VSB – Technical University of Ostrava Nanotechnology Centre, CEET

NanoOstrava 2025



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NanoOstrava 2025 – International Conference on Nanotechnology, Energy Materials, and Environmental Sustainability

Hosted in VSB- Technical University of Ostrava, CEET, Nanotechnology Centre, May 19-22,2025

We are delighted to welcome you to **NanoOstrava 2025**, the International Conference on Nanotechnology, Energy Materials, and Environmental Sustainability, held in the vibrant academic and innovation hub of **University City Ostrava**, Czech Republic. This unique conference brings together worldrenowned scientists, engineers, and researchers alongside the next generation of innovators—students from across the globe—for an inspiring exchange of ideas at the frontiers of science and technology.

Set against the dynamic backdrop of Ostrava, a city with a rich industrial heritage and a growing reputation as a centre for research and innovation, NanoOstrava 2025 reflects the urgent need for interdisciplinary collaboration to address the critical challenges facing our planet. As demands for clean energy, sustainable materials, and environmental resilience continue to grow, it is our collective responsibility to seek transformative solutions grounded in cuttingedge science.

At the heart of this conference are the three pillars that define our mission: **nanotechnology**, **energy materials**, and the **environment**. Nanotechnology, with its ability to manipulate matter at the atomic and molecular scale, offers unprecedented possibilities across all scientific domains—from next-generation electronics to smart materials and biomedical applications. Energy materials research is accelerating the transition toward greener energy systems, including advanced batteries, fuel cells, photovoltaics, and catalytic technologies. Equally essential is our focus on environmental sustainability—developing new strategies for pollution control, waste minimization, carbon capture, and sustainable resource use.

NanoOstrava 2025 proudly features a distinguished line-up of keynote speakers and invited experts whose pioneering contributions are reshaping the landscape of modern science. Their presentations will span fundamental discoveries, technological breakthroughs, and real-world applications. We are equally proud to support and highlight the contributions of early-career researchers and students, whose innovative work is featured prominently in this abstract booklet. Their research, creativity, and vision represent the future of science and sustainability.

This booklet contains a curated collection of abstracts that reflect the breadth and depth of the conference. Each contribution has been selected for its scientific merit, relevance, and potential impact. Whether exploring quantum nanostructures, energy storage devices, sustainable materials, or environmental monitoring techniques, these abstracts offer a glimpse into the exciting developments that are driving global progress.

We express our heartfelt thanks to the organizing committee, scientific advisory board, sponsors, and academic partners who have made NanoOstrava 2025 possible. Their dedication ensures a world-class event that fosters collaboration, learning, and innovation.

As we gather in University City Ostrava, we encourage all participants to engage fully—ask questions, share insights, and build connections that extend beyond the conference halls. Let us seize this opportunity to spark new ideas, launch meaningful partnerships, and collectively contribute to a smarter, cleaner, and more sustainable future.

Welcome to NanoOstrava 2025. Let the dialogue begin.

yours Gražyna

1/land

Gražyna Simha Martynková Conference chairman, NanoOstrava2025

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Dear Conference participants, Visitors and Colleagues,

We welcome you to the NanoOstrava 2025 - 9th international biennial 'Nanomaterials and Nanotechnology Meeting' in Ostrava, which is the centre of the Moravian-Silesian region and, at the same time, the third largest city in the Czech Republic.

This year's conference we are returning to grounds of our University Aula.

The conference is organized under cooperation of scientists from the Nanotechnology Centre, CEET, VŠB - Technical University of Ostrava and Institute of Geonics AS CR.

For young researchers and students, NanoOstrava presents a unique opportunity to showcase their projects and receive feedback from more experienced colleagues. The conference not only provides a platform for sharing the most recent knowledge but also offers the opportunity to establish valuable professional contacts and collaborations.

The four scientific sessions dedicated to energy, environment and materials characterization in nanoscience will be packed with world-renowned scientists and a number of scientists and speakers from industry.

We wish you successful and fruitful conference – and enjoy Ostrava!

Organizing committee of NOM 2025

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The organizers would like to thank the following companies and partners for generously sponsoring this conference:

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(Aula, between rooms NA1 and NA4)

You can set up your poster from Wednesday morning time.

The best **3 students' posters** will be awarded. Special evaluation committee will be established and during the poster section all student's posters will be evaluate and best 3 awarded with diploma and practical price.

We kindly ask all student participants to take a part in the evaluation of poster competition during the conference evening.

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TOPIC 1 Advanced Nanostructured Materials and Innovative Technologies

Chair: Petr Ryšánek

Nanoparticles – natural and synthetic Polymer and ceramic nanocomposites Nanocarbons Nanoclays Additive technology Nano in automotive



Invited lectures (IL):

Nanostructured materials for solid state hydrogen storage

J. Hoskovec, <u>P. Čapková</u>

Centre for Nanomaterials and Biotechnology, J.E. Purkyně University in Ústí nad Labem, Czech Republic.

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Hydrogen storage is a highly relevant topic due to its crucial role in the power industry. However, so far more attention has been paid to various applications of hydrogen in fuel cells and mobility rather than its storage. A basic prerequisite for the introduction and development of the hydrogen economy is a high-capacity hydrogen storage system. Various hydrogen-adsorbing materials have been considered to store hydrogen: first of all membranes based on palladium, platinum and their alloys forming hydrides. Other metals such as Zr, Ti, Nb, Al, Mg have also been tested, but the energy and temperatures required for H₂ sorption and desorption are significantly higher than for Pd and Pt. Other materials for hydrogen capture reported in the literature are modified zeolites MOFs and a wide range of carbon-based materials. For a comprehensive review, see Zhang et al.¹ In any case the material for low-pressure hydrogen storage facility that operates at pressures between 4 and 30 bar and at ambient temperature is still a major challenge in today's hydrogen economy. We prepared hydrogen-capturing membrane based on electrospun polyurethane/larithane membrane modified with palladium nanoparticles operating under standard atmospheric conditions². Hydrogen sorption capacity achieved for this membrane at room temperature and at pressure of 1 bar is 207.7 ml/g (1.9 wt.%) and for 4 bar: 1173.3 ml/g (10.6 wt.%), measured by the standard Pressure Decay method (PD)². At the present time generally recommended nanostructured alloys of Mg, Si, Al + graphite require a pressure of 25 Bar and temperatures of 523-623°K to achieve a sorption capacity of 6 wt%.

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Graphitic carbon nitride: what is not talked about

P. Praus

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Graphitic carbon nitride $(g-C_3N_4)$ is used to be described as a "fascinating metal-free polymer semiconductor" that has gained considerable attention due to its tunable electronic structure, chemical stability and visible-light photocatalytic capabilities. The low-cost precursors and thermal polymerisation make $g-C_3N_4$ attractive for academic research with its declared status as a truly "green" material. However, its inherent drawbacks, such as rapidly limited specific surface area, charge recombination and low quantum yield, severely limit its effectiveness in real-world applications. Attempts to overcome these problems by doping or nanostructuring often lead to complex and unreproducible syntheses [1], raising concerns about consistency and industrial feasibility.

The structural stability of graphitic carbon nitride $(g-C_3N_4)$ refers to its resistance to chemical degradation under operational conditions such as light exposure [2], moisture, or oxidative environments [3]. But does it extend to its surface? Due to the surface chemical instability, the surface can be modified though its functional groups. The surface stability/modification [3,4] and photocatalytic stability of g-C_3N_4 under alkaline conditions should be discussed.

ACKNOWLEDGMENTS

This contribution was financially supported by the European Union under the REFRESH – Research Excellence For REgion Sustainability and High-tech Industries (Project No. CZ.10.03.01/00/22_003/0000048) via the Operational Programme Just Transition and by the OP JAK project "INOVO!!!" (No. CZ.02.01.01/00/23_021/0008588) provided by the Ministry of Education, Youth, and Sports and co-financed by the European Union.

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Oral presentations (OP):

Electron Beam Direct Writing of Graphene: Mechanisms, Materials, and Prospects for Nanoelectronics

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Recent advancements in direct graphene patterning using electron beams have opened new pathways for the fabrication of high-performance nanostructures in nanoelectronics. Here we present the current state of the direct graphene writing techniques as well as preliminary data regarding electron beaminduced polymer to graphene conversion. A key focus is the use of solid carbon precursors, such as poly(methyl methacrylate) (PMMA), while exploring catalytic substrates like copper, to enable in situ graphene formation under electron irradiation. Mechanistic insights reveal the interplay of knockon displacement, radiolysis, and local thermal effects in achieving graphitisation. Characterisation of the materials performed by vibrational spectroscopy (Raman, FTIR) provides insight on the directwrite methodology. This method of graphene growth facilitates maskless, scalable fabrication of graphene-based devices, including electrodes for all-carbon field-effect transistors, and provides a sustainable alternative to conventional lithography. Emphasis is placed on the influence of beam energy, dose, and substrate composition on the resulting structure, crystallinity, and electrical properties. The reviewed techniques represent a promising route towards additive manufacturing of nanomaterials in the post-silicon era.

ACKNOWLEDGMENTS

The work was supported by the project EBEAM – Electron Beam Emergent Additive Manufacturing funding from the European Union's Horizon Europe research and innovative programme under the grant No.101087143.

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Laser cladding has gained significant attention as a surface engineering technique for improving the wear and corrosion resistance of brake disc substrates¹. With the introduction of the Euro 7 regulation, which imposes stringent limits on brake particulate emissions, the need for advanced wear-resistant coatings has become more critical than ever¹⁻³. To improve the wear resistance of the brake disc (gray cast iron) containing lamellar graphite) under severe working conditions, 316L stainless steel-Cr₂O₃ composite coating was fabricated on its surface using laser cladding. The effect of laser power on microstructure, hardness, wear resistance, and coefficient of friction of the coatings is investigated. Process parameters are systematically optimized to ensure strong metallurgical bonding, minimal dilution, and defect-free coatings. Microstructural analysis is performed using scanning electron microscopy (SEM) and X-ray diffraction (XRD) to evaluate carbide distribution and phase transformations. Hardness measurements using the Vickers microhardness test are employed to examine the impact of Cr₂O₃ reinforcement. The microstructure, phase composition, and microhardness of the fabricated coatings were systematically analyzed, while their dry-sliding tribological behavior and corresponding wear mechanisms were investigated at different applied loads. The microstructure of the coating was observed to be dense and compact. As the solidification rate and temperature gradient varied, the microstructural morphology transitioned from columnar to cellular, followed by dendritic and eventually equiaxed structures. Based on the experimental findings, it can be concluded that laser-cladding 316L stainless steel-based coatings provides a practical approach to improving the tribological properties of brake discs. The ultimate objective is to contribute to the advancement of low-emission braking technologies that align with Euro 7 regulations, supporting the automotive industry's transition toward environmentally sustainable solutions.

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The influence of temperature on the parameters of spherical aluminosilicates

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Microspheres, thanks to their unique properties, are increasingly used in industry, including construction, mining, automotive, ceramics and composites. Microspheres consist of a glassy and a crystalline phase. The dominant glassy phase consists mainly of silicon and aluminium oxides and, to a much lesser extent, iron and calcium oxides. The crystalline phase, on the other hand, consists mainly of quartz and mullite, with hematite and magnetite in smaller amounts. It is environmentally friendly and very well tolerated by the body and can be used as a component of composite materials [1-2]. The mineral transformations along temperature can be followed by differential scanning calorimetry (DSC), provided that the formation and crystallization of mullite (3Al₂O₃·2SiO₂) are exothermic phenomena. The use of microspheres as a filler in composites offers the possibility to increase the durability of the composite at reduced temperatures and reduce the apparent density due to reduced absorption [1-4].

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Potential use of albumin stabilized metallic and trimetallic nanoclusters

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Much attention has been focused on the properties of metal nanoclusters due to their unique features. For instance, gold nanoclusters due to their fluorescent properties have been shown to have potential applications as a fluorescent and bioimaging probe as well as radiosensitizer in radiation therapy and photothermal therapy agents for cancer treatment^{1,2,3}. Together with other metals used in the synthesis, the fluorescence properties of these clusters may change, or they may take on additional unique properties as a contrast agent probe for the magnetic resonance imaging^{4,5}. Recently, we have used bovine serum albumin as a scaffold and reducing agent for an eco-friendly synthesis of metallic clusters, thus created clusters were further characterized by dynamic light scattering, zeta-potential, fluorescence spectrometer, transmission electron microscope, circular dichroism, cells viability and can be utilized as an contrast probe for the magnetic resonance and fluorescence imaging.

