Lem Next Gen Science Forum

at Wrocław Tech

Wrocław Tech

April 28–29, 2026

BOOK OF ABSTRACTS

Lem Next Gen Science Forum
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Wrocław, April 28–29, 2026

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WrocławTech

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Conference programme

Day 1 April 28, 2026 | Tuesday

8:00-9:00	**Registation**
9:00-10:45	**Opening** Lem Prize Ceremony The Lem Prize laureate lecture: **Li Tang,** École Polytechnique Fédérale de Lausanne, EPFL Discussion
10:45-11:00	**Coffee Break**
11:00-11:45	**Plenary Lecture:** **Anna Kuppuswamy,** Young Academy of Europe
11:45-12:30	Early-stage researcher grants talk: **Magdalena Baborska-Narożny, Mariusz Ptak (API), Adrian Różański (API), Bartosz Uniejewski (AIM**)
12:45–14:30	**Lunch**
14:30-15:15	**Student Talks** • Digital Horizons: AI, Data, and Information Technologies • Materials of the Future • Green Transformation
15:15-16:00	**Student Talks** • Smart Cities and Society of the Future • Health Engineering, Future Medicine, and Biotechnologies • Frontiers of Science: Extreme Technologies and Fundamental Research
16:00 -16:30	**Coffee Break**
16:30-17:15	**Thematic Panels** • Interdisciplinarity: Beyond Boundaries: The Power of Interdisciplinary Research **Robert Iskander, Grzegorz Soboń, Marta Rusnak, Dariusz Jagielski** • Internationalization and mobility: Global Research Journeys: Mobility, Networks & Opportunities **Renata Krzyżyńska, Łukasz Damurski, Karolina Kordek-Khalil, Izabela Walendzik, Bogusław Ziemniak** • Research excellence: Rethinking Excellence: Advancing the Future of Research **Łukasz Sterczewski, Sławomir Porada**
17:15-18:00	**Thematic Panels** • Research integrity and responsibility: Trust in Science: Integrity, Ethics & Responsible Research **Krzysztof Abramski, Jarosław Sotor, Szymon Zelewski, Li Tang** • Research Communication and impact: Making Research Matter: Communication, Outreach & Real-World Impact **Anna Siekierka, Maciej Mulak** • Mental wellbeing: Minds in Balance: Mental Wellbeing in the Research Environment **Irmina Dutkowska, Sabina Knichnicka, Marzena Lucyna Kierepka, Karolina Fila-Pawłowska**
18.00-19.00	**Poster Session**
19:30-21:30	**Dinner (SKS building)**

Day 2 April 29, 2026 | Wednesday

9:00-10:45	**Plenary Lecture:** **Tobias Dornheim,** Lem Prize 2024 laureate, Helmholtz-Zentrum Dresden-Rossendorf Discussion Early-stage grants talk: **Anna Siekierka, Łukasz Sterczewski, Sławomir Porada**
10:45-11:15	**Coffee Break**
11:15-12:45	**ESR grants talk** **Anna Kowalska-Pyzalska, Dominik Terefinko, Michał Mazur, Bartosz Zajączkowski, Marcin Syperek, Sebastian Kraszewski, Weronika Urbańska, Agnieszka Mirkowska**
12:45–14:30	**Lunch**
14:30-15:15	**Student Talks** • Digital Horizons: AI, Data, and Information Technologies • Materials of the Future • Green Transformation
15:15-16:00	**Student Talks** • Smart Cities and Society of the Future • Health Engineering, Future Medicine, and Biotechnologies • Frontiers of Science: Extreme Technologies and Fundamental Research
16:00 -16:30	**Coffee Break**
16:30-17:15	**Thematic Panels** • Funding: Navigating Funding Landscapes: From Ideas to Successful Grants **Piotr Młynarz, Krzysztof Pyrć, Krzysztof Jóźwiak** • Entrepreneurship: From Research to Innovation: Turning Ideas into Products **Anna Górecka, Daniel Strub, Kamila Krawiec, Artur Podhorodecki, Maciej Milewski** • Career paths: Careers Beyond Academia: Finding Your Path in a Changing World **Marcin Drąg, Anna Byzia, Agnieszka Dobrzyń, Rafał Witek**
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LIST OF AUTHORS

Materials of the Future: Posters

Green Transformation: Oral Presentation

Green Transformation: Posters

Smart Cities and Society of the Future: Oral Presentation

Smart Cities and Society of the Future: Posters

Health Engineering, Future Medicine, and Biotechnologies: Oral Presentation

Health Engineering, Future Medicine, and Biotechnologies: Posters

Frontiers of Science: Extreme Technologies and Fundamental Research: Oral Presentation

Frontiers of Science: Extreme Technologies and Fundamental Research: Posters

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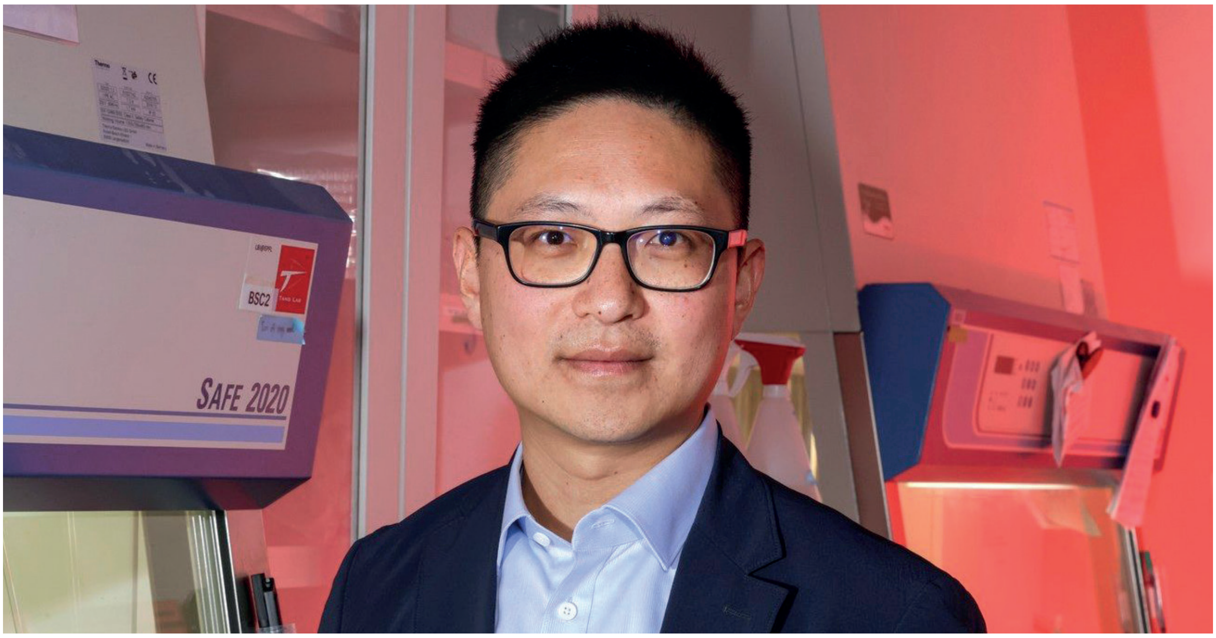
Prof. Li Tang



Prof. Li Tang received his B.S. in Chemistry from Peking University, China, in 2007, and Ph.D. in Materials Science and Engineering from University of Illinois at Urbana-Champaign, USA, in 2012, under the supervision of Prof. Jianjun Cheng.

He was a CRI Irvington Postdoctoral Fellow in the laboratory of Prof. Darrell Irvine at Massachusetts Institute of Technology during 2013-2016. He joined the faculty of Institute of Bioengineering, and Institute of Materials Science & Engineering, at École polytechnique fédérale de Lausanne (EPFL), Switzerland, as a Tenure-Track Assistant Professor in 2016, and promoted to Associate Professor with tenure in 2022. He is currently the Vice Dean for Innovation and Director of Innovate4Life program at School of Life Sciences, EPFL.

His research focuses on developing multidimensional immunoengineering approaches for enhanced cancer immunotherapies. The central paradigm of cancer immunotherapy for decades has been the exclusive focus on “type 1” immunity. While powerful, this approach has inherent limitations, leaving many patients with relapsed or incurable disease. The Tang lab discovered that a completely different, and largely neglected, arm of the immune system—type 2 immunity—holds the key to achieving lasting cures. The IL-10-expressing CD19 CAR-T cells they developed have achieved breakthrough clinical efficacy at extremely low doses in several on-going Phase 1 clinical trials. Dr. Tang is the recipient of Friedrich Miescher Award (2025) from Life Sciences Switzerland (LS2), Leenaards Prize for Translational Medical Research (2025), Biomaterials Science Lectureship (2025), CAB Mid-Career Investigator Award (2024), Biomaterials Award for Young Investigators (2024), Cancer Research Institute CLIP Award (2021), Anna Fuller Award (2021 and 2022), European Research Council (ERC) Starting Grant Award (2018), and named in the MIT Technology Review’s “Top 35 Innovators under Age 35” list of China region (2020).

Tobias Dornheim

Tobias Dornheim has earned a PhD in theoretical physics from Christian-Albrechts-Universität zu Kiel (Germany) in 2018. Since 2025, he is head of the High Energy Density (HED) department of the Institute of Radiation Physics at Helmholtz-Zentrum Dresden-Rossendorf (HZDR).

Dornheim’s work focuses on the development of novel methods for the description of quantum many-body systems and on the development and application of advanced x-ray scattering diagnostics for experiments with extreme states of matter. (laserfusion, laboratory astrophysics, etc.). His work has been recognized among other things with the Stanislaw Lem European Research Prize in 2024, with the John Dawson Award for Excellence in Plasma Physics Research by the American Physical Society (APS) in 2021 and with a Starting Grant from the European Research Council (ERC) in 2023.

Anna Kuppuswamy

Anna Kuppuswamy leads the Neurobiological and translational fatigue research laboratory at University of Leeds, United Kingdom.

Trained as a physiotherapist in India, with a PhD in Neuroscience from Imperial College London and postdoctoral training at National Institutes of Health, USA, she established her research group at UCL funded by the Wellcome Trust Henry Dale fellowship in 2016. In 2021 she was elected to the Young Academy of Europe, of which she is now chair. In 2023, she moved her group to University of Leeds where she teaches and continues to research fatigue.

Digital Horizons: AI, Data, and Information Technologies

ORAL PRESENTATION

A Proactive Fuzzy Inference Approach to Condition-Based Maintenance of Automated Guided Vehicles

Digital Horizons: AI, Data, and Information Technologies

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Keywords: AGVs, proactive maintenance, fuzzy logic, condition monitoring

Automated Guided Vehicles (AGVs) are increasingly deployed in modern warehouses, where their operational availability and reliability directly affect the efficiency of intralogistics processes. In such environments, maintenance decisions must account for variable workloads, operating conditions, and real-time system constraints. Consequently, data-driven and condition-based maintenance approaches are becoming important for warehouse operations.

Conventional maintenance strategies are often insufficient in dynamic operating environments. Their main limitation lies in the inability to adequately reflect progressive degradation processes, particularly when diagnostic information is incomplete, imprecise, or uncertain. This creates a need for decision-support methods that capable to integrating heterogeneous technical and operational data within a unified assessment framework.

To address this problem, this study proposes a proactive maintenance model for AGVs based on fuzzy inference system. The model combines selected technical and operational indicators, such as workload intensity, operating conditions, and diagnostic signals, to support the prioritisation of maintenance actions under uncertainty.

The obtained results indicate that the proposed framework can effectively support maintenance prioritisation in dynamic warehouse operations. The model contributes to improved fleet stability, more consistent maintenance planning, and better alignment between technical requirements and cost-related objectives. Owing to its flexible structure, the framework can also be adapted to different AGV types.

Advancing Innovation in the Age of Complexity: Strategic Ecosystems for Sustainable and Intelligent Value Creation

Digital Horizons: AI, Data, and Information Technologies

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Keywords: first keyword, second keyword, third keyword, fourth keyword

A significant disconnect is emerging in the modern market: the rapid advancement of Artificial Intelligence (AI) is generating a "technological push" that vastly outweighs the genuine "value pull". Consequently, organizations are frequently integrating AI capabilities into their products driven by mere technical feasibility, often overlooking human-centric value and organizational readiness. This technology-first approach risks creating unsustainable innovation models.

