently, the catalyst performance.



Catalytic activity in cross-aldol condensation of sulfonated BCs and Amberlyst-15: a) catalyst performance in terms of CPO, CHE conversions (X CPO, CHE) and products yields (Y C10-12 and Y C15-18); b) molar fraction of the different compounds in products mixture. CG: coffee grounds, OP: orange peel, PP: pineapple peel, BP: banana peel, GW: green waste.

SESSION 5

S5-1 |

DEVELOPMENT OF AN EASY-TO-USE METHODOLOGIES FOR MONITORING THE STATE OF CONSERVATION OF CONTEMPORARY MURAL PAINTINGS

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Painted Villages constitute a peculiar reality spread across the Italian territory. These small villages contain tens of contemporary mural paintings, the oldest of which date back to 1956. They constitute a significant material and immaterial heritage, since they also collect the history and traditions of the places, and important contemporary artists have painted them. The murals, realized with a wide range of materials, are exposed to the environment and therefore subjected to deterioration. The economic and management capabilities of the municipalities are different, and in some cases, it is impossible to perform ongoing monitoring of the artworks, and to record the state of conservation history of each single painting. This lack of information also does not allow monitoring how rapidly the degradation is happening. Considering that these villages are in different environmental conditions, and that the municipalities have not always professionals specifically for this monitoring, we suggest an easy-to-use monitoring system, developed to obtain a degradation index for each mural, and therefore, a list of conservation priorities. This methodology starts with an adaptation of the Art-Risk 1 model, a tool for preventive conservation of heritage. Thanks to an in-depth analysis of a lot of murals in different environmental contexts, it has been possible to select the most significant and impactful degradation phenomena, giving them a specific weight in terms of future damages and adapting the tool specifically for contemporary murals. The validation of the model was carried out by comparing two different strategies: a visual evaluation of degradation forms and an evaluation of the percentage of degradation effects through a degradation map on the most impactful degradation phenomena. The methodology was tested in two villages: Arcumeggia, the oldest painted village in Varese Province and Cibiana di Cadore in Belluno Province. The results are reported in a QGIS map, allowing the localization of the artworks at risk (as shown in Fig.). Parallel to the testing phase, a survey has been sent to 128 small towns, deemed Painted Villages by different sources, to test the applicability of this methodology from professionals not expert in heritage science.

Map of the village of Arcumeggia in QGIS, colors indicate different degradation index percentages.

S5-2 |

PICKERING EMULSIONS STABILIZED BY CLAYS FOR VERSATILE APPLICATIONS IN CULTURAL HERITAGE

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Using clays to stabilise waxes in an oil-in-water Pickering emulsion is a green solution for creating hybrid organic/inorganic systems with a wide range of applications, eliminating the need for surfactants or chemical solvents. This significantly enhances green chemistry and industrial applications. Pickering emulsions based on clays generally demonstrate suitability for stabilising hydrophobic compounds in a water matrix. Previous studies have documented the use of halloysite nanotubes in emulsifying different types of wax, including paraffin and beeswax, to create stable aqueous colloidal systems. These formulations have been tested for consolidating archaeological wood and for creating geopolymers for use as a hydrophobic coating on architectural surfaces to protect against weathering, improving the thermal and mechanical properties of the coating.
However, research exploring the potential application of other clays for this purpose is lacking. This study aims to address this knowledge gap by investigating the use of different clays in creating an O/W hybrid system and the stability of hydrophobic compound droplets. The clays to be investigated include other types of halloysite, sepiolite, zeolite, montmorillonite, kaolin and laponite, in terms of their potential for stabilising wax and for use in developing green products. The study employs a multifaceted approach, encompassing optical microscopy, droplet size analysis, z-potential analysis, sedimentation kinetics analysis, thermogravimetric analysis (TGA) and micro-differential scanning calorimetry (micro-DSC). This methodology allows us to analyse additional properties of the system that could be exploited when working with clays of different dimensions, structures, and surface charges.