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Polymer particles fabrication via the dewetting phenomenon

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The main subject of my work is preparation of biodegradable polymer particles, which can act as carriers of anticancer drugs. Polymer particles are fabricated from polylactide employing the dewetting phenomenon.¹ A thin polylactide film is spin-coated onto a glass slide, followed by melting the polymer in contact with a high boiling point, polar solvent (glycerol). Cooling down the sample yields nano- or micrometer-sized polymer particles attached to the glass surface. The particles can be used to incorporated guest species, e.g. doxorubicin (an anticancer drug).

In my experimental work I was using atomic force microscopy (AFM) to measure the thickness of spin-coated polymer film. To investigate the physicochemical properties of the polymer particles optical and scanning electron microscopies (SEM) were used. Preparation of the polymer particles with incorporated doxorubicin was based on heating previously prepared polylactide particles in an aqueous solution of doxorubicin. The resulting doxorubicin carriers were examined with several physicochemical techniques, including optical microscopy and confocal laser microscopy. Anticancer properties of the particles with embedded doxorubicin were examined in-vitro on a MDA-MB-231 human breast cancer cell line.

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Optimising UHMWPE/BaTiO₃ nanocomposites for biomedical applications: role of surface functionalisation in enhancing performance

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The advancement of sophisticated polymer nanocomposites for load-bearing orthopedic implants necessitates remarkable mechanical strength, wear resistance, and biocompatibility¹. This study focuses on the reinforcement of ultra-high molecular weight polyethylene (UHMWPE) with barium titanate (BaTiO₃) nanoparticles, aiming to produce nanocomposites that exhibit amended performance characteristics. The fabrication process employed solvent dispersion, followed by compression molding. A comprehensive evaluation was performed, which integrated mechanical testing, tribological analysis, and wettability assessment, in addition to further characterisations. After the initial performance, the composites were optimised through the functionalisation of BaTiO₃ with a silane coupling agent to enhance interfacial adhesion between the polymer matrix and the filler². The effects of this functionalisation were gauged through mechanical, tribological, and structural characterisations. Additionally, bioactivity tests were performed by immersing the composites in simulated body fluid to assess their ability to form hydroxyapatite.

The study demonstrated that unfunctionalised nanocomposites possess advantageous mechanical properties, substantial wear resistance, and biocompatibility. Notably, surface functionalisation significantly enhanced the interfacial bonding between the polymer matrix and nanoparticles, resulting in improved mechanical properties when compared to the unfunctionalised composites. This research highlights the potential of both unfunctionalised and functionalised UHMWPE/BaTiO₃ nanocomposites for load-bearing implant applications, emphasising the considerable performance benefits achieved through surface functionalisation.

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Preparation of polymer nanocomposites with silver nanoparticles

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The study focuses on the preparation of polymer nanocomposites with silver nanoparticles (AgNPs) synthesized via green synthesis using an extract from dried lavender leaves. The synthesized spherical AgNPs have an average size of 20 nm. Prepared AgNPs were incorporated into a polyvinyl alcohol (PVA) polymer matrix using the ex-situ method¹. The obtained PVA-AgNPs solution was used for the fabrication of thin foil (casting) and nonwoven textiles using the Nanospider (electrospinning technique). The produced polymer nanocomposites were subsequently tested for antibacterial properties, which successfully enhanced the non-toxic polymer with antimicrobial functionality. The structural and morphological properties of the nanocomposites were characterized using scanning electron microscopy (SEM), confirming the uniform distribution of AgNPs in the polymer matrix². Antibacterial tests were conducted against *Escherichia coli* and *Staphylococcus aureus*, revealing significant inhibition of bacterial growth in the AgNP-loaded nanocomposites. These results demonstrate the potential of bio-synthesized AgNPs for the development of advanced functional polymeric materials with applications in the biomedical and packaging industries. This research is focused on optimizing the synthesis parameters and evaluating the long-term stability of the antimicrobial properties³. These results demonstrate the potential of bio-synthesized AgNPs for the development of advanced functional polymeric materials with applications in the biomedical and packaging industries.

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Modification of biological surface activity of biomedical alloys using ultra-thin ALD layers

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Atomic Layer Deposition (ALD) is a vapor-phase thin-film deposition technique distinguished by its cyclic, self-limiting surface reactions. Precursors are introduced sequentially, reacting exclusively on the substrate surface, enabling atomic-scale thickness control by the number of cycles. The separation of precursor pulses effectively prevents unwanted gas-phase reactions, in contrast to Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD), where uncontrolled reactions or line-of-sight deposition can result in non-uniform coatings, particularly on complex three-dimensional structures.¹

ALD allows fabrication of ultra-thin, highly conformal coatings with precisely tailored chemical composition and morphology. Temperature management within a defined "process window" is crucial to ensure efficient chemisorption without precursor decomposition. A broad range of materials, including oxides (Al₂O₃, TiO₂, ZnO), nitrides, and sulfides, can be synthesized by ALD, significantly expanding its application field.²

This study explores the use of ALD ultra-thin layers to modify the biological surface activity of biomedical alloys. ALD coatings have been shown to enhance biocompatibility, improve osteoblast adhesion and proliferation, modulate protein adsorption, and reduce bacterial colonization, outperforming traditional CVD and PVD methods. Consequently, ALD offers a superior platform for designing next-generation biomaterials with precisely engineered biofunctionality at the nanoscale. ^{3,4}

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Poster presentations (PP):

Innovative technology for PVDF nanocomposite materials preparation

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The increasing interest in PVDF (polyvinylidene fluoride) and its copolymers for energy-harvesting applications stems from their advantageous properties such as good flexibility, environmental friendliness, high halogen and acid resistance, lightweight and good biocompatibility. However, enhancing their piezoelectric performance necessitates the development of efficient preparation technologies that precisely control their mainly structural characteristics. Preparation techniques, such as solution casting, electrospinning, melt processing and high-pressure poling, each exert distinct influences on the nucleation, growth, and spatial distribution of the PVDF crystalline phases.

The work provides an overview of key preparation methods for PVDF and its copolymer-based materials, emphasizing their impact on the resulting crystal phases and overall structure. It details the mechanisms governing the formation of the crucial piezoelectric β -phase and the transformation from the non-polar α -phase. The influence of various processing parameters inherent to each preparation technique, such as solvent casting (highlighting challenges like nanoparticle dispersion and resulting material properties), solution preparation (including solvent selection and temperature control), and post-processing treatments, on the final structural and piezoelectric properties is critically discussed.

It is a comprehensive understanding of how each preparation technology influences the resulting microstructure is paramount. This knowledge enables the rational design and optimization of fabrication processes to tailor the structural characteristics of PVDF-based materials, ultimately maximizing their efficiency and applicability in advanced energy-harvesting devices.

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Influence of Process Parameters on Graphene-Reinforced Galvanized Coatings for Pearlitic Steel Wire

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Galvanization is the most widely used coating method in industry for wear protection. The process involves immersing the substrate in a molten zinc bath, allowing zinc to diffuse onto the steel surface under elevated temperatures. Over time, micro- and macro-cracks can develop on the galvanized layer. Under mechanical stress and wear, these cracks propagate, leading to deformation of the coating. Once the layer is compromised, its resistance to corrosion and wear deteriorates rapidly. Graphene, with its exceptional flexibility, high surface area, and excellent wear resistance, offers a promising solution. Due to its intrinsic lubricating properties, graphene also serves as an effective solid lubricant in frictional environments^{1,2,3}.

In this study, a hybrid coating was developed by gradually introducing preheated graphene powders into a galvanizing bath maintained at 450 °C, under continuous stirring within a sealed argon atmosphere. The resulting graphene-reinforced coating was applied to plain carbon steel wires with a certain diameter. The diffusion mechanism of the coating into the substrate was subsequently analyzed. Tensile testing revealed that the incorporation of graphene contributed to improved coating flexibility and mechanical strength. Additionally, the formation and propagation of cracks under tensile stress were investigated to understand the deformation mechanism.

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Synthesis of Graphite and Multi-layer Graphene from a Low Molecular Weight Carbon Precursor

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Carbon materials formed from macromolecular sources and silicates are well studied, but similar processes using low molecular weight (LMW) carbon sources are less understood. This study investigates materials produced by calcining montmorillonite with ~25–50 wt.% LMW carbon cations at 1300 °C in argon. The products contained ~5–20 wt.% carbon, with higher yields corresponding to higher initial LMW content. Structural analyses (XRD, Raman, XPS) confirmed the presence of graphite alongside amorphous carbon. TEM revealed multi-layer graphene structures. The silicate/carbon composites reached electrical conductivities of ~35 S·m⁻¹. Raman and TEM data were comparable to materials derived from macromolecular precursors. These findings show that LMW compounds are effective for producing conductive carbon materials with graphite and multi-layer graphene.

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Assessment of the basic properties of nanostructured clay derived hybrid composites for CO₂ capture application

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Hydrotalcite-like materials (HT) are layered $[M^{2+}_{1-x}M^{3+}_x(OH)_2](A^{n-})_{x/n}\cdot mH_2O$ compounds. The interlayer space contains water molecules and the compensating A^{n-} anions. Upon thermal decomposition, mixed oxides are obtained. In this study, the basic properties of MgAl-HT precursors and their oxides, differ in composition and crystallinity, were comparatively investigated with the use of CO₂ molecules by in-situ FTIR and TPD methods. The changes occurring during the exhibition of calcined solids under the external condition of CO₂ doses in the absence or presence of water molecules are reported. FTIR studies of HT precursors and their oxides showed that CO₂ reacted with O^{2-} and OH⁻ centers to form carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻⁻) ions. The ageing time, Al content, and HT crystallinity affect the availability of formed basic centers and sorption capacity. The calcination increased HT basicity and O^{2-} centers showed higher strength than OH⁻ ones. Water played a significant role in the sorption of CO₂ molecules, improving the kinetics of CO₃²⁻ formation in the interlayers of the material. Intense XRD reflections originating from the hydrotalcite phase were observed after just 1h of exposition to air. The lack of water slowed down the kinetics of CO₃²⁻ formation in the interlayers, to more than one month.

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Cordierite ceramic foams decorated with Ag nanoparticles

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The aim of this study was to produce cordierite ceramics enriched with Ag nanoparticles and with different porosity and catalytic properties for their possible energy or environmental applications. Direct foaming represents cost effective and relatively easy way to obtain highly porous ceramic materials. The total porosity of foamed ceramics is influenced by amount of gas incorporated into the suspension or liquid medium during the foaming [1]. Firstly, cordierite ceramic foams were prepared form the pre-ceramic mixtures containing raw natural materials – kaolinite, talc and vermiculite and commercial Al_2O_3 . The second step included the preparation of ceramic slurries by the addition of foaming agent hydrogen peroxide. These slurries were subsequently heat-treated at 1300°C.Silver nanoparticles were synthesized by green method from *Urtica dioica* aqueous extract and AgNO₃ as Ag precursor. Generally, the plant extracts contain phytochemicals such as alkaloids, phenolics, flavonoids and terpenoids which cause the reduction of metal ions into metal nanoparticles and alongside stabilization [2]. The calcined ceramics were poured into the solutions containing Ag nanoparticles and their chemical and phase composition, microstructure was characterized by several methods. The addition of H₂O₂ into ceramic slurries caused the formation of microcellular cordierite ceramic materials.

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This study describes a simple, rapid, and eco-friendly biosynthesis of silver nanoparticles and compares two different extracts from the same plant. Silver nanoparticles (AgNPs) were prepared via green synthesis using extracts from dried flowers and leaves of lavender (*Lavandula angustifolia*). Both extracts demonstrated excellent ability to reduce silver nanoparticles from AgNO₃ solution. The nanoparticles synthesized from both extracts were spherical with an average size of 20 nm. Characterization of the silver nanoparticles was carried out using UV-vis absorption spectrometry, Fourier-transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM), and scanning electron microscopy (SEM). Based on UV-vis measurements, the leaf extract exhibited a higher reduction capability compared to the flower extract and contributed to the formation of more stable nanoparticles. The nanoparticles prepared using the leaf extract were incorporated into a polymer solution to fabricate thin polymer films and fibers. The antibiofilm activity was tested on algae against *Chlorella kessleri*.

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Design strategy of Amine Functionalized Graphene for Catalytic Applications

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The functionalization of graphene is a subject of growing interest in tailoring its properties for catalytic applications.¹ The introduction of amine groups onto graphene surfaces enhances electrical conductivity and interfacial interactions.^{2,3} On the other hand, fluorographene (FG), a precursor with uniform fluorine distribution, has attracted much attention as a precursor allows for controlled covalent functionalization via nucleophilic substitution, directly grafting molecules onto the graphene backbone.⁴ From this perspective, organic amines are excellent nucleophiles, which can react with FG to provide a tailored graphene. This study presents a computational design strategy employing semi-empirical quantum mechanical methods to explore amine-functionalization patterns and electronic properties of various AmFG configurations with differing functionalization patterns and degrees to predict their interactions with catalytically relevant copper species. Our simulations investigate the influence of amine functionalization on the graphene electronic structure, and metal-support interactions, aiming to identify promising AmFG structures for enhanced catalytic performance. This theoretical framework provides valuable guidance for experimental synthesis of tailored graphene-based catalysts.