This presentation investigates the current academic landscape surrounding this tension. By conducting a Systematic Literature Review (SLR), this research maps the intersection of AI, sustainability, and innovation management. It systematically identifies and analyze the current barriers, drivers, and future prospects of integrating AI into organizational processes.

It provides insights into the existing research gaps and learn how the literature defines the transition from technology-driven implementations to value-driven, sustainable innovation. Ultimately, this review provides a foundational framework for researchers and practitioners aiming to align AI capabilities with genuine market and product readiness.
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Artificial Intelligence Based Tool for Revealing Informative Features in Fault-Related Data

Digital Horizons: AI, Data, and Information Technologies

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Keywords: electric drives, neural networks, feature analysis, fault diagnosis

In classical diagnostic approaches, fault identification has relied primarily on prior expert knowledge and physical understanding of the phenomena occurring under the fault conditions. With the development of artificial intelligence (AI), automatic classification has become more effective and widely used. However, many AI-based solutions still require prior selection of diagnostic features, which is often based on literature or designer experience. In modern industrial systems, where large numbers of variables are supervised under complex and noisy conditions, classical analysis is often insufficient, and the effectiveness of diagnostic systems remains strongly dependent on the selected input information.

This study proposes an AI-based approach that enables systematic evaluation of feature combinations using experimental data. Neural networks were used to assess thousands of different feature vectors, and the best-performing models were identified based on classification performance. The analysis revealed which feature combinations consistently provided the most informative representation of fault conditions.

These results demonstrate that AI methods can be used not only as a classification tool but also as a method for revealing informative structures in data. This approach supports understanding of fault-related phenomena and offers a new perspective on the role of AI in diagnostic analysis.

ASSESSING MICROCLIMATIC AND KINETIC IMPACTS OF LARGE-SCALE WIND FARMS WITH AI

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Wind Turbines, Wind Farm Wakes, Atmospheric Modeling, Machine Learning

Wind energy plays a central role in the transition toward low-carbon energy systems. However, large wind farms extract kinetic energy from the atmosphere and generate turbulence, which can influence local microclimatic conditions and atmospheric boundary-layer dynamics.

Recent studies indicate that turbine-induced mixing may modify temperature, humidity, and turbulence patterns, particularly during stable nocturnal atmospheric conditions [1, 2]. Despite increasing deployment of wind farms, predicting the cumulative atmospheric impact of multiple wind farm clusters remains computationally challenging as high-resolution computational fluid dynamics (CFD) simulations are expensive and difficult to scale.

This work proposes using machine learning incorporating CFD simulations with data-driven modeling. A synthetic dataset is generated by systematically varying wind farm layouts, turbine spacing and wind conditions across numerous scenarios. Machine learning models are then trained on this dataset to predict wake interactions and the resulting kinematic energy deficit for previously unseen wind farm configurations. With this it is intended to demonstrate that AI-based models can capture key flow characteristics and significantly reduce the computational cost and time of evaluating large wind farm clusters. This approach enables faster environmental assessment and planning of wind energy systems, providing a scalable tool for analyzing wind farm driven atmosphere interactions and supporting more sustainable deployment of wind energy infrastructure.

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Bio-Cybersecurity: Silent Data Manipulation in mRNA Databases and the Illusion of Off-Chain Security

Digital Horizons: AI, Data, and Information Technologies

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Keywords: bio-cybersecurity, mRNA databases, cryptographic signatures, data integrity

Synthetic biology now heavily relies on digitized genomic data, essentially turning natural biological processes into software workflows. While we trust digital tools to design mRNA vaccines, the cybersecurity of the plain-text databases (like .fasta files) holding this code is a major blind spot. Current bio-security models focus almost entirely on data privacy and access control. However, they miss a vital step: verifying the genetic sequence's integrity right before physical manufacture. If a hacker breaches an off-chain lab database and alters synonymous codons, a DNA synthesizer will blindly print corrupted biological agents. To solve this, this study proposes a Bio-Cybersecurity model that embeds cryptographic hashing (SHA-256) and End-to-End Encryption (E2EE) directly into DNA synthesis architectures. Digitally signing these sequences ensures the genetic data remains completely untouched from the computer design phase to physical production. As the Internet of Bio-Things grows, we must look beyond basic access control and guarantee absolute data integrity to stop silent bio-sabotage.

Comparative Study of Model-Based and Data-Driven Approaches for the Classification and Compensation of Speed Sensor Faults in Electric Drive Systems

Digital Horizons: AI, Data, and Information Technologies

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Keywords: speed sensor fault, MLP based classifier, CNN based classifier

In modern industry, monitoring the condition of the electric drive systems plays a crucial role in ensuring safe and reliable operation. This is essential in high-integrity fields such as robotics and electromobility. However, the performance of electric drive systems can be significantly affected by various faults, including measurement sensors failures. For this reason, Artificial Intelligence (AI) methods are increasingly being applied in such critical applications.

In PMSM drive systems, three types of sensors are commonly used: speed, voltage, and current. Notably, the speed sensor is fundamental, as it is required for system operation. Sensor faults may cause unexpected process shutdowns. However, most studies focus on model-based fault detection, often neglecting experimental validation. This highlights the need for hybrid approaches that combine model-based and data-driven methods, improving the accuracy and reliability of speed sensor condition monitoring.

The main goal of this work is to analyze the application of AI and model-based approaches, for the classification and compensation of speed sensor faults in an electric drive system.

The proposed hybrid method improves the accuracy of speed sensor faults detection and provides detailed information about the type of failure through classification. Its effectiveness has been validated experimentally, demonstrating its potential for fault-tolerant operation.

Data and Knowledge from a Social Science Perspective

Digital Horizons: AI, Data, and Information Technologies

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Keywords: data, knowledge, social sciences, digital transformation

The issues of data and knowledge are among the most important operational aspects of digital transformation. Data, once called the “oil of the 21st century”, [1] was expected to build a “knowledge-based economy”, as predicted by Peter Drucker [2]. If this macrotrend is indeed inevitable, it is worth examining the conditions shaping this phenomenon not only from the perspective of dominant computer sciences, but also from the perspective of social sciences.

Political, historical, cultural, and communicational approaches can help us understand that the broad process of digitization is a consequence of certain civilizational transformations related to the processes of organizing societies, emergence of politics, mathematical and technological development, philosophy revalutations, the rise of capitalism [3], and broad scientific progress [4]. To better understand the origins of digital transformation, we must place it within a broader development logic and a long-term context.

Failure to recognize these various determinants is all the more important because we do not know in which direction the next great transformation – *AI* one – will develop. If it can have such far-reaching consequences as its creators and critics [5] predict, it is worthwhile to build a multi-perspective perspective based on the entire context of knowledge about digitalization.

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Decoding Honeybee Sound: Adaptive AR Representations in Estimating Fundamental Frequency Trajectories of Bee Sound Signals

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Keywords: Signal processing, Bioacoustics, Machine Learning, Apiculture 4.0

Acoustic monitoring of honeybee health is a developing research direction moving towards automation of the apicultural industry. With most research focused on measurements of sounds produced by bee colonies, much less focus is given to in-vitro experiments, which show the fundamental aspects of bee sound-based communication. This work focuses on providing a method for estimating fundamental frequency trajectories of bee-produced sounds. A dedicated measurement session was performed, with bees in a specialized measurement cage recorded using a low-noise measurement microphone. The recordings were then analyzed to find the optimal quasi-stationary window length as well as optimal AR model order. The study found a time window length of 50 milliseconds and an AR model order of 20 to 25 to be optimal for bee sound event analysis. Subsequently, the Lee-Morf adaptive algorithm was used to provide a time-frequency resolution much greater than with purely Fourier-based representation. The findings of this work inform future measurement and monitoring experiments, enabling researchers to include sound data as a parameter for in-vitro behavioral studies, and providing a tool for feature extraction in AI experiments. The method is also suitable for tracking the bee waggle dances, opening a new direction in honeybee communication research.

DIGITAL TRANSFORMATION IN THE BANKING INDUSTRY

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Digital Transformation, digitalization, banking Industry, electronic banking

This study investigates how digital transformation influences the banking sector. The research methodology includes reviewing the existing literature by using the Web of Science database and examining the role of digitalization in the banking industry, such as artificial intelligence (AI), new technologies and automation in the driving innovation model. After refining the articles, 38 academic papers out of 384 were identified as relevant to the topic and fit the purpose of this preliminary literature review under certain criteria.

Based on the findings of the selected studies, the aforementioned digital technologies play a crucial role in enabling the development of key elements of the electronic banking industry, such as service innovation, customer experience enhancement, process automation, data-driven decision-making, product lifecycle extension, and resource regeneration. This preliminary review provides a foundation for future research examining the synergies between digital transformation and the banking industry. As the study offers a broad overview of the topic, subsequent research focusing on in-depth case study investigations is a valuable scientific contribution.

Distribution-Based Deep Multiple Instance Learning for Tumor Proportion Scoring in NSCLC

Digital Horizons: AI, Data, and Information Technologies

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Keywords: digital pathology, tumor proportion score, non-small cell lung cancer, multiple instance learning, beta distribution

Accurate assessment of tumor proportion score (TPS) in non-small cell lung cancer (NSCLC) is critical for treatment planning and prognosis. Key challenges include the tedious manual work required to annotate each slide, combined with the limited number of experts certified for this task. Multiple instance learning (MIL) has proven to be an effective approach for predicting TPS scores at the slide level; however, existing methods struggle with non-expressive (zero class) images. Our approach involves two models: (1) an embedding-extraction and multiclass-classification network that captures the histopathological features of individual patches, and (2) a MIL model that aggregates these embeddings to predict zero-inflated beta (ZIBeta) parameters representing the overall TPS probability distribution for the entire slide. Using only slide-level TPS scores as labels, we demonstrate how this end-to-end framework can leverage a novel distribution-based architecture to improve prediction accuracy and explainability. ZIBeta modeling significantly outperforms baseline linear and ridge regression while capturing expected accuracy through distribution concentration.

Improving Construction Safety Training with Virtual Reality

Digital Horizons: AI, Data, and Information Technologies

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Keywords: virtual reality, OHS, civil engineering, trainings

Safety training is very important in the construction industry because workers often face dangerous situations. According to data from the Polish Central Statistical Office (GUS), last year 78 people died and 57 were seriously injured in 3,442 construction-related incidents. Recently, Virtual Reality (VR) has started to be used in training, allowing workers to practice safety procedures in realistic virtual environments without real risk. Traditional health and safety (OHS) training in construction usually includes lectures, presentations, or written materials. These methods may not fully prepare workers for real situations on construction sites. VR training fits well with the Kolb Experiential Learning Cycle, which is used to support learning new behaviors among adults through experience and reflection. Therefore, the hypothesis was formulated that VR-based training may be more effective than traditional training methods.

The results show that VR-based safety training helps workers better recognize hazards and remember safety rules. These findings suggest that VR can improve the quality of safety training in construction. Virtual simulations allow workers to practice dangerous situations in a safe environment while supporting experiential learning. VR is likely to play an important role in the future of training, but further research is needed to determine how to integrate it most effectively into safety training programs.

Interactive Data Visualization Tool in R Shiny for Optimizing Used Car Valuation Processes

Digital Horizons: AI, Data, and Information Technologies

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Keywords: car, R Shiny, desktop

Modern business intelligence tools are increasingly essential in the automotive industry for transforming complex market data into actionable insights. In the competitive trade-in market, customers leaving their vehicles in settlement expect a fast, efficient, reliable, and well-argued valuation. Providing such an objective assessment in real-time often poses a significant challenge for dealerships due to market volatility and subjective factors.

This study addresses these challenges by developing an analytical dashboard in R Shiny, following the CRISP-DM methodology. Based on interviews with experts from Auto Group Polska, the research focused on identifying key price determinants from a dataset of over 1,000 Otomoto advertisements. By analyzing variables such as mileage, engine power, and fuel type, a standardized assessment framework was established to minimize human error and subjectivity.