Wax droplets in the Pickering emulsion

S5-3 |

BUILDING WITH RAMMED EARTH: MATERIALS INSIGHTS FROM "CASA DEL THÈ" PAVILION CASE STUDY

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Over the last few years, the building sector has witnessed a rediscovery of raw earth as a sustainable alternative to traditional building materials. This study investigates the potential of rammed earth (RE) as a sustainable building material by examining the mechanical properties of an earth-based mixture from the "Casa del Thè" pavilion (Monticello d'Alba, CN, Italy). This installation utilised a specific rammed earth mixture (Pavilion mix) composed of waste soil from a Botticino marble extraction site (Tb), a vineyard soil (Tv), and an aggregate material (St). Comprehensive geotechnical (Atterberg Limits, Specific Gravity, Granulometry), chemical, and mineralogical characterisations (XRF, XRD, ATR-FTIR, TGA) were performed on the constituent materials. Unconfined Compressive Strength (UCS) test on cylindrical samples prepared at the construction site yielded 1.06 MPa for pure Tb samples and 1.67 MPa for the Pavilion mix. Subsequently, the mixtures were replicated in the laboratory, and cylindrical samples, dimensionally identical to those from the construction site, were prepared using the Proctor compaction apparatus. A comparative analysis between the construction site and laboratory-prepared samples revealed a notable influence of the preparation methodology on mechanical performance, with laboratory-prepared Tb and Pavilion mix samples achieving mean UCS values of 1.44 MPa and 1.24 MPa, respectively. Consequently, an attempt was made to optimise the soil mixture composition for improved mechanical properties. This involved establishing a rammed earth suitability criterion based on particle size distribution and Fuller's equation. Concurrently, a digital tool called *Granulometry Builder* was developed to predict the granulometric distribution of hypothetical raw earth mixtures. This allowed the formulation of an optimised mixture (Optimal mix) comprising Tb, St and a clayey soil designated as ABS, whose granulometric curve closely approximated the empirically derived ideal distribution. However, despite this compositional optimisation, the Optimal mix yielded a mean UCS value of 0.99 MPa, reflecting the complex interplay between mechanical properties, particle size distribution, the intrinsic nature of constituent materials, and residual water content. Nevertheless, this study provides foundational insights for future advancements in soil mix design and compaction techniques, thereby contributing to the broader application of rammed earth as a sustainable and structurally viable construction material.

S5-4 |

PRELIMINARY TESTING AND CHARACTERIZATION OF URBAN GLASS WASTE REINFORCED WITH WASTE-DERIVED CARBON FIBER FOR FOAM GLASS IN CONSTRUCTION

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While scrap carbon fiber is a common industrial by-product, urban glass waste is a major residential area waste product. By producing foam glass (FG) for a variety of purposes, especially in building, this study investigates an innovative way of utilizing these materials. Enhancing FG's characteristics to satisfy ever-tougher application-specific requirements is a major industrial problem. The porous structure of FG - crucial to its performance - is influenced by several factors, including the foaming process. High temperatures can cause carbon fibers to oxidize, producing a foaming phenomenon that gives the glass a porous matrix. The impact of powdered reycled carbon fiber (PRCF), a different technique for recovering waste carbon fiber, as the foaming agent of FG is examined in this study. In relation to powdered waste glass, PRCF has been used at mass concentrations of 0.5%, 1%, and 1.5%. A higher PRCF percentage improved porosity and foaming. The outcomes show that it is possible to produce FG on a wide scale with improved qualities without requiring a significant increase in investment, while simultaneously recycling two waste materials. Through the advancement of circular economy principles and waste valorization, this process aids in sustainable development.

S5-5 |

DEVELOPMENT OF NEW BIOCIDES FOR CULTURAL HERITAGE APPLICATION

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Biodeterioration induced by microorganisms—including *bacteria*, *archaea*, *fungi*, and *lichens*—represents one of the main challenges in the preservation of cultural heritage. This phenomenon can affect both the aesthetic appearance and structural integrity of materials, making the implementation of preventive conservation strategies essential. Over the years, several strategies have been developed to safeguard artworks from biodeterioration, among which the application of biocides is prominent. Biocides are active substances that eliminate, inhibit, neutralize, or prevent the proliferation of harmful organisms, thereby safeguarding human and animal health and preserving the integrity of both natural and synthetic materials A major limitation of conventional biocidal treatments is their limited persistence, which necessitates repeated applications and raises concerns about their long-term effects on both cultural heritage materials and the environment. Additional challenges include the emergence of resistant bacterial strains, the phenotypic variability of microbial communities, and the potential toxicity of these agents. In this context, the development of new biocidal agents is necessary and we propose two novel classes of biocides. Firstly, we describe the synthesis and characterization (by NMR and Gas chromatography-mass spectrometry) of new selenium-based biosimilar compounds. Additionally, we focus on the extraction of inuloxin A, a sesquiterpene lactone with biocidal properties, from the invasive plant *Dittrichia viscosa*. Quantification and characterization of inuloxin A was conducted by GC-MS and NMR. The biocidal activity of both classes of compounds was evaluated in collaboration with the *Suor Orsola Benincasa* University of Naples. Specifically, in vitro tests were carried out on mosaic tiles composed of stone materialsand the model organism *Raphidocelis subcapitata.*