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Effect of the surface etching on the cenospheres coating by silver nanoparticles

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Cenospheres are lightweight, hollow aluminosilicate spheres generated as by-products of coal combustion. Due to their low density, high surface area, chemical inertness, and thermal stability, these materials are suitable for use in composites, catalysis, paints, and related applications. Metal functionalization can endow cenospheres with additional properties: Pt and Pd coating makes cenospheres adequate for the catalytic hydrogenation; Ni, Co, and Fe coating makes them useful for magnetic applications, while Ag or Cu coating provides strong antibacterial properties. A universal method for metal deposition is polyol process¹, which consists in the chemical reduction of metal salts by using polyols at high temperatures. In the study commercial cenospheres have been coated by silver nitrate reduction in ethylene glycol at temperature of 80 and 100°C. Alkaline etching with hot NaOH aqueous solution² proved to be a critical surface activation step, capable of promoting the process of heterogeneous silver nucleation. Such treatment involves a desilication reaction. XRD analysis revealed that silver deposition occurs exclusively on the alkali-etched cenospheres, whereas homogeneous nucleation was observed without etching. SEM analysis confirmed surface erosion of the cenospheres surface, which promoted the nucleation phenomenon. These findings highlight the significance of tailored surface modification strategies in controlling metal deposition.

ACKNOWLEDGMENTS

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TOPIC 2 Materials and Technology for Environment

Chair: Štěpán Kment

Catalysis, photocatalysis and adsorption processes Filters and membranes Anti-biofouling and antimicrobial surfaces Green chemistry approaches Nanomaterials in healthcare NanoSafety



Invited lecture (IL):

Photoredox Catalysis with One or Two Photons & an Electron Transfer

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"Chemical synthesis with light", commonly known as photo(redox) catalysis, has experienced a resurgence in synthetic chemistry and has become a valuable tool for synthesizing high-value chemicals in both academic and industrial settings. In this lecture, I will explore the design and development of photoredox catalytic systems that efficiently harness,¹ effectively transduce,² regulate,³ or completely transfer⁴ the energy of visible-light photons for synthetic transformations. These systems facilitate the activation of very stable chemical bonds or the simultaneous activation of two chemical bonds for synthetic transformations, enabling, in some cases, the insertion of a heteroarene into carbon–heteroatom bonds.

Furthermore, I will discuss the applications of visible-light photoredox catalysis for general $C(sp^2)$ – (hetero)atom cross-coupling reactions involving nickel and visible light. The adaptive and dynamic nature of the catalytic system referred to as AD-HoC allows for the straightforward categorization of various classes of nucleophiles in cross-coupling reactions.⁵ This adaptability has been synthetically demonstrated in nine distinct bond-forming reactions, including $C(sp^2)$ –S, Se, N, P, B, O, $C(sp^3, sp^2, sp)$, Si, and Cl bonds, with hundreds of synthetic examples produced under predictable reaction conditions. The catalytic reaction centre(s) and conditions differ from one another by the added nucleophile, or if required, a commercially available, inexpensive amine base.

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The bacterial nanocellulose (BNC) was synthesized by cultivating the Komagataeibacter medellinensis strain in Hestrin-Schramm medium under static conditions.¹ Pd nanoparticles were supported on BNC by impregnating of palladium (II) acetate in acetone, followed by reduction of Pd ions using NaBH₄ in methanol. The 2wt% Pd/BNC and 4wt% Pd/BNC catalysts were synthesized and characterized by SEM, TEM, FTIR, XPS, and TA. The catalysts were screened in liquid phase hydrogenation in a batch reactor. Their reactivity in hydrogenation of acetophenone (ACP), furfural (FU), 5-hydroxymethylfurfural (HMF) and cinnamaldehyde (CAL) was tested under mild conditions $(p = 4-9 \text{ bar H}_2, T = 30-70^{\circ}\text{C})$ in various solvents, including water, isopropanol, ethanol, acetonitrile, and toluene. The catalysts exhibited high selectivity towards 1-phenylethanol (PE) during ACP hydrogenation in water and especially in isopropanol (ca. 100% PE). During FU hydrogenation, Pd/BNC primarily facilitated the formation of furfuryl alcohol, followed by saturation of the furan ring. Surprisingly, Pd/BNC demonstrated low catalytic activity in HMF hydrogenation in both nonpolar and polar solvents. In CAL hydrogenation, Pd/BNC exhibited 100% conversion and up to 96% selectivity towards hydrocinnamaldehyde (C=C bond saturation), almost independently of the solvent (isopropanol/toluene) used. The catalyst demonstrated excellent recyclability in CAL hydrogenation in isopropanol.

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Oral presentations (OP):

Comparative life cycle assessment of cathode synthesis methods for sodium-ion batteries

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In the growing global demand for energy, the need for efficient energy storage systems is increasing dramatically.¹ Although lithium-ion (Li-ion) batteries are widely used today, limited lithium resources, high costs and geopolitical risks challenge their sustainability.² Consequently, sodium-ion (Na-ion) batteries have emerged as a compelling alternative solution, owing to the abundance and cost-effectiveness of their raw materials, which are present in substantial quantities in the earth's crust.³ Early evaluation of the environmental impacts of development of novel cathode materials and synthesis methods are critical to guide sustainable technologies.⁴ In this study, the environmental impacts of potential commercial production of Na_{0.7}MnO_{2.05} cathode material by solid-state and solgel methods were compared by life cycle assessment (LCA). The system boundaries of the study were chosen as 'cradle-to-gate' to reflect the impacts of the production. The functional unit was determined as '1 kg cathode powder production'. In the impact assessment phase "the ReCiPe 2016 Midpoint (H) method" was used. In the inventory analysis, the material inputs/outputs and energy requirements of both methods were scaled to industrial production.⁵ The Global Warming Potential (GWP) for the Solid-State and Sol-Gel synthesis methods was determined as 6.97 and 38.3 kg CO₂eq/kg respectively. The Sol-Gel method's GWP effect is due to its electricity usage at 25%, whereas the Solid-State method's GWP effect is 3.5%. The Sol-Gel method's use of chemicals like citric acid and acrylamide caused an additional 18.35 kg CO₂-eq per kg production. Despite the sol-gel method's benefits in terms of homogeneous and small particle material production, it has negative environmental impacts that need to be addressed. The findings obtained reveal that the choice of method in cathode production is decisive on environmental impacts and provide guidance in terms of developing sustainable production strategies.

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The potential of using biodegradable polymer coatings as carriers of substances supporting bone tissue regeneration processes

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The regeneration of bone tissue remains a significant challenge in biomedical engineering. Biodegradable polymer coatings have emerged as promising carriers for bioactive substances that can enhance bone healing and regeneration processes. These coatings offer controlled release profiles, biocompatibility, and gradual degradation aligned with tissue repair timelines. Polymers such as polylactic acid (PLA), polyglycolic acid (PGA), and poly(lactic-co-glycolic acid) (PLGA) offer tunable degradation rates and excellent biocompatibility.¹ Functionalization of these coatings with osteoinductive molecules, anti-inflammatory agents, or antimicrobial compounds, can significantly enhance the biological response at the implant–tissue interface. The controlled release kinetics achievable through polymer matrix design enables sustained therapeutic effects that are synchronized with the stages of bone healing. In addition, local supply of the substance reduces the need for systemic pharmacotherapy.² The results obtained in this study indicate that the PLGA coating, containing HAp and DEX, can improve the biocompatibility of osteosynthesis implants by acting as a barrier to alloy metal ions released from the surface. The coating in question may support the recovery process by lowering the risk of peri-implant infection and reducing the need for systemic pharmacotherapy, as well as stimulating bone fusion by hydroxyapatite released from the surface.

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Evaluation of antimicrobial and biocompatible properties of nanocomposites

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Nanocomposite materials developed for medical and industrial applications should meet specific requirements for antimicrobial properties and biocompatibility. The objective was to evaluate antimicrobial and cytotoxic effects of composites containing fillers based on graphene oxide and vermiculite, which were modified with substances such as silver, hexadecylpyridinium or hexadecyltrimethylammonium cations, zinc oxide. Antimicrobial analyses were performed using the broth microdilution method, disk and well diffusion tests and plate count method on potentially pathogenic bacterial gram-positive (G+) strains (methicillin-resistant *Staphylococcus aureus*, *Streptococcus salivarius, Staphylococcus aureus*), gram-negative (G-) strains (*Acinetobacter baumannii, Pseudomonas aeruginosa, Escherichia coli, Enterobacter aerogenes, Proteus mirabilis*), and yeast strain (*Candida albicans*)^{1,2}.

The inhibitory effect of the composites on biofilm formation was detected by the Crystal violet biofilm assay. The formation of bacterial biofilm on composite materials was analyzed with a scanning electron microscope. In addition, the influence of the composites on the autoaggregation and motile properties of bacterial strains was monitored. The biocompatibility of the composites was determined by *in vitro* 3-(4,5-Dimethylthiazol-2-yl)-2,5-Diphenyltetrazolium Bromide (MTT) contact and extract assays with cell line A549. The antimicrobial and biocompatibility assessment, using a complex of detection assays, provided important information regarding the potential use of these nanocomposites for medical or industrial purposes.

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OP

MnO₂-coated smectites: Structural and sorption insights

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Smectite-based composites coated with manganese dioxide represent a promising class of hybrid materials for environmental remediation, particularly for the removal of contaminants from aqueous systems. In this study, MnO₂-coated montmorillonites were prepared via in situ precipitation of manganese oxides on purified clay matrices. Characterization techniques, including XRD, FT-IR, SEM, XRFS, and XPS, confirmed formation of cryptomelane-type coatings on clay surfaces, with manganese predominantly in the Mn⁴⁺ oxidation state. SEM imaging revealed fibrous MnO₂ structures uniformly distributed and tightly adhering to the smectite particles. The clay matrix served not only as a carrier but also enhanced stability and usability of MnO₂, addressing practical limitations associated with the use of fine oxide powders in wastewater treatment. The sorption efficiency of composites was evaluated for both organic and inorganic contaminants in aqueous systems. Batch adsorption experiments demonstrated high removal capacities for selected antibiotics. Additionally, the composites exhibited significant uptake of Cd(II) ions. The sorption behavior was strongly influenced by solution pH and adsorption isotherms indicated that Cd(II) sorption followed the Langmuir model. The findings demonstrate that MnO₂-coated smectites effectively combine structural advantages of clay minerals with high reactivity of manganese oxides, offering a promising and sustainable approach for pollutant immobilization in wastewater treatment applications.

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Green synthesis of gold nanoparticles

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Gold nanoparticles (AuNPs) have unique optical, chemical, and biological properties¹, depending on their size, shape, and synthesis method². In addition, they are corrosion-resistant, insoluble, and their surface can be chemically modified.

The work aimed to prepare AuNPs of various shapes by biological synthesis. HAuCl₄ solution (c_{Au} =50 mg/l) served as a precursor, and green tea leaf extract as a reducing/stabilizing agent. To influence the shape of the nanoparticles, the pH of the solutions was adjusted. The formation of AuNPs was confirmed by the change in the solution's color and by UV-vis spectrophotometry and Transmission Electron Microscopy (TEM). The prepared solutions' color varied depending on the pH, from yellow (11–12), red (8–10), and purple (3–7) to gray-blue (4–6), and at pH 2, a dichroic solution was obtained. TEM analysis confirmed the connection between the color and the shape: spherical (ABS_{max} ~500 nm, yellow), quasi-spherical (~540 nm, red), flower-like (~650 nm, gray-blue). The size of AuNPs also influenced color.

Biological synthesis of AuNPs is a promising method that allows for controlled modification of the shape and size of nanoparticles by simple pH adjustment. It is efficient, environmentally friendly, and uses biological renewable resources without toxic chemicals.