The key result is a functional managerial desktop that automates price suggestions, significantly reducing valuation time while increasing transparency in customer negotiations. Through dynamic visualizations, the tool provides a clear visual rationale for pricing, allowing sales representatives to justify offers effectively. This research demonstrates how specialized information technologies can optimize traditional sales workflows and enhance customer trust through evidence-based valuation models.

INTERNET BOTS DETECTION USING DISTILROBERTA MODEL

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Machine Learning, GenAI, Bot Detection

In this paper, the authors present an ML-based framework for identifying bot-written reviews using a fine-tuned distilRoBERTa model. The fine-tuning process used both human-written and artificially generated reviews. The artificial reviews were generated using the Gemma3:12B, LLAMA3.2:3B, and Ministral3:3B models. The entire process was conducted locally without using cloud services in order to determine whether, and to what extent, such a solution with limited resources is capable of performing the bot detection task. The study was designed to provide insight into the accuracy of the distilRoBERTa model in the considered scenario. Our preliminary results show very good detection accuracy, which is promising in the context of filtering out undesired content from e-retail or social media platforms.

Machine Learning Framework for Cervical Cancer Classification Based on Graph Features

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Graph-based features, cervical cancer, Machine Learning, CAD

Advancements in artificial intelligence are improving computer-aided diagnosis (CAD) methods used in cervical cancer cytology screening. Various geometric, topological, and textural features have been proposed to describe cancer cells, yet graph-based features have rarely been applied in this domain. Graph methods offer promising tools for representing multicellular images and intracellular relationships. In this study, centroids derived from cervical cell segmentations were used as vertices to construct Circular Neighborhood Cell Graph (CNCG). Additionally, graph measures were combined with Convolutional Neural Network (CNN) features and introduced to classifiers as an input. We compared this method with standard graph representations such as Minimum Spanning Tree and Delaunay Graph. Obtained results showed promising direction when only CNCG features were used accuracy and recall reached 0.83 and when combined with CNN features the classification metrics increased to the 0.96-0.99 range. Based on high recall rates we see that CNCG feature are sensitive to cancerous changes. Furthermore, from the results of the fused feature vector, we can conclude that the proposed methodology could assist pathologist in the identification of both neoplastic and benign cells. Also, the application of CNCG method may mimic the microscope visualization, which could facilitate a CAD framework integration.

MARKET MICROSTRUCTURE IN FRAGMENTED CRYPTO ETF MARKETS: A DATA-DRIVEN ANALYSIS

Digital Horizons: AI, Data, and Information Technologies

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Keywords: cryptocurrency ETF, anomaly detection, machine learning, market microstructure

Digital assets are reshaping financial markets, with cryptocurrency ETFs bringing blockchain-based investments to traditional exchanges and generating rich datasets for computational analysis. Trading venues produce minute-resolution data across dozens of fragmented markets, creating challenges and opportunities for understanding market microstructure. Cryptocurrency ETFs illustrate this complexity, with billions in assets trading across multiple exchanges with varying liquidity and raising fundamental questions about how these markets function during stress episodes. Despite their growing importance, regulators and investors lack understanding of how fragmented markets behave during stress periods, when bid-ask spreads widen and cross-venue price discovery potentially breaks down. We apply machine learning methods to identify anomalies in minute-resolution trading data from major crypto ETFs across XETRA, London Stock Exchange, and SIX Swiss Exchange during 2024-2025, examining market behavior during these stress episodes. Our analysis reveals patterns of market fragmentation, with secondary venues showing sparse trading activity during primary venue anomalies and cross-venue contagion rates lower than in traditional equity markets. These patterns suggest that crypto ETF trading venues function as segmented markets rather than integrated ecosystems. The observed fragmentation provides new empirical insights into market structure in digital asset products, with implications for understanding liquidity and price formation across fragmented trading environments.

Metrology-driven Subpixel Edge Detection and Quality Metrics in XCT Projections

Digital Horizons: AI, Data and Information Technology

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Keywords: X-ray computed tomography, subpixel detection, quality metrics, metrology

In X-ray computed tomography, projection images are typically treated merely as input for reconstruction, although they constitute the direct physical measurement of the sample. A formal, physically grounded definition of the projection envelope enabling metrologically stable subpixel edge detection and quantitative quality assessment at the projection level is currently lacking. Consequently, projection errors propagate into reconstructed 3D geometry without prior verification or control. Existing approaches remain largely heuristic and gradient-based, and no method is directly grounded in the physical signal while preserving its metrological integrity.

We propose a metrology-driven framework operating directly on raw projections, consisting of ISO-band detection, ISO-50% envelope determination, subpixel refinement without smoothing, and extraction of physically defined projection-level metrics not previously clearly formalized. The framework establishes a physically interpretable definition of the projection envelope suitable for quantitative analysis.

The method was experimentally evaluated against gradient-based approaches under varying acquisition parameters. Envelope deviation and metric stability were analyzed as functions of these parameters.

The proposed ISO-based framework demonstrated significantly higher metrological stability, improved subpixel consistency, and reduced envelope error compared to classical gradient methods across varying imaging conditions.

These results enable quantitative projection-level quality control prior to reconstruction and strengthen the reliability of the XCT measurement chain.

More Words, Less Specificity: Are LLMs Ready to Assist in Peer Review

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Generative AI, Large Language Models, Peer Review

Peer review drives the value of research, but the growing number of submitted papers has led to inefficiencies and decreasing attention to detail. Peer reviews are often criticized for subjectivity and variability between reviewers, nevertheless it remains unclear whether AI provides an objective and viable alternative. Large Language Models (LLMs) tempt reviewers with a seemingly straightforward substitute for labor-intensive reviewing. We assess in which aspects of the review process LLMs excel and where they fall short compared to human reviewers. Although previous studies explore the use of LLMs in reviews, there is a lack of analyses that assess the quality of reviews with a focus on style and specificity. Our findings indicate that LLMs only briefly refer to and analyze the specific content of a paper and differ from humans in readability. We observe that LLMs scores are less variable than human scores, but they report overestimated confidence and are positively biased, expressing acceptance towards low-quality papers. Additionally, LLMs tend to generate longer, more complex reviews, without necessarily reflecting a deeper analysis. We argue that addressing these limitations could help LLMs improve the review process, democratize it, and ensure fairness across all scientific domains.

Overcoming Data Scarcity in Ki-67 Assessment: a Semi-Supervised Learning Approach to Tumor Tissue and Nuclei Segmentation

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Ki-67 Index, Pseudo-Labeling, Tissue Segmentation, Digital Pathology

Cancer diagnosis and treatment planning rely heavily on precise prognostic biomarkers. In clinical pathology, the Ki-67 proliferation index is a critical breast cancer indicator, traditionally estimated through manual microscopic evaluation. However, manual scoring is subjective, time-consuming, and challenged by the need to distinguish active tumor cells from surrounding non-tumor tissue. While deep learning can automate this, the availability of high-quality multi-scale annotations remains a primary bottleneck.

To address this, we combined weakly and semi-supervised learning strategies – oversampling a small amount of medical-annotated ground truth alongside abundant pseudo-labeled data. Specifically, for robust tissue segmentation, we trained a Student model using Teacher-generated pseudo-labels from unannotated whole-slide images. For subsequent nuclei segmentation, we utilized QuPath to generate pseudo-annotations, effectively overcoming the scarcity of medical-annotated keypoints. The proposed strategies substantially improved upon the respective baselines.

For breast cancer tissue segmentation, our model improved mIoU by 8% and reduced ECE by 30% compared to the teacher model. The final Ki-67 index predictor achieved a patch-level MAE of 5.2% while maintaining interpretability via nuclei segmentation. Our results demonstrate efficient strategies to tackle the limited availability of high-quality training data, facilitating model adaptation to specific laboratory staining and imaging conditions.

Privacy-Preserving Synthetic Data Generation

Digital Horizons: AI, Data, and Information Technologies

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Keywords: privacy-preserving machine learning, synthetic tabular data generation, differential privacy, privacy evaluation.

Sharing datasets for machine learning is often limited by privacy concerns. Many real datasets contain sensitive information, so researchers cannot easily publish or reuse them. Synthetic data generation is one possible solution. The idea is to create artificial datasets that preserve useful statistical patterns without revealing individual records. However, achieving both strong privacy protection and high data utility remains difficult. Earlier approaches, such as DualQuery, introduced formal Differential Privacy guarantees but struggled to scale and often generated only a small number of useful samples. Later work moved toward deep learning methods.

Techniques such as DP-SGD enabled training neural networks under Differential Privacy, while models such as DP-GAN and PATE-GAN aimed to generate more realistic synthetic datasets. Although these methods improved performance, they still face a strong privacy–utility trade-off, in which stronger privacy can degrade data quality and downstream model performance.

More recent models for tabular data generation, including transformer-based approaches such as TabMT and TabTransGAN, can better capture relationships between features and often produce higher-quality synthetic data.

However, many of these models rely mainly on empirical privacy evaluation rather than formal privacy guarantees. At the same time, relatively little work studies how synthetic datasets affect both the predictive quality and explainability of classification models. This suggests an important research gap.

The goal of this research is to develop or modify a method for privacy-preserving synthetic tabular data generation. The method will be evaluated on classification tasks and compared with existing approaches.

Privacy risks will be assessed using the PrivEval framework, which evaluates potential information leakage through multiple privacy metrics. The expected outcome is a better understanding of how to generate synthetic tabular data that preserves both privacy and machine learning utility.

Spectrum-Based Synthetic Data Generation for Robust Broken Rotor Bar Diagnosis

Digital Horizons: AI, Data, and Information Technologies

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Keywords: broken rotor bar diagnosis, stator current, spectral synthesis, deep learning

Electric motors are core components of industrial and transport systems, and early fault detection helps reduce downtime and maintenance costs. One common defect in squirrel-cage induction motors is the broken rotor bar (BRB), which introduces characteristic changes in stator currents. In practice, diagnostic models often degrade when tested at operating conditions not covered during training, especially under different torque loads.

We propose a spectrum-based data synthesis approach that augments missing operating conditions using only the available experimental measurements. For each class (0–4 broken bars), three-phase currents are transformed to the frequency domain and treated as high-dimensional data points that vary smoothly with load. The spectra are extrapolated to unseen loads and converted back to time signals via inverse FFT, producing additional training samples for a CNN.

Under a load-wise exclusion protocol, synthetic samples markedly improve accuracy and stability on unseen loads compared with training on measured data only. The method is lightweight, interpretable, and can broaden training coverage when acquiring measurements for all operating points is impractical.

The Future of Drones and Their Swarms on the Battlefield

Digital Horizons: AI, Data, and Information Technologies

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Keywords: drone swarm, digital pheromones, semantic communication, federated machine learning

Drones and their swarms have long been regarded as simple devices and engineering solutions designed for precise, point-target strikes rather than area operations; however, this field is evolving rapidly. Since the outbreak of the war in Ukraine, we have observed a transformation of the entire art of warfare based on the incorporation of unmanned aerial vehicles (UAVs) into military arsenals. The key questions that arise are: In which direction is this technology heading? What will drones look like in future conflicts?

The aim of this presentation is to identify the direction currently taken by autonomous unmanned aerial systems (UAS), namely their dynamic transformation of the modern battlefield, shifting from operations of single platforms toward distributed, cooperative swarms. Advances in artificial intelligence, edge computing, and resilient communication architectures enable drones to operate as coordinated, adaptive networks rather than isolated units. Despite this progress, challenges remain in terms of scalable coordination, efficient bandwidth utilization, and resilience to electronic warfare.

During the presentation, I will introduce new swarm paradigms inspired by biological systems, in particular the concept of digital pheromones – virtual environmental markers exchanged in the information space to support decentralized decision-making. I will also discuss artificial intelligence algorithms used for swarm control, trends in drone power supply, as well as why drones are not the future but the present – and in some aspects, already the past.

The Phantomatics of Grief. From Lem's Visions to the Ethical Design of AI

Digital Horizons: AI, Data, and Information Technologies

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Keywords: AI, design, ethics, griefbots

The digital afterlife industry utilizes artificial intelligence to create interactive post-mortem avatars, known as griefbots. These systems simulate the voice, language, and behavior of deceased individuals, raising profound questions about the limits of human reproducibility.