S5-6 |

SMART MESOPOROUS SILICA NANOPARTICLES FOR CULTURAL HERITAGE: GROWING SUSTAINABLE PROTECTION STRATEGIES

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There is an increasing demand for cultural heritage conservation systems that align with ambitious environmental sustainability goals. In response, recent research has explored the controlled release of anticorrosive agents for metal substrates using mesoporous silica nanoparticles (MSNs). This method offers environmental advantages by reducing maintenance needs and employing eco-friendly materials. In this study, MSNs were synthesized through a high-throughput method and functionalized to act as pH-responsive nanocarriers. Two approaches were employed: loading the nanoparticles with a benzotriazole/silver complex or grafting them with benzoyl chloride. These modifications enable the nanoparticles to release anticorrosion agents on demand, in response to changes in pH. The functionalized MSNs were then embedded in acrylic coatings, allowing for the design of protective layers with dual action. First, a passive barrier is formed by the coating itself. Second, an active protection mechanism is triggered by the pH-sensitive release of corrosion inhibitors, which enhances the durability of metals and concrete structures exposed to corrosive environments. This smart release system not only extends the lifespan of protective coatings but also reduces the need for frequent maintenance, making it a sustainable choice for heritage conservation. The ability to tailor the release of active agents ensures targeted, efficient protection without the continuous presence of potentially harmful chemicals. Ongoing research is now focusing on further improving the sustainability of these systems. Efforts are being made to develop bio-based anticorrosive agents, such as L-arginine, and environmentally friendly polymers like bio-acrylates. These materials aim to replace conventional synthetic compounds, reducing the environmental impact of conservation treatments. With the aim of protecting stone substrates from biofilm formation and microbial growth that can compromise their aesthetic appearance, MSNs were functionalized with fungicidal agents and loaded with a bio-based essential oil. These smart nanocarriers were developed and characterized to provide targeted and long-lasting antimicrobial activity, while minimizing environmental impact. The system is designed to release active agents on demand, enhancing the durability and visual integrity of treated stone surfaces. This approach contributes to the sustainable conservation of cultural heritage materials, combining advanced nanotechnology with natural, eco-friendly compounds for effective and responsible surface protection. Overall, this approach represents a significant step toward the development of next-generation protective systems for cultural heritage. By combining smart material design with environmental responsibility, it supports the long-term preservation of historic structures while meeting modern ecological standards.

S5-7 |

REFINING SUSTAINABLE STRATEGIES WITH REUSABLE ELECTROSPUN PHOTOTHERMAL MATERIALS FOR STREET ART CONSERVATION

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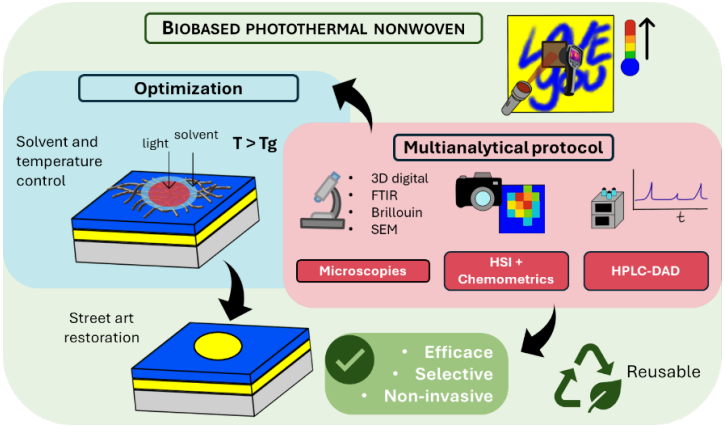
Electrospun (ES) nanofiber mats have found application in a broad range of technological fields, although few are examples in heritage science. This contribution presents the evolution of an innovative photothermal cleaning system for cultural heritage conservation based on electrospun pullulan nanofiber mats embedded with melanin nanoparticles. Initially developed as sustainable and biocompatible materials for the removal of highly insoluble alkyd-based spray paints from mural paintings and heritage surfaces, these composite mats exploit the photothermal properties of melanin to locally increase temperature under red light irradiation, enabling controlled solvent release and enhanced varnish removal. Building upon these foundations, the research has advanced to refine the selectivity, safety, and reusability of the system. An optimized setup now allows precise temperature control at the interface with artworks, reducing thermal risk. A multi-analytical approach—including imaging, chemometrics, HPLC-DAD, and Brillouin microspectroscopy—confirms the method's high selectivity, effectiveness, and non-invasiveness, while application time and solvent use were halved. Additionally, the mats demonstrated consistent performance over multiple reuse cycles, reinforcing their potential for sustainable treatments in contemporary art conservation. This work showcases the method's progression from proof-of-concept to a robust, field-ready solution for the selective and eco-conscious cleaning of delicate painted surfaces.