ACKNOWLEDGMENTS

KEGA 011TUKE-4/2025 Modern Materials for Energy: Innovative Education for Enhancing the Quality of Teaching Materials Engineering Subjects

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Poster presentations (PP):

Engineering Iron Dimers at the Atomic Scale for Tunable Biomass Oxidation in Water

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Developing efficient and selective oxidation catalysts is key for advancing sustainable chemical transformations. Herein, we present a durable heterogeneous catalyst featuring single-atom iron dimers anchored on nitrogen-doped graphene acid (Fe-NGA). The catalyst design enables stabilization of redox-flexible Fe^{2+}/Fe^{3+} centers through coordination with nitrogen and carboxyl groups. During catalysis, these centers generate $Fe^{3+}-Fe^{4+}$ species, analogous to reactive intermediates in non-heme diiron enzymes, facilitating controlled two-electron oxidation in aqueous media. Spectroscopic analyses, including X-ray absorption and electron paramagnetic resonance, confirm the formation of atomically dispersed, magnetically coupled iron dimers. This cooperative redox behavior is central to the system's high catalytic efficiency. As a demonstration, Fe-NGA catalyzes the oxidation of 5-hydroxymethylfurfural (HMF) into 2,5-diformylfuran (DFF) with complete HMF conversion, 93% DFF selectivity, and a turnover frequency of 17.3 h⁻¹, ranking among the highest for this transformation. By integrating redox versatility with structural robustness, Fe-NGA establishes a promising strategy for selective oxidation of renewable feedstocks under green conditions.

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Cobalt containing Cerium Oxide as a Multifunctional Nanocatalyst for various Selective organic transformations

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The development of a multifunctional nanocatalyst for industrially relevant selective organic transformations is highly needed for the sustainable future of chemical industries. Cobalt containing cerium oxide nanocatalyst (MPCo@CeO₂NC) was prepared via simple coprecipitation method. The characterization of MPCo@CeO₂NC was carried out using different physiochemical techniques such as PXRD, FE-SEM, HR-TEM, EDAX-mapping, TGA, BET, and XPS analysis. The structural characterizations such as XRD and XPS analysis discovered the presence of the mixed phase of cobalt such as cobalt and cobalt oxide present in MPCo@CeO₂NC. Based on sustainability various industrially relevant organic transformations such as (i) nitrile formation from aldehyde, (ii) aldehydes to form tertiary *N*,*N*-dimethyl amines, and (iii) direct acetylation of alcohols/amines were achieved in an excellent manner using MPCo@CeO₂NC as the multifunctional catalyst. Our catalyst showed superior substrates scope with excellent yield for each type of reaction and recyclability.

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Ruthenium based electrodes for electrooxidation of organic pollutants from industrial wastewater

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Industrial wastewater generated from painting and coating processes often contains complex mixtures of organic solvents with high chemical oxygen demand. This makes them difficult to treat with conventional biological methods. Among the promising technologies for the degradation of such pollutants is electrochemical oxidation, one of the advanced oxidation processes. These processes are recognized for their ability to generate highly reactive oxidizing species and are effective and sustainable solutions for wastewater treatment.¹

This study investigates the electro-oxidation of such wastewater using a titanium electrode coated with ruthenium oxide, a material known for its high electrical conductivity, chemical stability, and catalytic activity for oxidation reactions.² The ruthenium oxide layer was applied using magnetron sputtering, followed by thermal oxidation in an oxygen-rich atmosphere. The Ru based electrode represents a cost-effective alternative to other active dimensionally stable anodes type anodes, such as those based on iridium or platinum.³

The objective of this work is to evaluate the effectiveness of the ruthenium oxide coated electrode in reducing the chemical oxygen demand of industrial wastewater. The study focuses on how key process parameters, including current density, pH, and chloride ion concentration (added to promote the formation of oxidative chlorine species), influence the overall treatment efficiency.

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NanoOstrava 2025

Biodegradable polycaprolactone/clay nanocomposites for biotechnological applications

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Currently, a major problem and topic in medicine is the increasing incidence of resistant microbial infections. Equally serious is the formation of bacterial biofilm, which is a major complication of implantable medical devices and leads to therapeutically demanding chronic infections, especially in cases involving antibiotic-resistant bacteria.

Among the dynamically growing areas of material research is the development of polymer nanocomposites, as they play an important role in the field of antimicrobial materials for medical applications, because the surfaces of medical equipment and supplies are required to have sufficient antimicrobial properties, to be free of biofilm and to prevent such infectious surface transmission.

Addition of nanofiller leads to a two-way increase in the polymer nanocomposite activity, firstly by reinforcing the overall polymer structure and secondly acting as an active element against microbial infections. On the other hand, there is a polymer matrix, which, in view of the ever-increasing concerns about current environmental pollution, should be chosen from among biodegradable polymers. Therefore, hybrid nanocomposites, which are the result of the interaction between clay minerals and biodegradable polymers, appear to be very promising for these purposes.

The aim of this study is to present antimicrobial effectiveness of polymeric nanocomposites created by incorporating hybrid nanocomposites, derived from clay mineral vermiculite combined with the antimicrobial agents chlorhexidine diacetate, octenidine dihydrochloride, ciclopirox olamine and ZnO, into a biodegradable PCL matrix (thin film and nanofibers) and study of the structure of the prepared nanofibers and their degradation. The results show a significant inhibitory effect against both bacteria and biofilm, making these materials very promising for desired medical applications.

ACKNOWLEDGMENTS

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Noble metal nanoparticles supported on multicomponent metal alloys as catalysts for organic reactions

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Catalysts are essential for enhancing the efficiency and selectivity of organic reactions, which is particularly important in industries such as pharmaceuticals, cosmetics, and food processing^{1,2}. The development of innovative catalysts that are both durable and highly active remains a central goal in catalysis research^{1,3}. In this study, we present novel catalysts composed of noble metal nanoparticles (Ru, Re) supported on multicomponent metal alloys. These catalysts were tested in acetalization reactions of acetone with glycerol and 2-butanone with ethylene glycol. Notably, the alloy supports alone achieved over 80% conversion in the acetone–glycerol system, with further increases in catalytic activity observed when Ru or Re nanoparticles were incorporated. In the 2-butanone–ethylene glycol system, conversions ranged from over 60% to over 70%, depending on the specific support or catalyst used. These results suggest that alloy metal supports can effectively enhance the dispersion of noble metal nanoparticles and increase the availability of active sites^{4,5}, leading to higher catalytic activity. The high activity observed even with the supports alone underscores the significant role of metal alloys as supports in catalytic systems, positioning them as promising candidates for sustainable and efficient catalytic processes in various industrial applications.

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Phytoremediation potential of plant stems: adsorption of azo dyes

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Leaves and stems of various plants have shown potential for environmental applications, yet while leaves are often studied, stems remain underexplored. This study focuses on the adsorption capacity of plant stems for the removal of persistent azo dyes from aqueous solutions. We investigated the phytoremediation potential of stems from three plant species: bamboo (*Bambusoideae*), bulrush (*Typha*), and knotweed (*Reynoutria*). While bulrush can serve as an ornamental plant in gardens, and bamboo is commonly used both in horticulture and as a decorative material in households, knotweed is still primarily regarded as a dangerous invasive species.

The adsorption efficiency of these stems was tested against four synthetic dyes commonly used in the textile and paper industries: three cationic azo dyes - Crystal Violet, Methylene Blue, and Brilliant Green - and one anionic azo dye, Congo Red, all of which are resistant to natural degradation.

After 24 hours of contact, *Reynoutria bohemica* stems reduced dye concentrations by 91–95%. Bulrush stems achieved 83–96% reduction, while bamboo showed lower efficiency, ranging from 23–86%. These results suggest that even invasive plant can serve as effective, low-cost, eco-friendly materials for phytoremediation of dye-contaminated water.

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Medical applications of saponin-based emulsions: from drug delivery to immunotherapy

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Saponins are a diverse class of naturally occurring compounds in many plant species¹. Due to their amphiphilic properties, saponins act as effective natural emulsifiers by reducing surface tension and stabilizing mixtures of immiscible liquids². Saponin-based emulsions have demonstrated broad medical potential due to their anti-inflammatory, immunomodulatory, antibacterial, antiviral, and dermatological properties¹.

Saponin-based emulsions represent a promising approach to drug delivery, particularly for active pharmaceutical ingredients with poor water solubility. Thanks to their amphipathic structure, saponins can form stable emulsions that improve drug bioavailability, enabling efficient delivery to target sites within the body. For example, saponins have been shown to significantly enhance the bioavailability of curcumin, as demonstrated in studies where curcumin was encapsulated into nanoparticles using various saponins, resulting in a substantial increase in its oral bioavailability³.

Saponins can also play a key role as adjuvants in immunotherapy and vaccines by supporting the activation of immune responses through interactions with immune cells, with their efficacy depending on specific molecular interactions⁴. Recent studies highlight the promising use of saponin-based emulsions in cancer therapy, where their immunostimulatory properties may lead to more effective elimination of tumour cells⁵.

In conclusion, saponin-based emulsions offer novel opportunities in drug delivery and immunotherapeutic applications.

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Natural organo-gels as a platform for anaesthetic drugs: from synthesis to application

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Oleogels are semi-solid systems composed of liquid oils immobilized within a structured network of gelators, offering a versatile platform for drug delivery, particularly in topical and transdermal formulations¹. Thanks to their ability to encapsulate hydrophilic and lipophilic active ingredients, they are gaining attention as sustainable alternatives to synthetic carriers². Among natural oils, olive oil stands out due to its richness in unsaturated fatty acids and antioxidants, contributing to skin nourishment and enhanced biocompatibility³. In this study, olive oil-based organo-gels were developed with lidocaine, a commonly used local anaesthetic. The work focused on the effect of surfactant type and concentration—TWEEN 80 and SPAN 80—on the physicochemical, rheological, and structural properties of the oleogels. The emulsifiers were selected based on their contrasting hydrophilic-lipophilic balance (HLB) values. Characterization included FTIR spectroscopy, stability monitoring, sorption capacity, wettability, and rheological profiling. SPAN-stabilized systems exhibited superior long-term stability and enhanced viscoelastic properties. These findings support the suitability of natural organo-gels as effective and biocompatible platforms for local anaesthetic drug delivery, with tunable performance based on formulation parameters⁴.

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Genotoxicity detection of nanoparticles and nanocomposite ZnO by the Comet assay

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Nanoparticles are highly biologically active structures. After entrance into cells, they reduce cell vitality and induce lethality. The direct interaction of nanoparticles with DNA causes mutations. Secondary damage occurs when NPs generate oxidative stress causing DNA breaks.

The aim of this work was to detect the genotoxic effect of two types of commercially available ZnO nanoparticles with a size of 25 nm (Carl ROTH Germany) and < 100 nm (Sigma-Aldrich, USA) and a ZnO/vermiculite nanocomposite containing 28.6 % ZnO with ZnO nanoparticle size of 30 nm (VŠB-TU, Ostrava). To assess single and double breaks in DNA, the Comet assay¹ (SCGE, TG 489 OECD) on the A549 cell line was used. H_2O_2 was used as positive control.

The results showed that both samples of ZnO NP significantly induced genotoxic effect, the intensity of which varied depending on the particle size and applied concentration. Smaller particles of 25 nm induced a higher number of breaks in DNA than larger particles < 100 nm. An important finding was that the ZnO/vermiculite nanocomposite induced breaks in DNA with a very low frequency. From this point of view, it can be stated that the degree of genotoxic risk of the ZnO/vermiculite nanocomposite is practically negligible.

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Harnessing Carbon Dots for a Sustainable Environment

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Environmental degradation caused by pollution poses a critical challenge for both developing and developed nations. Conventional remediation techniques often fall short in addressing complex contamination scenarios, highlighting the urgent need for innovative and efficient alternatives. In recent years, nanomaterials have emerged as promising tools for environmental remediation due to their unique physicochemical properties.^[1] Among these, quantum dots (QDs)—semiconductor nanoparticles typically ranging from 1-10 nm—exhibit distinct optical and electronic characteristics influenced by quantum confinement effects, making them valuable for both sensing and remediation applications.^[2] Carbon dots (CDs), a class of carbon-based QDs, offer several advantages over traditional semiconductor QDs such as CdSe, including lower toxicity, superior biocompatibility, chemical stability, and tunable photoluminescence.^[3] CDs can be synthesized from sustainable and cost-effective precursors, enhancing their environmental compatibility and supporting waste minimization. This work aims to provide an overview of CDs synthesis methods and to examine the key properties that render them effective in detecting and removing chemical and microbial pollutants through mechanisms such as adsorption, photocatalytic degradation, and antimicrobial action.^[4] Recent advances in the application of CDs for environmental sensing and remediation are also discussed, emphasizing their potential in sustainable pollution management.

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Plant phytotoxic responses of nanoparticles

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Nanoparticles are becoming a problem because of their large amounts in water or air. when they can a problem for plants and organisms living in their natural habitat. In plants, nanomaterials can affect their growth, both positively and negatively, or shorten their life cycle^{1,2,3,4}. In the presented experiments, *Valerianella locusta* was used as a research plant on which the titanium dioxide nanoparticles were deposited by dry deposition and silver nanoparticles were deposited by wet deposition. The application of nanoparticles on the plant was done on a weekly basis where the chlorophyll concentration in the leaves of the plant was monitored. Both types of nanoparticles in the studied plants exhibited elements of oxidative stress during deposition, with visible stress reactions that can be described as phytotoxic reactions. These stress reactions were manifested on *Valerianella locusta* plant by various growth anomalies, changes in chlorophyll concentrations and chemical composition in the plant.