Engaging with these digital representations can complicate the natural mourning process and cause emotional distress. Without strict ethical boundaries, vulnerable grieving users risk confusing an algorithmic artifact with a real person, necessitating a critical evaluation from a personalist and theological perspective.

The study concludes that post-mortem avatars are merely digital artifacts, ethically permissible only as an instrumentum memoriae (instrument of memory) designed with strict transparency, a ban on first-person narration, and the deceased's prior consent.

Translating these theological-anthropological concepts into concrete design frameworks provides engineers with measurable standards of practice. This approach prevents harmful anthropomorphization and promotes responsible AI development that inherently respects human dignity.

What You Should Know About AI in Scanning: an Overview of Remote Sensing and Scanning Technologies

Digital Horizons: AI, Data, and Information Technologies

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Keywords: scanning, remote sensing, data, monitoring

Geoscience and environmental monitoring increasingly rely on remote sensing (RS) and laser scanning (LS) to assess complex ecosystems. Recently, the integration of artificial intelligence (AI), particularly deep learning algorithms, has fundamentally transformed spatial data analysis across these disciplines. As global ecological crises accelerate, there is a critical need for highly accurate, auditable methodologies to evaluate habitat dynamics and support robust ecosystem management. By synthesizing recent literature, this study demonstrates that the application of cutting-edge technologies, such as red-edge imaging, LiDAR, and advanced AI frameworks yields significantly enhanced accuracy and auditability in spatial data processing. These methodological improvements establish RS-based habitat mapping as a reliable backbone for contemporary biodiversity policy and ecosystem stewardship. Ultimately, this enhanced analytical capacity provides the transparent evidence required to guide ecological restoration, inform nature-based solutions, and track progress toward critical climate and biodiversity targets at multiple scales. We would like to present a research review that presents one of the mos t interesting parts of our field of study.

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POSTERS

A Machine Learning Clustering and Hybrid MCDM Framework for Nutritional Analysis of Fast-food Menus

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Machine Learning, Clustering Analysis, MCDM, Nutritional Analysis

Fast food consumption has increased significantly worldwide, raising concerns about nutritional quality and public health outcomes. Data-driven methods enable systematic evaluation of nutritional attributes and support more informed food choices. This study applies machine learning techniques to classify fast-food menu items into meaningful nutritional groups using normalized nutritional information (e.g., calories, fat, sugar, and protein).

The research addresses the absence of integrated analytical frameworks that combine clustering algorithms with decision-support methods for nutritional evaluation. Multiple clustering algorithms, including k-means, hierarchical clustering, and density-based methods, are applied to normalized nutritional data. A hybrid Multi-Criteria Decision-Making (MCDM) approach is then used to identify the nutritionally optimal cluster based on multi-criteria performance scores.

The integrated clustering–MCDM framework consistently identifies nutritionally optimal fast-food groups more effectively than standalone clustering approaches.

These findings support the development of intelligent decision-support systems for evidence-based dietary assessment and provide analytical tools for consumers, researchers, and the food industry. Furthermore, the study demonstrates how machine learning and data analytics can address real-world health-related challenges.

Benchmarking EEGNet Against Classical Machine Learning for Eye-State Classification on Chronologically Split EEG Data

Digital Horizons: AI, Data, and Information Technologies

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Keywords: electroencephalography, EEGNEt, eye state, machine learning, brain–computer interfaces

EEG-based eye-state classification is a simple but useful benchmark for evaluating signal processing and classification methods in brain-computer interface research. In this work, we compare selected classical machine learning approaches with EEGNet, a compact deep neural network designed for EEG analysis, on the public EEG Eye State dataset. The study examines how selected classical machine learning models, such as support vector machines, random forest, and gradient boosting methods, perform in comparison with EEGNet. To ensure a more reliable evaluation, the continuous EEG recording is split chronologically into training, validation, and test sets before segmentation, with temporal gaps introduced between the subsets to further reduce the risk of information leakage caused by neighboring samples. The models are assessed in terms of classification performance and computational efficiency. The main goal is to determine whether EEGNet provides a meaningful benefit over well-established classical methods on a small and temporally ordered EEG dataset. The obtained results contribute a lightweight and reproducible benchmark for eye-state detection and underline the importance of evaluation protocol when working with short continuous EEG recordings.

Comparison of Deep Learning Models for Multi-Organ Segmentation in Computed Tomography: A Study Protocol

Digital Horizons: AI, Data, and Information Technologies

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Keywords: deep learning, computed tomography, organ segmentation, nnU-Net

Automatic organ segmentation in computed tomography (CT) plays a key role in radiotherapy planning, surgical guidance, and quantitative image analysis. Convolutional neural networks, particularly U-Net and its variants, have become the standard approach for biomedical image segmentation due to their high accuracy and efficiency. More recently, self-configuring frameworks such as nnU-Net, as well as transformer-based models, have introduced new possibilities for automated medical image analysis.

The aim of this study is to compare selected deep learning architectures for multi-organ segmentation in abdominal CT scans under limited data conditions. The analysis was conducted on a dataset of 18 annotated volumetric examinations. All models were trained and evaluated using a unified preprocessing pipeline and consistent evaluation metrics to ensure a fair comparison.

The results indicate that nnU-Net achieved the highest overall segmentation performance (mean Dice ≈ 0.67), outperforming both classical U-Net variants and transformer-based models. In contrast, more complex architectures showed reduced performance, likely due to the limited size of the dataset.

By focusing on a small but clinically realistic dataset, this study highlights the importance of model selection in data-constrained environments. The findings suggest that self-configuring convolutional frameworks remain a robust choice for practical clinical applications where access to large annotated datasets is limited.

Current AI & Digitization Opportunities for Improving DFMEA & PFMEA

Digital Horizons: AI, Data and Information Technologies

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Keywords: digitization, DFMEA, PFMEA, AI

Possibilities to implement digitization and AI enhancement for DFMEA & PFMEA can be very profitable opportunity for companies, because of cutting time needed to prepare the possibly best version of product and manufacturing process. To achieve it, there is a need to adjust possibly helpful digitization and AI tools to the current standardised methodology of FMEA. In this case AI depends on quality data, especially information from internet, but there is also need to take care about correct design/process data preparation. The challenge is that AI is also quite new technology with its imperfections – especially the phenomenon of hallucinations, when it can generate incorrect data (for a different reasons). So we have to look at advantages and challenges and ask an important question: Is today's AI ready to improve DFMEA & PFMEA? If yes, then how to handle with it's imperfections and which limits are unbreakable for us now?

Detecting Regime Shifts in Non-Gaussian Cyclostationary Signals with Time-Varying Statistics

Digital Horizons: AI, Data, and Information Technologies

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Keywords: cyclostationary signals, non-Gaussian noise, change point detection, hidden Markov models, two-sample tests for equality of distributions

Cyclostationary signal analysis is widely used to model processes whose statistical properties vary periodically, with applications ranging from engineering diagnostics to biomedical monitoring. In practice, many such signals exhibit non-Gaussian and impulsive behavior, which limits the effectiveness of classical Gaussian-based identification methods. This study addresses the problem of detecting structural changes in time-varying non-Gaussian cyclostationary signals, motivated by the need for reliable segmentation of complex real-world data. The scope of the experiments includes simulated periodic autoregressive models driven by mixture-distributed noise with time-varying impulse probability, evaluated using Monte Carlo simulations across multiple sample sizes and parameter regimes. The results show that the direct hidden Markov model approach achieves the most accurate change-point localization, while distribution-distance methods provide superior robustness against false detections, especially for weak impulsivity. These findings demonstrate that method performance depends strongly on signal characteristics and that tailored approaches outperform generic segmentation techniques. The proposed framework advances the analysis of non-stationary signals by enabling adaptive detection strategies and supports broader applications in technical, biological, and financial systems requiring reliable automated monitoring.

EARTH SPECTRA REDISCOVERED WITH MACHINE LEARNING

Digital Horizons: AI, Data, and Information Technologies

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Keywords: hyperspectral images (HSI), machine learning (ML), spectral-wise models, explainable AI (xAI)

The spectral lines in the solar spectrum have been observed by Johan von Fraunhofer in the early 19th century. This discovery has pushed the research in many directions for years. Nowadays, with the application of machine learning (ML) methods, we are rediscovering this arena and studying vast amounts of HSI to extract knowledge from large piles of messy data.

Two key aspects are true nowadays. Access to HSI is easier. Several Earth-orbiting instruments provide data for various remote sensing applications. Also, ML algorithms facilitating automated pattern extraction from spectrally rich datasets are becoming more powerful.

For two concrete examples, we provide insights and are fully equipped benchmark for the real-world problem modelled using the actual, extensive hyperspectral dataset that we developed for the Earth observation task of bare soil detection. We present and share the HyBEAR collection, including all the data and code to enable the following scientific discoveries and reproducibility of the experiments. We also discuss spectral-wise ML models, including explainable algorithms, that, in addition to high performance, can deliver trustworthy insights. While reporting the key results, we believe the presented methods are powerful tools for modeling various phenomena and could be beneficial to many other disciplines.

EEG Analysis of Cognitive Overload and Reward in Short Form Scrolling

Digital Horizons: AI, Data, and Information Technologies

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Keywords: EEG, short-form video, cognitive load, reward system

The rapid consumption of short-form video content has become a dominant mode of digital interaction. This pervasive interface relies on continuous scrolling, exposing users to high-density streams of fast-paced visual information. While short videos are increasingly utilized for both entertainment and education ("smart content"), their physiological impact on cognitive processing remains poorly understood. This study utilizes Electroencephalography (EEG) to investigate how continuous scrolling and editing pace affect cognitive load, visual attention and reward mechanisms. Our analysis reveals that the short-form format inherently disrupts the deep cognitive processing necessary for educational content, while fast-paced "brainrot" triggers visual overstimulation that paradoxically remains highly engaging to the brain's reward system. These findings demonstrate that scrolling functions more as a mechanized neurological modifier than a conscious navigation tool. Understanding this paradox-where physiological exhaustion coexists with dopamine-driven engagement – highlights the critical limitations of using short media for education and underscores the need for neuro-ergonomic interface designs.

Evaluating the Darbellay-Vajda Partitioning Algorithm for Transfer Entropy and Conditional Joint Transfer Entropy in Causal Connectivity Analysis

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Transfer Entropy, Darbellay-Vajda Partitioning, Information Theory, Causality Analysis

Information theory-based methods provide a powerful framework for detecting causal relationships within complex systems. These techniques are particularly effective for analyzing dynamic, non-linear interactions, where traditional statistical models often fail to capture the underlying connectivity.

The performance of measures such as Transfer Entropy (TE) and Conditional Joint Transfer Entropy (CJTE) relies heavily on the chosen probability estimation technique. While the non-parametric Darbellay–Vajda Partitioning (DVP) algorithm has shown excellent results for TE in existing literature, its reliability and behavior within the CJTE framework have not yet been thoroughly explored, necessitating a comparative analysis using synthetic 2D and 3D models.

Simulation results demonstrate that TE-DVP accurately identifies causality with a few as 500 to 1,000 samples. However, the CJTE-DVP implementation is susceptible to “synergistic inflation” in three-dimensional systems, leading to significant overestimation of information transfer.

This study highlights the necessity of a multi-metric approach in information-theoretic analysis to safeguard against systematic overestimation. By establishing that CJTE should serve as complementary rather than a standalone tool, these findings offer a more reliable strategy for analyzing non-linear interactions in dynamic systems.

Hybrid Deep Sequence Modeling for Arousal Detection from Raw EEG Signals

Digital Horizons: AI, Data and Information Technologies

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Keywords: EEG, BCI, CNN, Bi-LSTM, deep modeling, arousal

Automatic recognition of emotional states from brain activity has emerged as a central objective in affective computing and neuroscience. Electroencephalography (EEG) provides a non-invasive and temporally precise modality for recording neural activity associated with affective processing. Recent advances in deep sequence modeling have opened new avenues for learning discriminative representations directly from raw multichannel biosignals, reducing reliance on manually engineered features.