Graphical abstract of the scientific contribution

S5-8 |

DEVELOPMENT AND CHARACTERISATION OF POLYPROPYLENE-BASED FIBRES (PURE AND RECYCLED) WITH INDUSTRIAL WASTE ADDITIVES FOR USE IN CONCRETE

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The present work focuses on the production and characterisation of fibres for concrete reinforcement, based on polypropylene (pure and recycled), with the addition of industrial waste from sanitaryware processing, in particular thermosetting resins and ceramics. The main objective is to promote the use of recycled materials and contribute to the end-of-life management of industrial waste through its reuse in composite materials. The use of composite fibres obtained from recycled and waste materials can be an effective strategy to reduce environmental impact and production costs and foster innovation in building materials with a view to the circular economy. The fibres were produced through following steps: grinding of the polypropylene granules and heat treatment in an oven, mechanical mixing of the three materials, first extrusion using a twin-screw extruder to obtain pellets, and second extrusion using a single-screw extruder to produce fibres with a controlled diameter. The fibres thus obtained were subjected to mechanical stretching to promote chain alignment. Characterisation of the stretched fibres obtained included mechanical tests (tensile test), spectroscopic analyses (FT-IR), thermal analyses (DSC and TGA) and morphological observations by microscopy, with the aim of assessing the characteristics of this new material. The chemical-physical characteristics of the composite fibres were compared with virgin polypropylene fibres and the impact of the addition of industrial waste on the performance of the final material was assessed.

S5-9 |

ENCAPSULATION OF THYME ESSENTIAL OIL IN FUNCTIONALIZED MESOPOROUS SILICA NNANOPARTICLES FOR ENHANCING ANTIFOULING ACTIVITY IN CULTURAL HERITAGE CONSERVATION

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Essential oils (EOs) are gaining increasing attention across a wide range of applications due to their natural antimicrobial, antioxidant, and antifouling activities. However, their practical use over time is limited by their high volatility and sensitivity to environmental factors such as light and oxygen as well as leaching by liquid water. Nanocarriers offer a viable strategy to protect EOs from degradation, control their release kinetics in terms of volatilisation and leaching in water and inhibit their rapid sublimation. Among nanocarriers, Mesoporous Silica Nanoparticles (MSNs) are particularly suited for EOs encapsulation due to their high surface area, easy surface functionalization and excellent thermal and chemical stability. In our work, MSNs were synthesised and functionalized via a one-step production employing tetraethyl orthosilicate (TEOS) and benzyl silane as modifying agent. By adjusting the TEOS-to-silane ratio, a uniform functionalization of both internal and external surfaces was achieved. Benzyl groups were introduced to promote π–π interactions with EO components, enhancing encapsulation efficiency and retention performance. Both thyme essential oil and its active compound, thymol, were loaded into the nanoparticles through a vacuum-assisted method. The volatilization kinetics of both pure and encapsulated oil were measured at 30°C using isothermal thermogravimetric analysis. Encapsulation in functionalized silica notably reduced the rate of oil volatilization by 80% compared to the pure oil and also decreased EO water release by approximately 30% with respect to non-functionalized silica. In vitro biological assays performed on algal species showed a significant enhancement in antifouling activity for the encapsulated EO compared to the free oil, with prolonged effectiveness. The impact was further amplified at higher temperatures and with increased concentrations of nanoparticles, expressed as the active compound weight to surface ratio. These findings highlight the important role of the mesoporous silica matrix in retaining volatile compounds, ensuring that their concentration remains above the threshold level necessary for effective antifouling activity against algae. EO-loaded MSNs shows promising applicability in the conservation of stone-based cultural heritage, offering a sustainable alternative to conventional biocides and supporting long-term conservation of artworks.

The authors gratefully acknowledge the support of the ISIS@MACH ITALIA Research Infrastructure, the hub of ISIS Neutron and Muon Source (UK) [MUR official registry U. 0008642.28-05-2020—16th April 2020]. IM@IT is listed in the Italian Ministry of University and Research's Piano Nazionale delle Infrastrutture di Ricerca (PNIR 2021–2027) "in the broader notion of ISIS", and ISIS Facility and IM@IT are jointly listed as high priority RIs (see Table 6, page 30, note 38, PNIR in 2021–2027).