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Synergistic Pd-Ni Alloy on H-NbOx: Boosting Hydrogenation of Lignin Derivatives to Cyclic Hydrocarbons and Alcohols

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The hydrogenation of lignin-derived bio-oil and β -O-4 linkages, which serve as representative lignin model compounds.¹ The hydrogenation of these substrates leads to the formation of cyclic hydrocarbons and valuable aromatic platform chemicals.¹⁻³ A hydrothermally synthesized H-NbOx material, prepared via acid treatment of Nb2O5, was used as the catalyst support. Alloying 3 wt% Pd and 3 wt% Ni on H-NbOx yielded the bimetallic PdNi/H-NbOx catalyst. Comprehensive characterization using XPS, NH₃-TPD, and O₂-TPD confirmed the presence of intrinsic active sites, strong metal-support interactions, and enhanced oxygen vacancies, all contributing to superior catalytic performance.⁴ The PdNi/H-NbOx catalyst achieved >98% selectivity toward cyclic hydrocarbons, primarily cyclohexane and ethyl cyclohexane. In contrast, monometallic catalysts (3Pd/H-NbOx and 3Ni/H-NbOx) exhibited varied product distributions, yielding mixtures of ethylbenzene, phenol, ethyl cyclohexane, and cyclohexanol. Notably, CTH in isopropanol facilitated the selective formation of aromatic compounds. The PdNi/H-NbOx catalyst was also effective in hydrogenating lignin bio-oil derived from wheat straw. The process delivered high yields of saturated cyclic alcohols. These findings highlight the dual capability of the developed catalytic system to generate aromatic compounds via CTH and cyclic hydrocarbons via direct hydrogenation, offering a promising strategy for addressing energy and chemical demands through lignin valorization.

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Hygroscopic growth of submicrometer aerosols for targeted pulmonary deposition

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Asthma affects more than 300 million people worldwide, yet conventional inhalers often deliver pharmaceutical aerosols inefficiently.¹ A large portion of the aerosol deposits in the oral cavity, leading to reduced therapeutic effectiveness and increased risk of side effects. One strategy to improve delivery efficiency is controlled aerosol growth, which reduces early deposition and enhances transport to the lungs.²

This method involves the use of dry, hygroscopic submicrometer particles. As these particles are inhaled along with air at a temperature below body temperature, water vapor condenses onto their surfaces, promoting growth to an optimal size for deep lung deposition.

This work presents experimental studies of aerosol growth in a laboratory setup designed to replicate the human mouth-throat region – a key site of deposition losses. Sodium chloride was used as the hygroscopic material. The influence of relative humidity and initial particle size on aerosol growth was systematically investigated. Particle sizes before and after growth were measured using a Scanning Mobility Particle Sizer and an Aerodynamic Particle Sizer, respectively. Based on these measurements, growth factors were evaluated to quantify the effectiveness of this approach. The results confirm that humidity-driven particle growth offers a viable way to control aerosol deposition for targeted pulmonary delivery.

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Electrospun PA6 Nanofibers Bearing the CeO₂ Dephosphorylation Catalyst

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Electrospun nanofibers have garnered significant attention in recent years due to their unique properties and wide-ranging applications across various fields. In this study, we present one step modification of PA6 nanofibers by incorporating cerium oxide (CeO₂) nanoparticles as a dephosphorylation catalyst.

Herein, we demonstrate the fabrication of electrospun PA6 nanofibers embedded with two types of CeO₂ nanoparticles (CENPs) using one step electrospinning process. The morphology and structure of the resulting nanofibers are characterized using scanning and transmission electron microscopy (SEM, TEM) and X-ray diffraction (XRD). The concentration of Ce on the nanofiber surface was determined by XPS, and the total concentration of Ce was analysed by ICP-MS.

The dephosphorylation activity of prepared nanocomposites was demonstrated by monitoring the hydrolytic cleavage of three phosphodiester molecules (*p*-NP-TMP, *p*-NPPC, BNPP) in water by the HPLC method. This procedure allowed us to study the kinetics and mechanism of the hydrolytic cleavage and the ability of immobilized CeNPs to cleave different types of P–O bonds. One of the main hydrolysis products, *p*-nitrophenol, was effectively adsorbed on PA6 nanofibers, which may allow the selective separation of the degradation products after hydrolysis.

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One-step preparation of nanofibrous material based on polyacrylonitrile and cellulose acetate for CO₂ capture

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There is an increasing effort to decrease the usage on fossil fuels because of the rising levels of carbon dioxide (CO_2) in the atmosphere. This study explores the potential of nanofibrous polymeric membranes—specifically cellulose acetate (CA) and polyacrylonitrile (PAN)—for the adsorption of carbon dioxide (CO_2) . Emphasis was placed on scalable, cost-effective one-step electrospinning processes, where functional additives such as amines or zeolites were incorporated directly into the spinning solution, eliminating the need for post-treatment. Two electrospinning methods—needleless (wire-based) and needle-based—were used to compare the effects on fiber morphology and sorption performance.

Amines including hexadecylamine (HDA), diethylenetriamine (DETA), triethylenetetramine (TETA), and tetraethylenepentamine (TEPA) were selected for their strong basicity and affinity for acidic CO₂ molecules. Zeolites were also tested as low-cost, porous additives. While post-spinning modifications were examined, they posed limitations in scalability and uniformity.

The incorporation of these additives significantly enhanced (several times) CO₂ sorption capacities compared to unmodified membranes. Importantly, the covalent bonding of amines to polymer chains conferred chemical stability. Although the overall sorption capacity was lower than that of commercial powdered sorbents, the nanofiber-based materials offer advantages in reusability, spontaneous desorption, cost, and suitability for large-scale fabrication.

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Highly Efficient Antimicrobial Coating Based on Polylactide Prepared via Supercritical Fluid Technology

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This study presents the development of a novel antimicrobial coating composed of poly[3-butyl-5-(2-methacryloyloxy)ethyl]-4-methylthiazol-3-ium iodide (PMTA-BuI) applied onto a polylactide (PLA) matrix using supercritical fluid technology (SFT). The environmentally friendly SFT process enables efficient, uniform incorporation of the cationic polymer into the PLA surface, significantly altering surface properties and enhancing antimicrobial activity. The resulting composites were characterized using FTIR, SEM, AFM, XRD, TGA, and DSC techniques. The antimicrobial performance was assessed against clinically relevant strains, including Acinetobacter baumannii, Escherichia coli, Staphylococcus aureus, and MRSA, using biofilm inhibition assays. The PLA/PMTA-BuI composites showed substantial biofilm suppression, particularly at 10 wt % PMTA-BuI loading, achieving inhibition rates over 80 % across all tested strains. Surface analyses revealed changes in roughness and wettability, contributing synergistically to antimicrobial effects. Furthermore, the thermal and crystalline behavior of the PLA matrix was modulated by the polymer coating. These results highlight the potential of PLA/PMTA-BuI materials as customizable, biodegradable antimicrobial solutions suitable for medical packaging and device applications, particularly in hospital environments where sterility and resistance to microbial colonization are critical.

KEYWORDS

polylactide, antimicrobial polymers, supercritical fluid technology

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TOPIC 3 Materials for Energy Harvesting and Storage

Chair: Tuğrul Çetinkaya

Batteries Photovoltaics Materials for accumulation, release and transport of hydrogen Solar Fuel Cells Smart sustainable material



Invited lectures (IL):

Fabrication of high-performance graphene oxide-reinforced Ni-P composite coatings via ultrasonic-assisted pulse electrodeposition

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Graphene family nanoplatelets (GFNs), as 2D nanomaterials with layered structures, are promising solid lubricants for enhancing the performance of metallic matrix composite coatings^[1]. Among GFNs, graphene oxide (GO) is particularly advantageous due to its good dispersibility in coating baths^[2,3]. The incorporation of GO into nickel-based coatings has been shown to reduce friction and improve wear resistance by imparting solid lubrication properties^[4,5]. This study explores the wear and electrochemical behavior of Ni-P-GO composite coatings fabricated via pulse electrodeposition under varying current densities (1, 2, 4, and 8 A/dm²). Coating characterization was conducted using electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PDP) to assess corrosion resistance, while mechanical performance was evaluated through wear and friction testing. Results demonstrated that GO addition significantly enhances both corrosion and wear resistance. The coating deposited at 4 A/dm² exhibited the highest charge transfer resistance and the lowest corrosion current density, indicating superior corrosion protection. Wear tests revealed a decrease in the coefficient of friction with increasing current density, with the 4 A/dm² sample achieving the lowest wear rate, attributed to the self-lubricating effect of GO. These findings highlight the potential of Ni-P-GO composite coatings for applications requiring enhanced corrosion resistance, wear durability, and mechanical strength in aggressive environments.

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Low-dimensional functional materials for energy security

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Functional low-dimensional materials with judicious hetero- and single-atom engineering may unlock versatile platforms for high-performance electrochemical energy storage and efficient, earthabundant catalysis. In the first part of the talk I will trace how tailored graphene derivatives and organic architectures push the limits of batteries and supercapacitors. Examples include nitrogensuperdoped graphene with diamond-like interlayer bonds that reaches benchmark volumetric energies;¹ graphene acid whose dense carboxylation raises its lithium-ion capacity beyond high-quality single layer graphene;² and self-assembled organic nanowire Li-ion anodes that store up to 1900 mAh g⁻¹.³ Such graphene derivatives also enable direct up-cycling of spent sorbents for water purification into electrodes for energy storage, mitigating costs and wastes through circular design and sustainable resource management principles.⁴

The second part highlights catalytic technologies that exploit materials of similar design, which are key to decreasing the energy and environmental footprint of the chemicals industry. An aminoacidanchored graphene acid organocatalyst outperforms homogeneous acids for solvent-free valorization of waste organics and for biofuel production.^{5,6} Embedding earth abundant transition metal atoms in such graphene derivatives affords redox-switchable mixed-valence catalysts that efficiently drive aerobic oxidative transformations of lower-value molecules to key chemicals for the pharmaceutical and polymer industry.⁷ Together, these studies demonstrate how molecularly functionalized materials and metal-carbon seamless architectures can deliver advances in catalysis for low energy organic tranformations and electrochemical energy storage technologies.

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Advancing Li-S Batteries: Two-Dimensional (2D) Heterostructures for Enhanced Performance and Longevity

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Lithium–sulfur (Li–S) batteries have been deemed as very promising candidates for next-generation energy storage systems, providing an exceptionally high theoretical energy density (~2600 Wh kg⁻¹) and using the natural availability, cheap cost, and environmental benignity of sulfur. Notwithstanding these benefits, the commercial feasibility of Li-S batteries is hindered by various intrinsic obstacles, such as the dissolution and unregulated migration of lithium polysulfide intermediates (shuttle effect), the intrinsically low electrical conductivity of sulfur and its discharge products, and the electrochemical and mechanical instability of traditional separators and cathode architectures during extended cycling. This talk will examine recent advancements in the design and utilization of twodimensional (2D) material heterostructures specifically MXenes, MBenes, graphene-based materials, metal-organic frameworks (MOFs), and Covalent organic frameworks (COFs) as multifunctional components in separator coatings and cathode topologies. These materials demonstrate outstanding physicochemical properties, including as elevated electrical conductivity, adjustable porosity, and polar surface functions that allow for efficient confinement of polysulfides and promote selective lithium-ion transport. On the cathode side, 2D heterostructures optimize sulfur usage, accelerate redox kinetics, and improve structural integrity, resulting in prolonged cycle life and greater overall battery performance¹⁻⁴.

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The Future of Batteries and Supercapacitors: Unlocking the Power of 2D Materials

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Electrochemical energy storage offers an efficient and eco-friendly solution to growing energy and environmental issues. However, its widespread use is hindered by limitations in current electrode materials, which are often costly or lack sufficient performance. Thus, developing low-cost, high-performance materials is essential. Two-dimensional (2D) materials, with their large lateral size and atomic thickness, exhibit unique physicochemical properties [1]. Their high surface area enhances ion adsorption and capacitance, while excellent conductivity supports rapid electron transport. Tunable interlayer spacing and active sites further boost ion intercalation and electrocatalytic activity, making them ideal for energy storage [1,2]. The discovery of graphene revolutionized materials science and inspired the development of other 2D materials, such as transition metal dichalcogenides (TMDs) and MXenes—transition metal carbides, nitrides, and carbonitrides broadening the possibilities for advanced energy storage technologies [3,4].