Despite progress in coarse valence-arousal classification, robust arousal detection from consumer-grade EEG remains an open challenge, particularly under realistic conditions of inter-subject variability and class imbalance. This study investigates binary arousal classification using the modified EEGEmotions-27 dataset, in which 27 discrete emotion labels were mapped to high- and low-arousal classes following Russell's circumplex model. A hybrid CNN-BiLSTM architecture augmented with additive self-attention was trained on epochs from 10 randomly selected participants, incorporating weighted sampling.

The proposed architecture CNN-BiLSTM model achieved substantially higher accuracy than a baseline BiLSTM, demonstrating that local convolutional feature extraction combined with bidirectional temporal modeling significantly improves arousal detection from raw EEG.

These findings indicate that end-to-end deep architectures can serve as computationally tractable alternatives to handcrafted spectral pipelines for affective BCI applications. The results support broader adoption of hybrid sequence models in real-time emotion-aware systems operating on low-density, consumer-grade EEG hardware.

Improving the Comprehensibility of Patient Informed Consent Texts Using Artificial Intelligence-Based Tools

Digital Horizons: AI, Data, and Information Technologies

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Keywords: informed patient consent, legal rules in medicine, artificial intelligence, computational approach

Introduction to the field: Informed patient consent is a fundamental element of ethical and legal medical practice. However, consent documents often contain complex, specialized language that can be difficult for patients to understand. In recent years, the development of AI-based tools has opened up new possibilities for simplifying and improving the readability of medical texts.

Background and rationale: Despite growing awareness of the need for plain language, many informed consent forms still fail to meet understandability standards. Tools such as large language models (LLMs) and language simplicity assessment systems, such as blaskpis.pl, can support automated text analysis and simplification. This study aims to determine whether their combination can effectively improve the understandability of medical documents.

Main findings and conclusions: The use of LLMs supported by the blaskpis.pl assessment tool significantly reduced the linguistic complexity of informed consent texts while maintaining their substantive content.

Broader context and impact: The results indicate that AI tools can provide practical support in creating more patient-friendly medical documents. Improving text comprehensibility can enhance patient autonomy and the quality of healthcare decision-making. In a broader perspective, this approach can also be applied to other medical communication materials.

LEARNING DYNAMICS IN AN EMPIRICALLY-GROUNDED MULTI-AGENT SIMULATION: A CASE STUDY

Digital Horizons: AI, Data, and Information Technologies

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Keywords: multi-agent simulation, empirical data, learning dynamics, social interactions

AI methods, including multi-agent simulations, enable the study of complex social processes that are challenging to observe empirically. Multi-agent simulation allows autonomous individuals to interact within a shared environment, enabling observation and analysis of agents' behavioural dynamics in a controlled setting.

In a real school environment, studying and analysing students' behaviours is challenging and rarely yields clear conclusions. To our knowledge, no tools combine empirical data and simulation models to study knowledge transfer and learning dynamics. Data collected from students (via a targeted survey) allowed us to build an empirical-data-based multi-agent simulation. It enabled exploration of the impact of different group compositions on learning dynamics without involving actual students.

Our empirically-grounded model faithfully reconstructs the educational phenomena we observe daily, providing a basis to analyse how group structure and interactions influence learning outcomes. By analysing differently structured groups, we have concluded that the amount of knowledge its members can gain is strictly related to the group's composition.

Our work shows that a multi-agent simulation based on the empirical data may be an effective AI tool for studying educational processes. Integration of real-world data with multi-agent modeling advances data-driven simulation methods for exploring learning dynamics in a controlled, ethically responsible way.

MINING MODERN ROMANCE: MULTIMODAL ANALYSIS OF POLISH TINDER PROFILES

Digital Horizons: AI, Data, and Information Technologies

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Keywords: online dating, multimodal analysis, natural language processing, computer vision, social media mining, machine learning

Online dating platforms have become an important part of relationship formation. According to a 2025 CBOS survey, approximately 9% of couples aged 18–44 met through dating applications. Despite their growing social significance, the mechanisms through which users present themselves in digital dating environments remain relatively underexplored.

This study investigates self-presentation strategies on Tinder using a multimodal data analysis approach. We collected a dataset of 8,000 Tinder profiles containing approximately 44,000 images, bio descriptions, lifestyle tags and demographic metadata. Bio texts were embedded using multilingual sentence transformers and clustered, while images were encoded with the SigLip2 model and grouped using HDBSCAN. Additional semantic analysis of bios was performed using BERT-based topic modeling to extract recurring themes and relationship signals.

Our results show that Tinder bios form a semantic continuum rather than clearly separated categories with distinct clusters representing archetypes such as humor-focused profiles, hobby-centered presentations and internationally oriented users.

These findings demonstrate that multimodal embeddings enable interpretable analysis of social behavior in digital dating environments. Even short profile descriptions and images encode meaningful signals about lifestyle, intentions and identity. Proposed approach highlights the potential of combining NLP and computer vision to study emerging forms of social interaction in online platforms.

Molecular Patient Profile 5P: an Innovative AI-Driven Diagnostic Platform Using EPR Spectroscopy in Preventive Medicine

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Keywords: Preventive Medicine, EPR Spectroscopy, Oxidative Stress, Artificial Intelligence, MedTech

Understanding cellular health is a cornerstone of modern personalized medicine. Traditional diagnostics often rely on late-stage biochemical markers, missing early molecular dysfunctions that lead to civilization diseases.

Electron Paramagnetic Resonance (EPR) spectroscopy allows for the absolute, real-time quantification of reactive oxygen species (ROS). Historically confined to quantum physics laboratories, its clinical application in Point-of-Care settings has been limited due to the complexity of raw biophysical data interpretation.

We developed the “Molecular Patient Profile 5P”, a web-based Clinical Decision Support System (CDSS) integrating EPR diagnostics with Artificial Intelligence. The system processes capillary blood EPR signals to evaluate global oxidative stress (CMA) alongside specific mitochondrial (eCMA MITO) and endothelial (eCMA ENDO) parameters. Utilizing React architecture and LLM-based algorithms, the platform translates complex biophysical data into an intuitive “traffic light” visual report for patients. Simultaneously, it generates detailed therapeutic guidelines for clinicians, automatically recommending evidence-based interventions (e.g., targeted antioxidant supplementation or Intermittent Hypoxia-Hyperoxia Training). Initial implementation demonstrates that AI-driven visualization of cellular processes significantly improves patient health awareness and adherence to preventive protocols.

This platform bridges the critical gap between quantum biophysics and everyday clinical practice. By automating the interpretation of EPR data, it enables the early detection of cardiometabolic and neurodegenerative risks, actively engaging patients in the 5P medicine paradigm (Preventive, Predictive, Personalized, Participatory, and Precision).

New Technologies in Startup Recruitment: Findings from a Systematic Literature Review

Digital Horizons: AI, Data, and Information Technologies

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Keywords: startup, entrepreneurship, recruitment, hiring strategy

Startups drive innovation, economic growth, and job creation, yet face persistent challenges in talent acquisition due to resource constraints, limited employer brand, and information asymmetry relative to established firms – making recruitment second in importance for the startup survival only to securing financing.

Despite growing scholarly interest, knowledge of recruitment channels and strategies remains fragmented, with new technology-mediated channels practically unexamined in the startup context.

A systematic literature review of 74 empirical studies (1998–2025) identified eight thematic clusters, revealing that while social networks remain the dominant talent acquisition mechanism, technology-mediated recruitment – including social media, crowdsourcing or gamified tools – is emerging as an increasingly significant channel in the war for talent.

These findings confirm that startup recruitment is a genuinely distinct phenomenon inadequately explained by theories developed for large organizations. This review provides the first systematic synthesis through the lens of recruitment channels and technology adoption, consolidating a fragmented evidence base and identifying new technologies as one of the most critical areas for both researchers and startup founders competing for talent in an increasingly digital labor market.

OPTIMIZATION OF DYNAMIC 5G/6G XHAUL NETWORKS

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Xhaul networks, 5G/6G networks, network optimization, machine learning

Next-generation mobile network systems require advanced transport infrastructure capable of handling high data rates with ultra-low latency. Xhaul networks, which connect distributed radio access nodes with centralized resources, play a critical role in enabling these capabilities and ensuring efficient data transport across the network.

Current resource management approaches for Xhaul networks are typically designed for static or simplified network conditions [1]. In real deployments, traffic and service requirements change dynamically, while multiple services compete for shared resources. This creates a need for adaptive and efficient optimization methods capable of operating in highly dynamic network environments.

This work-in-progress explores optimization strategies for dynamic multi-service and multilayer Xhaul networks by combining classical optimization methods, including mixed-integer linear programming and heuristic algorithms, with machine learning techniques such as reinforcement learning [2, 3]. Resource allocation and routing problems are analyzed using simulation-based evaluation in a dynamic network environment.

The goal of ongoing research is to develop hybrid optimization frameworks capable of adaptive resource management. Such approaches may contribute to more scalable, flexible, and energy-efficient transport networks for future 5G and 6G systems [4].

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Plausible Goals Are Enough: Evaluating Language Supervision for Vision-Language-Action Models

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Keywords: Vision-Language-Action Models, Imitation Learning, Automatic annotations

Vision-Language-Action (VLA) models learn robot policies conditioned on visual observations and natural language instructions. Their training typically relies on large-scale demonstration datasets paired with manually annotated task descriptions, which are costly and difficult to scale. In this work, we investigate whether precise ground-truth task instructions are strictly necessary for effective VLA training.

We analyze robotic trajectories at the level of short action chunks and introduce the concept of plausible goals-task descriptions that are compatible with the observed motion of a trajectory segment without requiring knowledge of the final task outcome. Using human annotations on chunked transitions derived from the BridgeV2 dataset, we evaluate how different forms of language supervision influence the training of OpenVLA policies. We find that policies trained with behaviorally plausible goals achieve performance close to that obtained using original dataset instructions, with moderate degradation but stable convergence behavior.

Finally, we examine whether Vision-Language Models can automatically generate plausible goals. While zero-shot VLMs struggle to produce reliable descriptions, fine-tuning on 1000 annotated examples enables generation of goal descriptions that support effective VLA training. Together, our results suggest that chunk-level plausible goals provide a viable supervision signal and that language models can partially automate annotation in robotic learning pipelines.

PRIVACY-PRESERVING ADVERSARIAL IDENTITY MASKING FOR 3D GAUSSIAN AVATARS

Digital Horizons: AI, Data, and Information Technologies

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Keywords: 3D Gaussian Avatars, Adversarial Perturbations, Face Verification, Identity Masking

Photorealistic 3D facial avatars, particularly those built on 3D Gaussian Splatting, are becoming widely used in metaverse applications and video communication. Their persistent, high-fidelity nature introduces serious risks of identity theft through biometric extraction, enabling large-scale spoofing and impersonation attacks. Existing privacy protection methods operate in 2D image space and are fundamentally unsuitable for 3D avatars. Approaches such as adversarial pixel perturbations or generative anonymization must be reapplied per viewpoint, fail under pose changes, and leave the underlying 3D representation unprotected. This creates a critical gap in privacy protection for controllable, photorealistic digital personas. We present a framework that embeds adversarial protection directly into the 3D avatar representation by perturbing the base color coefficients of Gaussian primitives through constrained optimization, guided by face verification networks. Preliminary results on 28 subjects demonstrate complete de-identification, reducing face retrieval and verification accuracy to 0%, while maintaining high perceptual quality and preserving key facial attributes including age, gender, race, and emotion. A region-adaptive variant further improves the privacy–quality trade-off by assigning per-region perturbation budgets. This line of research offers a practical path toward geometry-consistent, viewpoint-stable identity protection for interactive 3D avatar applications, addressing an important and previously unexplored privacy challenge.

Reconstructing Peer to Peer Networks in Distributed Ledger Technologies

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Blockchain, Ethereum network measurement, Peer-to-peer, topology

Distributed ledger technology (DLT) is a digital record-keeping system which enables its independent participants to reach consensus with cryptographically signed transactions. Understanding the structure of the underlying peer-to-peer network behind, is key to security, performance, and resilience against targeted attacks. Additionally, while the blockchain space consists of many large-scale networks, peering protocols often hide the connections between peers. Consequently, real-world data about network structure is scarce, making any security and robustness analysis a challenging task.