This presentation provides a comprehensive overview of two-dimensional (2D) materials specifically graphene, MoS_2 , and $Ti_3C_2T_x$ - with a focus on their potential applications in electrochemical energy storage systems. It will explore advanced synthesis methods and electrode design strategies aimed at optimizing the performance of these materials. Furthermore, their suitability for use in supercapacitors, lithium-ion batteries, lithium-air batteries, and multivalent ion batteries will be critically assessed.

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Oral presentations (OP):

Graphitic carbon nitride as Green electrocatalyst for highly selective overall Water splitting

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The development of efficient, low-cost, non-noble metal-oxide-based nanohybrid materials for overall water splitting is a critical strategy for enhancing clean energy use and addressing environmental issues. In this study, an interfacial engineering strategy for the development of bimetallic Co-Ni nanoparticles on graphitic carbon nitride (g-C3N4) using ultrasonication followed by coprecipitation is conveyed. These nanoparticles demonstrate high efficacy as bifunctional electrocatalysts for the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) in alkaline conditions. Co-Ni nanoparticles on graphitic carbon nitride demonstrate an increased surface area via ultrasonication and subsequent coprecipitation. The g-C3N4 combined with Co-Ni nanoparticles lead to the development of bifunctional catalysts that exhibit significant efficiency in both HER and OER, and their interfacial properties are investigated for the first time. The chemical composition and morphology of g-C3N4 integrated with Co-Ni nanoparticles significantly influence the modulation of redox-active sites and the facilitation of electron transfer, resulting in improved splitting efficiency. The interactions between the Co-Ni bimetal and g-C3N4 demonstrate exceptional electrochemical performance for water splitting. Consequently, the 20% 20-Co-Nigraphitic carbon nitride electrode demonstrated superior HER performance, comparable to the other electrodes. In the results, it is indicated that an increased molar ratio of Co and Ni incorporated in graphitic carbon nitride significantly improves HER performance.

Effect of water electrolyte on properties of nanocomposite PVDF and PVDF-CTFE membranes

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Battery production reach 1490 GWh in 2024, with Li-ion batteries comprising 80%. This growing demand raises condition on enhanced battery safety. [1] Key component influencing safety is the separator, which electrically insulates the electrodes while enabling Li⁺ ions transport. Polyvinylidene fluoride (PVDF) and its copolymer with chlorotrifluoroethylene (PVDF-CTFE) are promising alternatives to commercial separators. [2] Their properties can be further improved using nanofillers to enhance mechanical strength, thermal resistance, electrochemical stability, and ionic conductivity. Another approach to improving safety is replacing organic electrolytes with aqueous ones, offering benefits in safety, production, recyclability, and lifecycle performance. [3] However, this requires suitable separator materials. This study investigates PVDF and PVDF-CTFE nanocomposite membranes, prepared by solvent casting method. The nanocomposite materials were characterized by phase, morphology, thermal, mechanical and wettability measurement. Results shows that nanofiller selection significantly enhances safety-related properties, making PVDF and PVDF-CTFE nanocomposites promising separators for aqueous Li⁺ ion batteries, contributing to the advancement of safer and more durable energy storage technologies.

The study highlights that the choice of nanofillers positively impacts safety-related properties of the PVDF and PVDF-CTFE nanocomposite separators which are highly suitable for use in aqueous battery systems. This research contributes to the development of more efficient and durable energy storage solutions.

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Enhanced solid electrolyte interface by innovative producing method: Screen-printed LATP solid electrolyte

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LATP is a promising solid electrolyte candidate for solid-state batteries due to its ability to provide ionic conductivity in the range of approximately $10^{-4} - 10^{-5}$ S cm at room temperature. However, in Generation 4 batteries, direct contact with lithium metal reduces Ti⁴⁺ to Ti³⁺ in the LATP crystal structure. ¹ Therefore, combining LATP with polymer electrolytes that enable fast ion transfer at room temperature and offer high electrode wettability emerges as a rational solution.

In this study, PEO-based polymer electrolytes, which facilitate fast ion transfer due to their segmental mobility at room temperature, are used as a binder at a 90 wt.% ratio to prepare LATP-based ceramic solid electrolyte inks. Another novelty of this study is the adaptation of printing technologies to solid-electrolyte coatings on the electrode surface which can also control the electrolyte thickness and accelerate electrolyte coating compared to the traditional tape casting methods in both lab and large-scale producing lines.

The produced hybrid polymer in ceramic-type electrolyte (PCE) ink was printed on an LFP electrode. Printed PCE's physical and electrochemical tests were carried out. Promising ionic conductivity (8.3 x 10^{-5} S cm⁻¹) and specific capacity (140 mAh g⁻¹) were obtained at room temperature. The suggested hybrid PCE and printing technique have strategic importance for the development of Gen4 batteries and for reducing production costs.

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Optimizing printable LFP electrode ink formulations: Binder and viscosity effects on printing quality and electrode performance

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The rapid growth of electric vehicles and portable electronics has positioned lithium-ion batteries at the core of global energy storage technologies. As the battery industry is projected to exceed \$400 billion by 2030, there is an increasing demand for scalable, cost-effective, and sustainable electrode fabrication methods.¹ Conventional techniques such as slurry casting suffer from high energy consumption, limited design flexibility, and material inefficiencies, making them less suitable for next-generation applications like flexible and miniaturized devices.

Screen printing emerges as a promising alternative owing to its simplicity, high throughput, pattern versatility, and compatibility with multilayer architectures. In this study, we investigate the printability and pattern integrity of electrode inks formulated with different polymeric binders polyethylene oxide (PEO) and polyvinylpyrrolidone (PVP). The impact of ink rheology, particularly viscosity and thixotropic behaviour, on the electrochemical performance and resolution of printed electrodes is examined. This work highlights the critical role of binder and solvent selection in screen-printed electrode manufacturing and provides insight into optimizing ink formulations for advanced electrode fabrications, which may decrease production costs and the amount of solvent needed.

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Poster presentations (PP):

Electrochemical Investigation of Hard Carbon Anode and Na(Ni1/3Fe1/3Mn1/3)O₂ Cathode using Different Electrolyte with FEC Additives for Na-Ion Batteries

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Sodium-ion batteries (SIBs) consist of a cathode, anode, sodium-ion conducting electrolyte, and a separator. While similar to lithium-ion batteries (LIBs), the larger ionic radius and higher atomic mass of sodium result in slower kinetics and lower capacity¹. Electrolytes play a key role in determining capacity, cycle life, and safety. Understanding the (electro)chemical interactions at the electrode– electrolyte interface (EEI) is essential to improving long-term performance. Although sodium and lithium ions share structural and electrochemical similarities, studies show that electrolyte behavior in LIBs cannot be fully applied to SIBs^{2,3}.

In this study, various organic solvent mixtures EC:PC, EC:DMC, and EC:DMC:PC were investigated in combination with different sodium salts (NaPF₆, NaClO₄, and NaTFSI) and varying concentrations of FEC additives (1%, 3%, and 5%). All electrolyte formulations were prepared in an argon-filled glove box to prevent moisture and oxygen contamination. These electrolytes were then evaluated in sodium-ion cells using a hard carbon anode and a Na(Ni1/3Fe1/3Mn1/3)O₂ cathode. Among all tested combinations, the electrolyte consisting of NaClO₄ dissolved in EC:DMC with 1% FEC additive demonstrated the best overall performance in terms of stability and capacity retention.

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Porous carbon in energy storage

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Porous carbon materials are highly demanded materials for incorporation in energy storage as separator and electrodes. Their possibility of tailoring and very good properties such as stability, mechanical durability, conductivity and inexpensivness are reasons for it. Activated carbon (AC) was prepared and studied for comparison between different source materials. Precursor was firstly cleaned, then activated by KOH and then carbonized at 700°C. Carbon nanotubes (CNT) and jet milled carbon nanotubes were modified by sulfur and compared. Modification was done by firstly oxidizing the tubes by piranha solution, then using surfactant to modify them further and keep them dispersed and finally adding sulfur containing compound.

The properties and morphology of prepared materials were observed and compared. AC showed two different materials which needs to be studied further to determine their possible use. Jet milled CNT showed better modification with sulfur, with higher amount of sulfur present, better dispersion, higher ionic conductivity and higher oxidation compared to normal CNT.



Fig. 1: Activated carbon from bamboo and walnut shells

KEYWORDS CNT, AC, sulfur, carbonization

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Single atom ruthenium decorated on MOF-derived porous carbon for overall water splitting

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The scalable production of green hydrogen critically depends on the development of highly active and durable single-atom electrocatalysts capable of operating efficiently for overall water splitting.¹ Yet, poor reaction kinetics and the ongoing challenge of balancing catalytic activity with long-term stability continue to impede progress. This study tackles the pressing challenge of creating efficient and long-lasting electrocatalysts for green hydrogen production by introducing a strategically designed, single-atom catalyst for overall water splitting. The core innovation involves the deliberate incorporation of Ru-N₄ single-atom sites into a MOF-derived porous graphitic carbon framework.² This design enhances the accessibility of active sites, promotes rapid electron transport, and delivers outstanding stability across a wide pH range. The resulting Ru₁/Ni-NPGC catalyst exhibits impressive electrocatalytic activity, achieving low overpotentials of ~191 mV for the oxygen evolution reaction and \sim 52 mV for the hydrogen evolution reaction under alkaline conditions-surpassing many leading catalysts. Notably, it supports efficient water electrolysis at cell voltages of ~ 1.48 V to reach a current density of 10 mA/cm². Operando spectroscopic analyses further reveal the central role of Ru as the active site, shedding light on the underlying structure-activity relationship. By overcoming key limitations such as sluggish kinetics and the trade-off between activity and durability, this work offers a promising pathway toward the development of robust and high-performance electrocatalysts for sustainable hydrogen generation.

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Cu(I)/Cu(II) Single Atoms Over N-Doped Graphene Acid for Electrocatalytic Nitrate Reduction to Ammonia

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The escalating global demand for energy continues to drive a significant increase in greenhouse gas emissions, a concern highlighted at the 27^{th} Conference of the Parties, which underscored the urgent need for coordinated action toward sustainable energy systems and carbon mitigation technologies. Among the most energy-intensive industrial processes is the Haber-Bosch method for ammonia synthesis, which accounts for a substantial share of anthropogenic CO₂ emissions. Given ammonia's critical role as a nitrogen source in fertilizers, identifying alternative, low-emission synthesis routes is vital for ensuring long-term food security.

In this study, we present a sustainable approach to ammonia production via electrocatalytic nitrate reduction, leveraging nitrate ions commonly present in wastewater as a nitrogen source. Our method utilizes Single Atom Catalysts (SACs), engineered by immobilizing individual copper atoms onto functionalized graphene supports. Specifically, we synthesize Cu(I)/Cu(II) mixed-valence species stabilized on nitrogen-doped graphene acid. The functional groups within the graphene lattice play a dual role: enhancing metal atom stabilization and promoting in situ reduction of Cu(II) to catalytically active Cu(I) centers. During electrocatalysis, Cu(I) sites facilitate proton adsorption and activation (forming H*_{ads}), while Cu(II) sites coordinate with nitrate ions. The proximity of these two sites enables the transfer of H*_{ads} to bound nitrate, promoting its stepwise reduction to ammonia. This dual-site mechanism not only offers a low-carbon route for ammonia electrosynthesis but also contributes to wastewater remediation by converting nitrate pollutants into valuable chemical products, thereby addressing both environmental and agricultural challenges.

ACKNOWLEDGMENTS

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Clay minerals and porous carbon for battery applications

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A suitable alternative to conventional Li-ion batteries is the use of solid-state batteries. They are safer for the environment and less prone to leakage of electrolytes and dendrite formation. However, the SSBs have a relatively low performance due to their ionic conductivity and interface interactions. To improve the performance of SSBs, it is important to consider materials that improve the ionic conductivity and interface interactions, as well as those that are economically viable and safe to use. Clay minerals can play a major role as a composite material for solid-state electrolytes by acting as a fire retardant and suppressing dendrite formation. The layered structure of clays like vermiculite along with Li-salts, polymers, and carbon materials like graphene oxide can enhance ionic conductivity. Porous carbon like schwarzites possesses excellent mechanical strength and high surface areas. They can be synthesized by template removal from zeolites and have promising properties for their role as an anode material for battery applications.

KEYWORDS

Solid-state electrolytes, clay minerals, porous carbon, schwarzite

ACKNOWLEDGMENTS

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Heat treated phosphate ceramics in battery applications

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Advanced battery concepts like all-solid-state batteries (ASBs) are considered one of the most promising candidates for future energy storage technologies, because they offer several advantages over conventional Lithium-Ion Batteries (LIBs), especially with regard to stability, safety, and energy density¹. Electrolytes are key components of all-solid-state batteries, as they are crucial in determining the batteries' efficiency². Ceramics based on phosphate compound with specific framework $A_xM_2(PO_4)_3$ (A = Li, Na and M = Cr, Zr, Fe, Zn etc.) have been reported to be fast alkalion conductors³.

Based on this framework – several types of phosphate ceramics were synthesised with the most promising being a combination of sodium and manganese. Experiment was designed that chemical formula of samples was based on phosphate $A_xM_2(PO_4)_3$ (A = Li, Na and M = Mn, Cr etc.). Phosphate ceramics were studied before and after heat treatment. Phase composition was studied using X-ray diffraction (XRD); morphology was studied using scanning electron microscopy (SEM) and temperature behaviour was studied using differential scanning calorimetry (DSC). XRD analysis confirmed the highly crystalline state of the phosphate ceramics.

KEYWORDS

Phosphate ceramics, heat treatment, phase structure, morphology, temperature behaviour

ACKNOWLEDGMENTS

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Modified polyolefine separators for safe Li-batteries

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The increasing use of lithium batteries along with the use of electrical devices also brings safety risks if not produced as a result of sufficient engineering. These safety risks are related to the risk of heat leakage, ignition or explosion.

The study presents the types and effects of separators used to increase the performance and safety of LIBs with modification. The experimental part of the study focused on evaluating the effects of the prepared separators. The morphological and surface properties of the prepared separators were analyzed and compared with SEM. FTIR analysis was performed for the bond structure interactions of the prepared samples. Crystal structure and phase changes were analyzed with XRD and information about the performance was obtained with ionic conductivity tests.

The studies have shown that the selection of separator has a great effect on battery performance and reliability and the main factors affecting these changes were determined. The study contributes to a better understanding of the importance of separators to increase the safety and performance of LIBs. Multilayer separators have been found to be more stable in terms of safety in lithium-ion batteries.¹

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Li-lon battery separators and the importance of their life cycle assessment for smarter design and recycling strategies

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Separators in lithium-ion batteries are a key element in ensuring the safe and efficient operation of these energy storage devices. Their primary function is to physically separate the cathode and anode, thereby preventing short circuits, while allowing the passage of lithium ions through the electrolyte. Traditionally, polyolefin membranes such as polyethylene (PE) and polypropylene (PP) have been used, which offer good mechanical strength and chemical stability. However, their limited thermal resistance and tendency to shrink at higher temperatures pose a potential risk to battery safety [1].

In response to these challenges, research is focused on developing advanced separators, including ceramic composites and multifunctional membranes, which combine high thermal stability with improved electrolyte wettability and ionic conductivity. Current trends also include the use of environmentally friendly materials such as cellulose and mineral composites, which offer more sustainable alternatives to traditional polymer separators [2].

Life cycle assessment is a useful tool for businesses, product developers and decision-makers who want to better understand the overall environmental impacts of their activities. This way, they can more effectively design and implement changes towards more sustainable and greener alternatives. The life cycle of manually separated Li-ion battery separator made of polyethylene (PE), one side of which is coated with a layer of boehmite AlO(OH), is carried out. The material composition of separator has been verified using analytical methods, e. g. XRD, SEM-EDS and FTIR to understand the mechanical, physicochemical and degradation properties [1].

The main goal of the ongoing research is to determine the material and related energy flows in the life cycle of PE/AlO(OH) separator and to define the strengths and weaknesses of this particular material. Based on pilot results supported by LCA software evaluation (Sphera), the effort is then made to optimize the existing separator or to propose material functional alternatives with a better life cycle and economic-ecological impact. This comprehensive research is also connected to the question of whether and under what conditions the separator from a given type of used battery can be effectively recycled and further processed into a secondary raw material usable either again in the battery industry or elsewhere [3].

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TOPIC 4

Instrumentation-Driven Design and Characterization of Materials

Chair: Marcin Basiaga

Advanced testing Nanomaterials detection Surface properties Structure characterization Morphology and topography



ΙL

Invited lectures (IL):

Silicon nanowire devices and optical methods to characterize them

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Efficient harvesting of solar energy and potential storage of energy for later use are some of the most important problems of the societal transition to renewable energy. We will discuss here the potential of using radial junction devices based on silicon nanowires with large surface areas to harvest solar energy and store it in the form of hydrogen fuel. Previously, the efficient harvesting of solar energy using silicon nanowire devices with radial junction configuration has been demonstrated [1]. In order to store the solar energy in the form of hydrogen gas using a water-splitting reaction, there is a need to increase the potential difference on electrodes to reach at least 1.8 V [2]. We have demonstrated radial triple-junction devices based on silicon nanowires able to provide large open circuit voltage (V_{oc}) above 2 V [3].

The optimization of the device performance, especially in the multi-junction configuration, requires dimensional characterization and models able to predict the device performance. To tackle this challenge, we have focused on using advanced optical methods, namely Mueller matrix polarimetry, to determine relevant dimensions and properties of silicon nanowires produced using metal-assisted etching [4] and electron-beam lithography [5]. We will discuss the challenges to accurately characterize vertical nanowire arrays and demonstrate the application of advanced optical methods to the fabricated samples.

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Oral presentations (OP):

Comparing Analytical Techniques for (Nano)Particle and Molecular Size and Concentration Measurements

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Nanoparticles are used in various sectors of human activity and in the development of new drugs. Their distribution in nature and behavior in the human body are not well studied. In order to prevent their uncontrolled production and release into the environment, the European Union has defined the term nanomaterial based on the size and relative amount of particles smaller in at least one dimension than 100 nm. The lecture will present a comparison of instruments for analyzing the size and concentration of particles in liquid samples, which can perform the analysis in units or less than tens of minutes, which is an order of magnitude faster than standard analysis with electron microscopes. The comparison will include three completely unique techniques: multi-angle dynamic light scattering (Malvern Panalytical, Zetasizer Ultra Red label instrument), the technique of optical tracking of nanoparticle trajectories (Malvern Panalytical NanoSight NS300) and a low-flow cytometer (NanoFCM, Flow NanoAnalyzer instrument). The main areas of application of these devices include the targeted delivery of drugs, nanomedicine, vaccines, viruses and similar particles, lipid and extracellular vesicles, and generally organic and inorganic nanomaterials and biomolecules.

NMR relaxometry to characterize the interlayer spaces of the vermiculite nanostructured materials

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This work presents the application of NMR relaxometry for characterization of the interlayer space in clay minerals. As a non-invasive technique, NMR relaxometry provides indirect insight into interlayer structure by monitoring the relaxation times of water protons. Variations in the transverse relaxation time (T_2) reflect changes in both the width and total volume of the interlayer space.

The NMR relaxometry data revealed multimodal T_2 relaxation time distributions indicating different pores in the vermiculite structure. The shortest T_2 component, attributed to water molecules confined within the interlayer spaces, exhibited a strong dependence on the hydration state and the type of interlayer cations. The longer T_2 components, on the other hand, were associated with water molecules between the vermiculite grains. In our study, we focus on short T_2 components that correspond to the interlayer space. The calculated interlayer dimensions range from 0.6 to 1.9 nm, confirming the sensitivity of NMR methods to nanoscale structural changes in layered materials.

The relaxation time distributions provide a comprehensive understanding of the pore structure, surface interactions, and the dynamic behavior of fluids within the vermiculite matrix. These insights are pivotal for optimizing the performance of vermiculite in various industrial applications.

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Design and characterization of biochips for surface plasmon resonance ellipsometry

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Surface plasmon resonance (SPR) sensors find wide applications in biomedicine¹. It is based on the enhancement of p-polarized electromagnetic wave using the generation of the surface plasmon and detection of fine refractive index change in the analyte. Polarized light detection and ellipsometry have been applied to enhance sensitivity of SPR sensors^{2,3}. The sensitivity to antibody is increased by biochip surface chemistry spotting. In this paper we further enhance biochip sensitivity by combining of Tamm plasmon polariton waves in dielectric multilayers⁴ with surface plasmon polariton in noble metal film. Fine optimization of oth s- and p-polarization resonances by multilayer thicknesses enable to enhance angular sensitivity to analyte refractive index. The designed structure consists of Ag, SiO2, and Ta2O5 multilayer structure prepared by magnetron sputtering. The real thicknesses of the films were determined using Mueller matrix spectroscopic ellipsometry at variable angle of incidence (Woollam RC2-DI) in the spectral range from 193 nm to 1.7 μ m. The structure was also characterized using the total internal reflection from air and demineralized water analyte. The application of the designed biochip with enhanced sensitivity by surface plasmon resonance ellipsometry in biochemistry and biomedicine is discussed.

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Semiconductor spin-lasers with periodic gratings for ultrafast applications

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Vertical-Cavity Surface-Emitting Lasers (VCSELs) are key components in modern optical communication systems due to their compactness and energy efficiency. However, their conventional intensity modulation (IM) bandwidth is fundamentally limited by carrier and photon dynamics, typically to 30–50 GHz. Spin-polarized VCSELs (spin-VCSELs) offer an alternative through polarization modulation (PM), enabling much higher data rates by exploiting ultrafast polarization oscillations governed by birefringence. This thesis investigates monolithic integration of 1D surface gratings as a method to tailor birefringence in the laser cavity, while minimizing polarization damping caused by loss anisotropy. Simulations are performed using the PLaSK framework, a multiphysics solver based on Plane-Wave Admittance Method, which allows for self-consistent modeling of optical, thermal, and electrical phenomena in VCSELs. By optimizing grating parameters — period, fill factor, thickness—and cavity design, we demonstrate frequency splitting exceeding 280 GHz while preserving practical photon lifetimes. Furthermore, we show that modifying the cap layer can compensate for gain anisotropy, reducing dichroism to near-zero. The resulting design enables compact, fabrication-ready spin-VCSELs with integrated birefringence control, suitable for ultrafast polarization-encoded data transmission.

KEYWORDS: Spin-VCSELs, ultrafast data transfer, anisotropy, dielectric gratings, resonant cavity

ACKNOWLEDGMENTS

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Advancing Microscopy: Introducing Bruker's New FTIR and Raman Solutions

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FTIR and Raman microscopy are essential tools for high-resolution molecular analysis, providing precise insights into complex samples across materials science, life sciences, and industrial quality control. Bruker's latest generation of FTIR and Raman microscopes combines proven spectroscopic performance with groundbreaking new technologies.

Innovations such as Focal Plane Array (FPA) detectors dramatically increase spatial resolution and data acquisition speed in FTIR imaging, while Quantum Cascade Laser (QCL) sources provide highintensity illumination and push measurement speeds even further, achieving rates of over 60,000 spectra per second. On the Raman side, line-shaped laser excitation accelerates mapping workflows and enhances sensitivity across larger areas without sacrificing detail.

Together with advanced automation, intuitive software interfaces, and integrated AI-based data evaluation, these systems reduce user workload while boosting analytical confidence.

The effect of interfacial hydrogen bonding and electrostatic interactions on the surface properties and foam stability in saponin mixtures

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Surface modification via molecular interactions at the gas-liquid interface offers a promising route for tuning foam stability and properties in soft matter systems. In this study, we explore how interfacial hydrogen bonding and electrostatic interactions modulate surface properties and foam behavior in saponin-based systems. Natural saponin, a biodegradable and biocompatible biosurfactant, was combined with selected hydrogen bond donors and acceptors—urea, glycerol, and choline chloride—at various concentrations to form binary and ternary mixtures.

Surface tension kinetics and dilatational interfacial rheology were measured using pendant drop tensiometry, while foam formation and decay were characterized with both dynamic foam analyzers and optical microscopy. Our results reveal that hydrogen bonding interactions between saponin and additives significantly affect the physicochemical properties of the solutions. Choline chloride, a hydrogen bond acceptor, showed the strongest impact on lowering surface tension and modulating interfacial elasticity, enhancing foamability through synergistic electrostatic interactions. Conversely, glycerol increased surface elasticity and foam stability, while urea weakened the interfacial film, accelerating foam aging processes such as drainage and coalescence.

The observed trends emphasize that tailored interfacial structuring via specific molecular interactions enables rational design of functional, biodegradable foaming systems. These insights contribute to the development of novel saponin-based biofoams with adjustable physicochemical profiles for applications in food, cosmetic, and pharmaceutical formulations.

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Broadband optical function detection from THz to Ultraviolet range

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The optical function of a material describes the interaction between light and the material, quantifying the alterations in the properties of light resulting from illumination. This characterization is critical in fields such as photonics, optical device development, and materials science.