Existing methods for P2P network reconstruction basically are divided into two fractions: passive with low precision, and active with high cost. The aim of this research is to find a passive approach with low reproduction costs, while utilising important elements from active techniques.

This work extends the results of the EthNetPRecover project, moving from a single "super node" observation model to a distributed measurement architecture with multiple observation points. By deploying measurement nodes in different parts of the world, it is possible to reconstruct a larger portion of the Ethereum peer-to-peer network and to cross-verify neighbouring nodes. As a result, this methodology represents a more realistic assessment of validation, the precision of method itself, as well as the effectiveness of research on blockchain network topology.

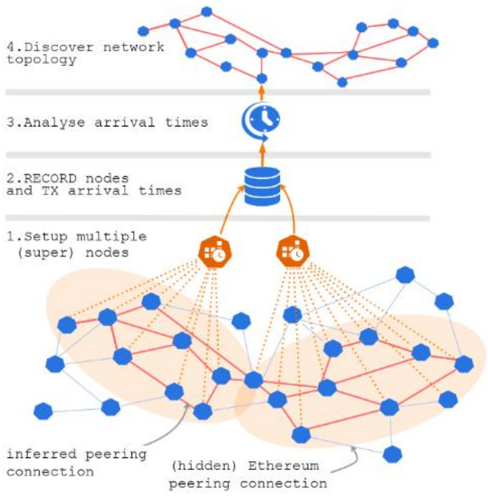

Fig. 1. Overview of the proposed topology inference framework

Remote Sensing Analysis of Post-Mining Environmental Changes

Digital Horizons: AI, Data and Information Technology

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Keywords: Airborne Laser Scanning, water detection, geospatial data

After mining activities end, groundwater levels previously lowered by mine dewatering begin to recover, which sometimes may lead to the formation of new water bodies in post-mining landscapes. Monitoring and assessing spatio-temporal dynamics of emerging surface water is essential for effective risk management. The use of remote sensing geospatial datasets is particularly suitable for this purpose, as it enables detailed analysis and assessment of environmental changes over time.

Water extent is typically mapped using spectral indices on multispectral imagery. However, in the selected case-study: post-mining Olkusz region (Southern Poland) accurate detection is difficult, as emerging surface water occur in forested areas and therefore partially flooded trees obscure the water beneath.

This study presents different approach based on Airborne Laser Scanning (ALS) Light Detection And Ranging (LiDAR) data for water delineation, including water beneath partially submerged vegetation. Methodology uses water-edge points and intentionally exploits LiDAR's limitation of no returns over water.

The results indicate that LiDAR no-returns method estimates water similarly to Sentinel-2 image-derived water index (mean difference of 6000 m^2 for each water body) but provided higher spatial detail. Water-edge points method allowed delineation of water boundaries even in densely forested areas, identifying approx. 103 500 m^2 more water for each lake, compared with no-returns method.

This data-driven approach enhances remote sensing monitoring of post-mining environments and demonstrates the potential of LiDAR geospatial data for novel analyses and alternative approach to determine waterlogged areas in complex landscapes and challenging cases.

RGBChem: Image-like Representation of Chemical Compounds for Absorption Spectra Prediction

Digital Horizons: AI, Data and Information Technology

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Keywords: convolutional neural networks, transition metal complexes, absorption spectra predictions, machine learning

Predicting molecular properties using machine learning (ML) has become an important tool in modern computational chemistry and materials discovery. Chemical structures are most commonly represented as graphs or feature vectors that encode structural information. In contrast, image-based representations combined with convolutional neural networks (CNNs) have been used relatively rarely for chemical data processing.

RGBChem is an image-based molecular representation method that converts chemical structures into RGB images used to train CNN models for property prediction. In this work, we investigate a data augmentation strategy that exploits the arbitrary ordering of atoms in .xyz files. By permuting atom indices, multiple distinct image representations can be generated for a single molecule, effectively increasing the training dataset size without introducing new chemical structures. This is particularly useful because chemical datasets are often limited, which makes training complex neural networks challenging.

Our results show that models trained on augmented datasets containing multiple image representations per molecule achieve higher predictive accuracy than models trained using only a single representation per compound.

Finally, we apply RGBChem to the tmQMg* database of transition metal complexes and their absorption spectra, demonstrating its suitability for predicting optical properties relevant to photocatalytic applications.

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Simulating Peer-Review: a Persona-Based AI System for Enhancing Manuscript Quality

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Large Language Models, Retrieval-Augmented Generation, Automated Peer Review, Multi-modal Analysis

Scientific research is increasingly bottlenecked by hyper-competitive conference acceptance rates. As the volume of submissions grows, authors frequently struggle to maintain an objective perspective on their own work, making it difficult to catch errors. To provide authors with critical first-instance external feedback and help them strategically tailor their manuscripts to specific academic venues, we propose a multi-agent Large Language Model (LLM) framework simulating the peer-review process.

Our system leverages Retrieval-Augmented Generation to integrate official conference guidelines and utilizes few-shot learning with historical, venue-specific reviews to accurately mimic institutional standards. The framework deploys distinct reviewer personas reflecting real-world archetypes: Substantive (logic and merit-oriented), Aesthete (style and grammar), Lazy (generalizing based on length and superficiality), and Hater (hyper--critical and fault-finding). Our framework adopts a dual-modality approach, integrating textual and visual LLMs to analyze the entire manuscript. This allows for a comprehensive evaluation that detects flaws across written text and visual elements like charts and graphics. By exposing manuscripts to this adversarial simulation, authors can identify mistakes missed during the writing, address methodological gaps, and align framing with venue expectations. This tool aims to democratize access to high-quality pre-submission feedback, empowering researchers to navigate the academic bottleneck and maximize chances of acceptance.

Universal Framework for Change Point Detection in Gaussian Cyclostationary models

Digital Horizons: AI, Data, and Information Technologies

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Keywords: structure break point, cyclostationary model, estimation, Monte Carlo simulation

Cyclostationary models are utilized across a diverse range of disciplines. They are fundamentally characterized by statistical properties that exhibit periodic fluctuations over time. However, classical cyclostationary frameworks often prove inadequate for characterizing complex phenomena, as empirical data frequently reveal non-homogeneous behaviors that suggest underlying structural transitions within the model. Thus, our research addresses the identification of structural changes within cyclostationary models. Particular emphasis is placed on the periodic autoregressive (PAR) model, a classical time series framework characterized by second-order cyclostationarity (i.e., when autocovariance function is periodic in time). We propose novel algorithms for regime change point estimation based on the analysis in time-frequency representation. The efficacy of the proposed approaches is validated through Monte Carlo simulations. The received results clearly demonstrate that the proposed frameworks are effective for identifying structural changes in models with complex structures, which holds significant practical implications. Although the analyses were conducted on a specific cyclostationary model, the underlying methodology is universal. We identify substantial potential for the practical application of this algorithm, as models with periodic characteristics are fundamental to fields such as condition monitoring, biomedical engineering, and telecommunications. Our future research will focus on identifying structural changes in cyclostationary models with non-Gaussian distributions.

This work is supported by National Center of Science under Weave-Unisono project No. 2025/07/Y/ST8/00070 “Advanced signal processing techniques for cyclostationary modelling in Gaussian and non-Gaussian noisy environment -detection of cyclic sources, estimation, optimisation of algorithms and validation in the context of fault identification”.

VOLTAGE STABILITY AND POWER QUALITY PREDICTIVE ANALYSIS IN RENEWABLE ENERGY SYSTEMS USING MACHINE LEARNING

Digital Horizons: AI, Data, and Information Technologies

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Keywords: Graph Neural Network, Unscented Kalman Filter, Power System Stability, Power Quality Assessment, Renewable Energy Integration, Solar Energy, Wind Energy, Voltage and Frequency Estimation, Real-Time Monitoring, Hybrid Power Grids, AI, Data, and Information Technologies

The reliable operation of hybrid renewable power grids critically depends on stability and power quality assessment, particularly as solar and wind generation introduce intermittent fluctuations in voltage and frequency. Maintaining secure and efficient grid performance requires advanced monitoring and predictive tools capable of handling dynamic and stochastic operating conditions. This study addresses this challenge by developing a hybrid framework that combines an Unscented Kalman Filter (UKF) with a Graph Neural Network (GNN) to simultaneously estimate system states, evaluate dynamic stability, and monitor power quality. The UKF ensures accurate voltage and frequency tracking under disturbances, while the GNN classifies operating states as stable, marginal, or unstable. Validation under multiple scenarios – including nominal operation, high-load conditions, renewable intermittency, faults, and measurement noise demonstrates the effectiveness of the approach. Results show low estimation errors, with voltage and frequency RMSEs of 0.06 pu and 0.08 Hz, respectively, and a GNN classification accuracy exceeding 94%. Thermal mapping and standard power quality indices, such as voltage sag/swell, frequency deviation, and total harmonic distortion, confirm the robustness and generalizability of the method. The proposed UKF-GNN framework offers a real-time, scalable solution for modern renewable-energy-based grids, advancing the capability to maintain operational stability and ensure high power quality amid increasing integration of variable energy sources.

Materials of the Future

ORAL PRESENTATION

Application-Specific Design of Cementitious Materials for 3D Concrete Printing

Materials of the Future

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Keywords: 3DCP, additive construction, 3DCP mix design

Concrete 3D printing (3DCP) brings additive manufacturing principles to traditional construction industry, enabling complex structural design, reduced material waste and unparalleled customization. At the same time, it imposes new and demanding requirements on cementitious materials being used, which must perform not only after hardening but also during mixing, pumping, extrusion and deposition.

This presentation discusses the basis for the application-specific design of cementitious materials for 3D concrete printing. The main challenge arises from conflicting process requirements, where pumpability and extrudability must be balanced with shape retention, structural build-up and the capacity to support subsequently deposited layers. Particular attention is given to the relationship between composition and rheological behavior, including the roles of yield stress and viscosity, as well as to the potential use of recycled aggregates for addressing sustainability issues.

The main conclusion is that cementitious materials for 3DCP should be designed as process-oriented systems matched to specific applications rather than adapted directly from conventional concrete technology. This approach supports the development of future construction materials by linking composition, process requirements and sustainability-oriented material design.

Carbon Nanodots – a Fascinating Fluorescence-Based Sensor

Materials for the Future

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Keywords: carbon nanodots, fluorescence-based sensor, pH sensing

Carbon nanodots (CNDs) are a class of fluorescent nanomaterials of sizes smaller than 10 nm. Their fascinating properties include excellent photostability, biocompatibility, and tunability of light emission [1].

Non-toxic and biocompatible sensors are crucial for in vivo studies. In particular, fluorescent materials that can be excited via an extremely localized and less harmful (due to lower photon energy) two-photon excitation have the upper hand over typical one-photon excited dyes.

In the past, we have developed carbon nanodots emitting cyan and yellow light that possess high fluorescence efficiencies (quantum yields exceeding 65% and 40%, respectively) and exhibit two-photon excited fluorescence [2]. Here, we report a strong dependence of their fluorescence intensity on the pH of the surrounding medium under two-photon excitation. This is one of the first reports of such a phenomenon. Our findings provide researchers with an excellent and sensitive material for applications in sensing in the physiological pH range (6.5–8). Moreover, our results contribute to the discussion on the mechanism of such pH dependence to further understand the nature of this novel yet fascinating nanomaterial.

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Effect of UV Aging on the Mechanical and Structural Properties of Wood-Filled Biodegradable Polymer Composites

Materials of the Future

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Keywords: biodegradable composites, PLA, PHB, wood filler

Biodegradable polymer composites are increasingly considered as sustainable alternatives to conventional plastics in short- and medium-term applications. However, their long-term performance under environmental exposure remains a critical issue.

This study evaluates the effect of UV ageing on the mechanical and structural properties of injection-molded composites based on PLA, PHB and a PLA/PHB (80:20) blend containing 0, 5 and 10 wt.% wood fibers. Mechanical and structural properties were determined before and after controlled UV exposure.