Regarding the measurement of a material's optical function, several established techniques have been successfully applied across various regions of the electromagnetic spectrum. This paper focuses on combining three distinct methods—terahertz time-domain spectroscopic ellipsometry (THz-TDSE)¹, Fourier transform infrared spectroscopy (FTIR)², and Mueller matrix ellipsometry (MME)³—with the aim of determining the optical function of materials within the terahertz, infrared, visible, and ultraviolet frequency ranges.

In this study, mercury chloride (Hg₂Cl₂) crystal is employed as the sample for all measurements due to its high refractive indices, strong birefringence, and broad transmission spectrum⁴. Using terahertz time-domain spectroscopic ellipsometry (THz-TDSE), transmission measurements were conducted at various sample azimuthal angles, allowing the determination of the Jones matrices of Hg₂Cl₂ with both amplitude and phase information. Subsequently, Fourier transform infrared spectroscopy (FTIR) was utilized to measure the sample's transmittance and reflectance in the infrared range. Lastly, Mueller matrix ellipsometry (MME) measurements were performed in the visible and ultraviolet spectral regions. Data obtained from these three techniques were fitted using multiple oscillators consistent with the Kramers–Kronig relations. Ultimately, all oscillators were integrated into a unified optical model, enabling the determination of the permittivity of Hg₂Cl₂ across a broad frequency range, from terahertz to ultraviolet. The resulting comprehensive optical characteristics enhance the accuracy of optical parameter determination, facilitating the effective application of materials across an extensive frequency spectrum.

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Infrared Nanoscopy / nano-FTIR Spectroscopy Fundamentals and Practical Aspects

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Scattering-type scanning near-field optical microscopy (s-SNOM) is the ideal technology to investigate modern nanomaterials at the real nanoscale. SNOM technique combines highlights of two worlds: high spatial resolution of Atomic Force Microscopy (AFM) and analytical power of optical microscopy and spectroscopy. By achieving an unmatched spatial resolution below 10 nanometres this technology opens a new era for modern nano-analytical applications such as chemical identification, free-carrier profiling and plasmonics near-field mapping. We will introduce the basic principles of near-field microscopy for imaging and spectroscopy with 10 nanometres spatial resolution and address their impact and key applications.

KEYWORDS

SNOM, Raman, FT-IR, spectroscopy, microscopy

INTRODUCTION

Main limitation of FTIR and Raman microscopy for study of nanomaterials are its spatial resolution limits. Usually is infrared (FTIR) microscopy limited by diffraction limit at approximately 10 micrometres and Raman microscopy around 400 nanometres. Spatial resolution of AFM is on the hand excellent, mostly optical and chemical other but with no information. So, there is logical need to combine analytical power of optical spectroscopy with high spatial resolution AFM. Main focus of this presentation is introduction to this quite new research area via description of some key applications.

EXPERIMENTAL/THEORETICAL STUDY

All examples in this presentation are performed with new line of nanoscopy instruments from German company Attocube systems AG: **neaSCOPE line** (original company Neaspec was founded in 2007 by the world's leading experts of near-field microscopy as a spin-off from the the Max-Planck-Institute of Biochemistry).

RESULTS AND DISCUSSION

As a nano-analytical tool, there is a wide variety of application for SNOM: 2D materials, semiconductors, nanowires, mineralogy, catalysis, polymer research, microplastics in environment, Li-ion batteries research, Plasmonics, bio research etc. Development of new single widely tuneable laser leads to unmatched possibility of fast measurement of infrared spectra (FTIR) in wide range 7140 – 540 cm⁻¹ with spatial resolution around 10 nanometres (only limitations are AFM tips properties) and spectral resolution better than 4 cm⁻¹. Imaging (or hyperspectral imaging) of samples leads to comprehensive amounts of information about given samples from AFM map(s) and spectroscopy images in one step of sample analysis. We will also provide examples for variety of

different excitation light sources, especially THz-SNOM applications, nanoscale imaging of protein distribution in Alzheimer affected neurons and also Nano-aquarium: a new s-SNOM platform to observe live biological cells in action.



Fig.1. neaSCOPE configuration options

CONCLUSION

Breaking diffraction limits of optical spectroscopy via combination with modern AFM technology leads to new options for nano-imaging of many different kinds of materials and to better material understanding in many different research areas. Focus of this presentation was on real examples of application of this technology in variable research areas.

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Magneto-Optic Kerr Effects of Higher Orders in Magnetization in Structural Analysis of Heusler Alloys, Twinning Detection in Cubic Crystal Structures and Vectorial Magnetometry

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The magneto-optical Kerr effect (MOKE) manifests itself as a change in the polarization of light reflected from a magnetized surface. It is a widely used tool in the study of thin film magnetism, where it can be used to measure hysteresis loops, vectorial magnetometry, MOKE spectroscopy, or to probe magnetisation dynamics in time-resolved experiments using femtosecond pulsed lasers. Because the light can be tightly focused, MOKE can also be used to study the magnetic properties of microstructures. In most of the studies where MOKE is used, the linear dependence on magnetization **M** is assumed. Although the broad community is usually aware of the existence of quadratic MOKE

(QMOKE), which is proportional to M^2 , it is considered rather rarely in the model.

Here, we show how the QMOKE can be used to sense the ordering of the Co_2MnSi Heusler alloy. In our study we show that the QMOKE amplitude is linearly dependent on the amount of $L2_1$ ordering of the Co_2MnSi Heusler alloy in the broad spectral range¹. Although QMOKE is not a direct structural probe, the required experimental equipment is inexpensive and the sample does not require no additional preparation, so it can be successfully used as a first indication of the structural order in some Heusler alloy sample series.

The third-order contribution to MOKE, called cubic MOKE (CMOKE), which is proportional to M^3 , has been reported experimentally some time ago², but has not been studied in detail until now. Here we show the anistropies of CMOKE with (111) oriented cubic crystal structures and discuss how the CMOKE contribution can be exploited, e.g. for the detection of twinning in (111)-oriented cubic crystal structures³ or, for in-plane magnetization detection with normal angle of incidence.

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Design and fabrication of metastructures for terahertz applications

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Recent advances in terahertz (THz) science have expanded its applications, particularly in material spectroscopy. This progress has created a growing demand for efficient wavefront control and the exploration of new electromagnetic phenomena at THz frequencies. Such possibilities can be realized through metastructures, artificial materials exhibiting exotic electromagnetic properties not found in natural materials. This work focuses on the design of three specific metastructures using the commercial simulation software CST Studio Suite. The first is a wire-grid polarizer, an essential component for THz time-domain spectroscopic ellipsometry. Wire-grid polarizers were fabricated using direct laser writing lithography and physical vapor deposition, and their functionality was experimentally validated through terahertz time-domain spectroscopy. The second is a metalens, a flat focusing device replacing bulky traditional optics and enabling high-power THz output from spintronic THz emitters. The third is a chiral metastructure, an artificial chiral material exhibiting strong optical activity, intended as a reference for other optically active materials in the THz range. For the latter two metastructures, the fabrication strategies are discussed based on advanced lithographic techniques.

KEYWORDS: terahertz, metamaterial, metasurface, metastructure, electromagnetic simulation, lithography, terahertz time-domain spectroscopy, CST studio, metalens, wire-grid polarizer, chiral metastructure

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Micro-arc oxidation for thin layer preparation

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Micro-Arc Oxidation (MAO) using a pulsed unipolar source is a unique method of surface treatment technology. MAO method enables achieve the required increased mechanical properties, insulating properties and corrosion resistance of metallic materials. Significant interest is focused to carried out of MAO processing on Ti6Al4V alloy. Ti6Al4V alloy shows superior properties, such as high specific strength, superior corrosion resistance, and excellent biocompatibility¹, using in advanced materials, particularly for aerospace and medical applications.² The above properties of the Ti6Al4V alloy can be improved using MAO technology and, in addition, selected elements can be added to the prepared coating to increase material adhesion and cell proliferation.³ Moreover, the MAO fully complies with today's industry standards while achieving low operating costs and environmentally friendly technology operation. This paper provides a brief summary of the MAO technique in the design and surface modification development of Ti6Al4V alloy for orthopedic implants.

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Computational determination of preferred out-of-plane orientation of heteroepitaxial films

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Characterization of heteroepitaxial films is time-consuming and financially demanding. Our computational method "Structure Compatibility Calculation" (SCC) minimizes the time-consuming task to minutes, while also being cheap. Basis of the calculation method used in the SCC is purely geometric – the mere atomic arrangement in the substrate(hkl)/film(hkl) adjacent planes allows to determine their preferred out-of-plane orientation. The pair of substrate(hkl)/film(hkl) planes with the largest amount of mutual atomic overlap corresponds to the preferred out-of-plane orientation. This is demonstrated by comparing the results obtained by the SCC method and experimentally determined out-of-plane orientation (as provided in the literature) for eight substrate/film systems: Si/ZnO¹, C/ZnO², MgO/ZnO³, SrTiO₃/ZnO⁴, Al₂MgO₄/ZnO⁵, Ni/BN⁶, GaN/FeN⁷ and Si/AlN⁸. The SCC always included the substrate plane(hkl) used in the experiment described in the literature and a number of various densely occupied film planes(hkl), including those experimentally determined. The results demonstrated the effectiveness and reliability of the SCC method – agreement with the experimentally determined preferred out-of-plane orientation was achieved for all eight systems. The effects of the substrate(hkl) and film(hkl) elements selection was also monitored. The results proved that the selection of elements did not affect the agreement.

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The Electrokinetic and spectroscopic characteristic of novel conjugates of neuroleptics with gold nanoparticles

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Chlorpromazine (CPZ) and fluphenazine (FPZ) are well-known neuroleptics that have attracted considerable scientific interest. Although methods for encapsulating and delivering these neuroleptics to enhance their activity and reduce side effects have been developed, there is still limited knowledge about their conjugation with gold nanoparticles (AuNPs). Therefore, the aim of this research was to develop a preparation method for stable conjugates of CPZ-AuNPs and FPZ-AuNPs and to investigate their physicochemical properties. Both types of conjugates were synthesized via a ligand exchange process on the surface of AuNPs with average sizes of 17±5 nm and 55±5 nm, respectively. Electrokinetic measurements revealed that the zeta potential of the conjugates strongly depends on the amount of CPZ and FPZ adsorbed onto the AuNP surface. Additionally, the conjugates exhibited an isoelectric point at pH 8.8. Surface-enhanced Raman spectroscopy (SERS) and surface-enhanced infrared absorption spectroscopy (SEIRA) were used to elucidate the adsorption structure of the neuroleptics on the AuNPs. The interpretation of the spectra was based on the Raman and FTIR spectra of CPZ and FPZ, supported by calculations performed using Density Functional Theory (DFT). The results indicated that CPZ primarily interacts with the TC-AuNP surface through an angularly oriented phenothiazine ring and the propylene bridge. Furthermore, it was shown that the C–N–C fragment is oriented perpendicular to the surface of the TC-AuNP with which it interacts. In the case of FPZ, it was also found that the phenothiazine ring is the main structural element involved in interactions with the gold surface.

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Determination of major mineral content in sedimentary rocks by Raman spectroscopy

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In geology, the mineral composition of rocks plays a significant role in understanding their physical and chemical properties. The most common technique for determining mineral content is X-ray diffraction (XRD); however, alternative approaches such as FTIR and Raman spectroscopy can be also employed. In our work, we focused on the possibility of using Raman spectroscopy to predict the content of major silicate minerals in selected sedimentary rock samples. The collected Raman spectra were affected by the presence of strong fluorescence and overlapping bands, which made it unfeasible to use classical approaches for quantification. For these reasons, multivariate calibration models were developed. This approach has the potential to be used for simple, rapid and non-destructive estimation of mineral composition of rocks using portable Raman instruments.

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Influence of process parameters on the structure and properties of chromium oxide films deposited by reactive high power impulse magnetron sputtering

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In this study thin chromium oxide coatings were prepared by reactive high power impulse magnetron sputtering (HiPIMs), their structure was evaluated, and testing was performed to determine their tribological properties. The coating depositions were conducted on multiple different substrate materials, encapsulating tool steels, and high temperature nickel super alloys Inconel. To achieve significant ion bombardment of the coated surface, either a bias on the substrate or a positive kick on the sputtering target was applied. The impact of these methods on the structure and properties of the coating was then investigated.

The surface and cross-section of coatings underwent examination by scanning electron microscopy (SEM), and chemical analysis was performed using energy-dispersive x-ray spectroscopy (EDS). The structure of the coatings was studied using X-ray diffraction (XRD). The influence of the coating process on surface roughness and the presence of coating defects was further studied using phase shifting interferometry (PSI) and optical light microscopy. Tribological testing was performed by pin on disc method at room temperature and high temperature using Al₂O₃ counterbodies. During high temperatures tests, coatings exhibited low wear and stable friction, predisposing them to use in application at elevated temperature.

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