Wood fiber addition increased stiffness but reduced tensile strength in all matrices. UV ageing caused pronounced embrittlement and strength deterioration in PLA and PHB, while the PLA/PHB blend exhibited increased tensile strength after exposure.

The results demonstrate that matrix composition governs UV response more strongly than filler content. The improved post-ageing performance of the blend indicates that designed morphology may enhance durability of biodegradable composites, contributing to the development of more UV-resistant bio-based materials for outdoor applications.

Electrical Conductivity of Additives to Concrete in Loose and Compacted State

Materials of the Future

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Keywords: concrete, electrical conductivity, carbon nanostructures, material functionalization

Contemporary construction increasingly focuses on giving classic materials additional functions. One such material is concrete, whose main function in a building is to ensure the load-bearing capacity and durability of the structure. A promising material in this regard is electrically conductive concrete, which, in addition to its structural function, will serve as a storage medium for energy from renewable sources.

Achieving adequate electrical conductivity in concrete requires the incorporation of conductive additives, such as carbon nanostructures. However, the relationship between the electrical properties of these additives and the conductivity of the final concrete composite is still not fully understood. The present study aims to improve the understanding of the behavior of these materials.

The research indicates that the use of carbon nanostructures and the degree of compaction significantly affect the electrical conductivity values of the tested mineral powders. In particular, the addition of carbon black significantly increases the electrical conductivity of the powders in the compacted state.

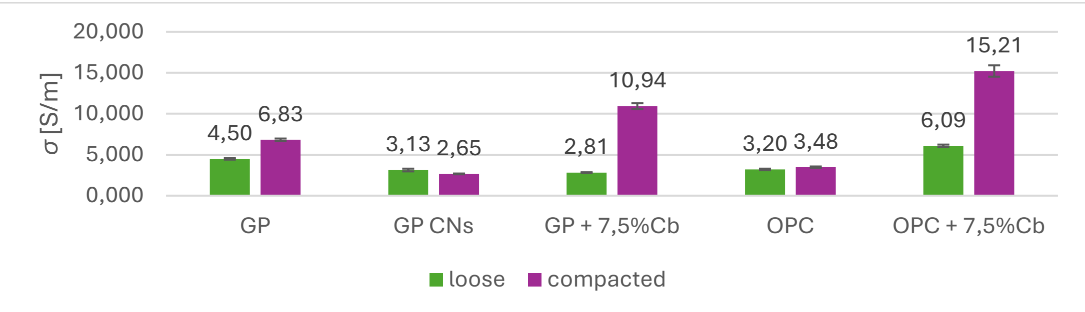

Fig. 1. Comparison of electrical conductivity of concrete additives

The obtained results, presented in Fig. 1, constitute a basis for further analysis aimed at selecting appropriate additives for use in conductive concretes. The proper selection of additives will contribute to the more effective design of multifunctional materials supporting sustainable and energy-efficient infrastructure.

This work was supported by the National Science Centre, Poland under project: Understanding the properties of the new generation of environmentally friendly nanocarbon-based conductive concrete: a step toward construction of the future (Carbon4Future), grant: OPUS 28 number 2024/55/B/ST8/00738.

ELECTRON BEAM-DEPOSITED CeO_2 THIN FILMS FOR HIGH-PERFORMANCE TRANSPARENT GAS SENSORS

Materials of the Future

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Keywords: cerium oxide, thin film, low temperature gas sensing

Semiconducting metal oxides are widely investigated for gas sensing due to their sensitivity and stability. They operate via changes in electrical resistance upon interaction with target gases and are used in environmental, healthcare, and energy applications. Among them, cerium oxide is particularly attractive because of its reversible Ce^{4+}/Ce^{3+} redox couple and high oxygen storage capacity; however, the influence of deposition conditions on sensing performance of CeO_2 thin films, especially in the context of transparent and room-temperature devices, remains insufficiently understood.

In this work, CeO_2 thin films were fabricated by electron beam evaporation (EBE) under various process conditions, coated with Pd catalyst, and characterized by XRD, SEM/EDS, AFM, UV-Vis, Raman, and XPS. Substrate heating and ion beam assistance promoted formation of oxygen vacancy-related defects and increased surface roughness, enhancing gas adsorption and diffusion.

The Pd/CeO_2 structures are selective to ethanol at elevated temperatures and respond to low H_2 concentrations at near-ambient conditions. The sensing performance was directly correlated with changes in band alignment and Ce^{4+}/Ce^{3+} ratios during exposure to gases, providing insight into the sensing mechanism.

These results demonstrate that tailoring EBE parameters enables control of defect structure and morphology, paving the way for high-performance, optically transparent CeO_2-based gas sensors compatible with microelectronic technologies.

Electrospun Protein-Based Nanofibers as a Versatile Sensing Platform

Materials of the Future

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Keywords: electrospinning, biomaterials, sensors, nanofibers

In response to current environmental challenges and the increasing demand for sustainable materials, protein-based matrices are gaining more interest across many fields of science. Naturally abundant proteins are renewable and versatile resources that can be processed into functional structures using fabrication techniques like electrospinning. Electrospun protein-based nanofibers are especially attractive because of their high surface area, tunable morphology, and varied chemical functionality, which allow for further modification and integration into complex systems. Despite rapid advances in sensing and biosensing technologies, developing materials that combine strong biomolecular binding affinity, simple fabrication, and low production costs remains a major challenge for large-scale applications. Protein-based nanofibers made from widely used and stable proteins, such as bovine serum albumin and lysozyme, offer a promising solution. Nanospectroscopic investigations allowed us to examine the internal architecture and provide evidence of the molecular-scale structural repeatability of protein-based nanofibers. Fabricated electrochemical biosensors, on the other hand, demonstrate that they form a stable and adaptable matrix suitable for constructing enzyme- and antibody-based sensing platforms. These findings open new pathways for environmentally friendly materials in healthcare and analytical science.

This work was financially supported by the National Science Centre of Poland, grant no. 2021/41/B/ST5/01797.

ELECTROSPUN PVA FIBERS WITH NADES-DERIVED POLYPHENOL EXTRACTS

Materials of the Future

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Keywords: Electrospinning; Deep Eutectic Solvents; Polyphenols; Nanofibers

Electrospinning enables the fabrication of advanced fibrous materials with precisely tunable architecture and multifunctional performance. The incorporation of bioactive plant-derived compounds into polymer nanofibers represents a promising strategy for engineering next-generation sustainable materials. Poly(vinyl alcohol) (PVA) is widely used in electrospinning due to its favorable processability; however, integrating complex solvent systems such as natural deep eutectic solvents (NADES) into spinning formulations remains technologically challenging. The high viscosity and conductivity of NADES-based extracts can destabilize jet formation and compromise fiber uniformity. This study addresses the material design challenge of incorporating both ethanol- and NADES-derived polyphenolic extracts from acorns into electrospun PVA matrices while maintaining process stability and structural control. The introduction of 5% (w/w) ethanol into the PVA/NADES formulation enabled stable electrospinning, yielding uniform, defect-free fibers with a consistent average diameter of approximately 200 nm across all systems, as confirmed by SEM imaging. Comprehensive SEM, FTIR, TGA, and tensile analyses demonstrated that the extraction medium and crosslinking type influence intermolecular interactions, thermal behavior, and mechanical performance. The proposed strategy establishes a scalable pathway for integrating green extraction systems into electrospun biopolymer platforms, advancing the technological readiness of sustainable materials for advanced biomedical and packaging applications.

Energy-Absorbing Rubberized Concrete Barriers

Materials of the Future

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Keywords: Rubberized concrete, Energy absorption, Highway barriers, Waste tire rubber, Road safety

Road accidents on highways are often associated with severe injuries and fatalities due to the high-impact forces generated when vehicles collide with median dividers or roadside barriers. Therefore, improving the energy-dissipation capacity of such barriers is important for enhancing road safety. Rubberized concrete is an innovative approach that enables the utilization of recycled waste materials. Concrete mixed with rubber particles exhibits better energy dissipation properties compared to conventional concrete.

This study investigates the feasibility of using rubberized concrete in the production of New Jersey-type highway barriers. The research evaluates the energy dissipation capacity and impact performance of barriers produced using rubber-modified concrete. Experimental results indicate that the inclusion of rubber particles increases the ductility of the material and improves its energy absorption capacity under impact loading.

According to the experimental results, the energy absorption capacity of the rubberized concrete barriers is higher than that of the conventional concrete barriers. This property can reduce the impact forces of rebounding vehicles during collision with the barriers to a considerable extent. Hence, the suggested approach can reduce injury and fatality rates during accidents by dissipating the energy of the vehicles rather than reflecting the impact forces back to them. Moreover, the suggested approach is based on the principles of sustainable construction practices, which utilize recycled rubber materials to mitigate the environmental problem of waste tires.

From Heterojunction Design to Practical Water Treatment: Bi_2WO_6@WS_2-PVDF-HFP Sonophotocatalytic Membranes

Materials for the Future

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Keywords: Bi_2WO_6@WS_2 heterojunction, PVDF-HFP composite membrane, trimethoprim degradation, Advanced Oxidation Processes (AOPs)

The continuous presence of pharmaceutical pollutants in aquatic systems and their inadequate removal by conventional treatment methods pose increasing environmental and health risks. In this study, we develop a hybrid Bi_2WO_6@WS_2- PVDF-HFP composite membrane as an efficient and reusable platform for the sonophotocatalytic degradation of trimethoprim (TMP) antibiotic. A type-II Bi_2WO_6@WS_2 heterojunction is embedded within a piezoelectric PVDF-HFP matrix, promoting synergistic photo- and sono-catalytic effects.

Comprehensive structural, optical, and electrochemical analyses reveal strong interfacial coupling, enhanced visible-light absorption, improved charge separation, and suppressed electron-hole recombination. Under simultaneous light irradiation and ultrasonic activation, the membrane achieves complete TMP degradation, outperforming single-component systems. Kinetic results follow a pseudo-first order model, while adsorption studies indicate favourable monolayer adsorption on catalyst active sites with heterogeneous adsorption on the polymer matrix.

The membrane maintains high degradation efficiency in complex water matrices, including surface and groundwater, demonstrating practical applicability. Reusability tests confirm sustained 100% removal efficiency over three cycles, indicating excellent stability and durability. LC-MS analysis shows effective breakdown of TMP with minimal accumulation of toxic intermediates.

Overall, this scalable and environmentally friendly membrane integrates photocatalysis, piezoelectric enhancement, and structural stability, offering a promising strategy for removing emerging pharmaceutical contaminants from real water systems.

This work received support from the Horizon Europe Framework Programme (HORIZON-TMA-MSCA-SE), project No. 101131229, “Piezoelectricity in 2D-materials: materials, modeling, and applications (Piezo2D).

Gasochromic Effect in WO_3 Thin Films for Optical Sensing Applications

Materials of the Future

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Keywords: gasochromic effect, tungsten oxide, thin films, hydrogen

Along with the development of hydrogen technologies, ensuring the safe storage and handling of hydrogen is becoming increasingly important. Due to its flammability and low ignition energy, sensitive and reliable detection systems are required. Optical detection methods ensure internal safety and enable remote monitoring.

Optical detection based on tungsten oxide (WO_3) gasochromic thin films is a promising approach for the reliable detection of hydrogen. This material exhibits reversible changes in transparency upon exposure to hydrogen. Although this phenomenon enables the development of promising sensor technologies, the gasochromic performance has not been fully explained, indicating a clear need for advanced mechanistic analysis.

This study investigated the structural, optical and gas detection properties of WO_3 thin films deposited by electron beam evaporation, demonstrating the influence of various factors related to the fabrication method, post-processing treatment and test conditions on gasochromic properties. In particular, annealed WO_3 films exhibited a response of 3.69 at 1000 ppm H_2, outperforming as-deposited films (1.67).

Comparisons between literature studies remain difficult due to differences in deposition methods and testing conditions, resulting in fragmented conclusions and a lack of universal performance indicators. Through systematic analysis of film parameters and their impact on gasochromic response, this work contributes to a better understanding of this phenomenon, supporting research into hydrogen sensors.

Hemocompatible Hydrogenated and Nitrogenataed Carbon Coatings for Pediatric Ventricular Assist Devices

Materials of the Future

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Keywords: hemocompability, biocompability, mechanical circulatory support (MCS), Physical Vapor Deposition (PVD)

Mechanical circulatory support (MCS) is a life-saving therapy for advanced heart failure, widely applied in adults using ventricular assist devices (VADs). In pediatric patients, however, safe and effective short-term support options remain limited due to anatomical constraints, altered hemodynamics, and increased susceptibility to device-related complications. Improving the hemocompatibility and mechanical durability of blood-contacting components is therefore essential for the development of reliable pediatric assist devices.

This study investigates amorphous carbon coatings modified with hydrogen and nitrogen as candidate for surface solutions for heart support systems. The scope of the experiments included the evaluation of surface wettability and surface free energy, as well as tribological performance, residual stress state, in vitro biological response, and blood–material interactions assessed using a radial flow chamber test. Nitrogen incorporation increased surface polarity and compressive residual stress, whereas hydrogen addition reduced internal stress and improved coating durability. Hydrogen-doped coatings exhibited the lowest cytotoxicity levels and reduced cell adhesion under flow, indicating improved hemocompatibility, while maintaining favorable mechanical stability.

Hydrogenated amorphous carbon coatings provide the most balanced combination of surface characteristics, mechanical reliability, and biological performance. These findings support their potential application in pediatric ventricular assist devices, contributing to safer and more durable blood-contacting surfaces in minimally invasive MCS systems.

This work was supported by the Polish National Center for Research and Development as a part of the project M-ERA.NET3/2023/98/KIDmicroBLOODpump/2024 “Miniaturization of impeller pump as minimal invasive implanted mechanical heart assist for children & teenagers KIDmicroBLOODpump”.

Influence of Recycled PET Aggregate on the Mechanical Behaviour and Stiffness of Cement-Based Composites

Materials of the Future

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Keywords: recycled PET, concrete, circular construction, mechanical performance

Plastic waste accumulation remains a significant environmental challenge in Europe, requiring technically grounded solutions that extend beyond conventional recycling systems. In construction engineering, the integration of waste materials into structural composites represents a practical pathway toward more circular material use.

This study investigates the mechanical behaviour of cement mortar and concrete incorporating recycled PET aggregate as partial replacement of natural aggregate. A two-stage experimental methodology was applied. Mortar mixtures with 30–70% replacement were first analysed to isolate fundamental PET–cement matrix interaction mechanisms under controlled conditions. Subsequently, concrete mixtures with up to 33% aggregate replacement were assessed at structural scale. Compressive strength and static modulus of elasticity were determined.

PET incorporation resulted in compressive strength reductions ranging from approximately 20% to 40%, depending on replacement level, while the modulus of elasticity decreased by 5–15%. Up to 172 kg of PET per 1 m^3 of concrete can be actively incorporated into the composite.

The findings indicate that recycled PET can be introduced within controlled limits while maintaining measurable structural performance, providing a technically viable pathway toward material circularity in structural applications.

METAL-ORGANIC FRAMEWORKS FOR CATALYTIC CONVERSION OF CO_2

Materials of the Future

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Keywords: metal-organic frameworks, conversion of CO_2, UiO-66, carboxylation of diols

Metal-organic frameworks (MOFs) are hybrid, crystalline materials that consist of metal clusters bonded with organic ligands. This class of materials is characterized with unique structure, tunable porosity, large specific surface area and exposed active sites, and has been thoroughly investigated as heterogenous catalysts, gas adsorbents or separators. The importance of MOFs was highlighted by the Nobel Prize in Chemistry in 2025 for pioneering contributions to reticular chemistry.

The rising concentration of atmospheric CO_2 creates an urgent need not only for efficient capture but also for its conversion into industrially valuable chemicals, such as cyclic organic carbonates (OCs), used in polycarbonates production, as inert solvents, or as components of the electrolyte in lithium-ion batteries. The conventional production of OCs often involves highly toxic reagents, such as phosgene or epoxides. Therefore, developing stable catalysts for converting CO_2 with diols represents an attractive and greener alternative for OCs formation.

In this study we obtained one of MOFs - UiO-66 modified by the introduction of cerium and copper phases and investigated it in the reaction of propylene glycol carboxylation. This work contributes to the development of strategies that integrate carbon capture with the production of valuable chemicals, supporting the transition toward greener chemical technologies.

Microstructure And Mechanical Properties of FeCoNiAlSi High Entropy Alloy

Materials of the Future

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Keywords: High-entropy alloy, multi-principal element alloy, thermal stability

High-entropy alloys (HEAs) represent a promising class of materials in which multiple principal elements are combined to achieve superior performance compared with conventional alloys. These materials have attracted increasing interest for applications in extreme environments, such as aerospace and power-generation systems, where mechanical performance and thermal stability are critical. Unlike traditional alloys, which are typically based on one or two principal elements, HEAs benefit from high configurational entropy, which can promote the formation of stable phases.

This study investigates the $Fe_{41.4}Co_{37.7}Ni_{10}Al_{9.8}Si_{1.1}$ high-entropy alloy, composed entirely of abundant elements, as a candidate material for high-temperature applications requiring favorable mechanical and physicochemical properties. The results show that annealing at 1190°C for 5 h, followed by water quenching, leads to microstructural homogenization and improved mechanical performance. In the as-cast state, the alloy exhibits a two-phase microstructure with hardness values of 367.5 HV1 and 380 HV1, whereas the annealed alloy presents a single-phase structure with an increased hardness of 387.5 HV1. The produced alloys also exhibit magnetic behavior over a wide temperature range. DSC/M-TG measurements revealed that the ferromagnetic to paramagnetic transition during heating occurs at 930°C for the as-cast alloy and 917.5°C for the annealed alloy. In addition, the investigated alloys are characterized by a high onset melting temperature of 1382°C.

Thse findings indicate that $Fe_{41.4}Co_{37.7}Ni_{10}Al_{9.8}Si_{1.1}$ HEA is promising candidate for high-temperature applications. The study demonstrates a cost-effective alloy design strategy that combines microstructural tunability with favorable thermal and mechanical properties, offering potential for use in next-generation turbines and engines.

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MOLECULAR, EXCITONIC, AND PHONON DYNAMICS AT THE SURFACE OF SEMICONDUCTOR NANOSTRUCTURES

Materials of the Future

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Keywords: surface effects, nanowires, core-shell, gallium nitride

Semiconductor nanostructures offer enhanced functionalities compared to classical systems, arising from quantum confinement and size-dependent effects. However, their performance is often dominated by surface phenomena, making deterministic control of these effects a central challenge in the design of functional devices.

Gallium nitride (GaN) nanowires are an ideal platform for studying surface effects due to their well-known optical and mechanical properties, high thermal and chemical stability, and large surface-to-volume ratio. High surface states density increases nanowire sensitivity and can reduce their optical efficiency. Thereby, we systematically investigate surface phenomena in nanostructure and propose atomic layer deposition of wide-bandgap oxide shells as a strategy to modulate these effects.[1]

We show that excitonic dynamics in the core-shell nanowires are governed by both surface molecular interactions and internal strain, which depends on the morphology of the deposited shells. The photoluminescence measurements reveal that nanowires undergo photo-adsorption, affecting excitons recombination. Transmission electron microscopy and Raman spectroscopy further show that shell modify strain, which can promote radiative recombination.

These findings give insight into nanostructure functionality in presence of surface phenomena, which open a pathway toward stable, reproducible, and high-performance microelectronic, optoelectronic, and catalytic nanomaterials, facilitating next-generation semiconductor architectures.

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Performance of Sustainable Steel Fiber-Reinforced Ultra-High-Performance Mortar for Shotcrete 3D Printing

Materials of the Future

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Keywords: Concrete, UHPM, Steel fibers, Shotcrete 3D printing

The development of 3D printing in construction requires materials with controlled rheological properties in the fresh state and high mechanical strength after hardening. Shotcrete-based 3D printing demands mixtures ensuring pumpability, sprayability, and structural capacity. This study investigates a sustainable steel-fiber-reinforced ultra-high-performance mortar (UHPM) designed for shotcrete 3D printing. The objective was to identify a mixture composition providing a proper balance between workability and mechanical performance. After 28 days of curing, manually cast specimens were tested in flexure using $4 \times 4 \times 16$ cm beams and in compression using $4 \times 4 \times 8$ cm specimens. The highest average flexural strength of 22.34 MPa was achieved for the mixture containing 3% steel fibers and 3.5% superplasticizer, while the highest average compressive strength of 116.25 MPa was obtained for specimens with 2% steel fibers and 3.5% superplasticizer. For 7x7 cm cubes cut from a prism produced using the shotcrete 3D printing process with 3% steel fibers and 1.5% superplasticizer, compressive strengths of 125–135 MPa were recorded after 28 days. These results confirm the possibility of obtaining a self-compacting mixture with high load-bearing capacity suitable for shotcrete 3D printing. These findings demonstrate that sustainable steel-fiber-reinforced UHPM can meet the mechanical and rheological requirements of shotcrete 3D printing and contribute to the development of structurally reliable 3D printing technologies in construction.

Photonic Processes as a Source of Entropy for Random Number Generators

Materials of the Future

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Keywords: random lasers, dual laser emission, random numbers, pseudorandom number generator

In recent years, the European Union Agency for Cybersecurity has reported a significant increase in cybercrimes, describing them as "a force to be reckoned with" [1]. To protect sensitive data against these growing threats, random number generators (RNGs) have become essential in information security. Among available methods to obtain RNGs, photonic processes are especially attractive because they are often free from repeating patterns in output signals [2]. Random lasers, as one example, are therefore considered promising candidates due to their unpredictable behavior [3]. However, their statistical behavior follows a Lévy flight distribution characterized by a heavy tail [4], which prevents equal probability for digital elements, limiting their direct use in RNGs.

To address this limitation, we demonstrate that increasing molecular aggregation in an aggregation-induced emission (AIE) dye, 2,4,6-OMe-TCF, leads not only to the emergence of a second emission band but also to the normalization of the system's statistical distribution. Therefore, enabling the generation of random numbers with nearly equal probabilities of "0" and "1". The generated data was further processed using the SHAKE-256 algorithm and then successfully passed the NIST statistical tests. These results confirm the strong potential of this approach for future applications in cybersecurity.

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POLYCAPROLACTONE THERMAL HISTORY EFFECTS ON FOAMING IN SUPERCRITICAL CARBON DIOXIDE

Materials of the Future

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Keywords: polycaprolactone, foaming, crystallinity, supercritical carbon dioxide

Supercritical carbon dioxide (scCO_2) foaming is a promising technique for producing advanced polymeric porous materials, with applications in fields such as tissue engineering and active packaging. In this technique, particular foam morphologies are achieved by varying processing parameters, but comparatively little work has been carried out on material properties and how they influence foaming. This is especially the case for semicrystalline polymers, which offer functional advantages but display more complex behaviour in scCO_2 than their amorphous counterparts.

This study explores the effects of thermal history on foaming of semicrystalline polycaprolactone, a promising material in biomedicine due to its biocompatibility and processability. The polymer was extruded and cooled using either air, water, or liquid nitrogen to achieve various levels of crystallinity (45-60%). DSC revealed an increase in crystallinity corresponding to decreased cooling rate. The samples, including as-received pellets and standard extruded polycaprolactone as references, were foamed at 20 MPa and 40°C. It was found that even after 24 hours of soaking in scCO_2 thermal history effects were evident in pore surface morphology, size, and distribution, with bimodality present in the case of water cooling. This work suggests that pretreatment of semicrystalline polymers is an important consideration when selecting conditions for foaming.

Tunable Luminescence in Ce^{3+} and Sm^{3+}-Doped Phosphates for Smart Agricultural Lighting Systems

Materials of the Future

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Keywords: luminescent materials, lanthanides, lighting systems, indoor agriculture

The luminescent inorganic materials doped with lanthanide ions have been extensively investigated in recent years due to their wide range of applications, such as LED lighting, scintillators, bioimaging, and laser media [1, 2]. Among these, their use as phosphors for LEDs has gathered particular attention, because such materials can convert any excitation line into a broad, lower-energy emission band suited to the specific needs, depending on the optical properties of the dopant ion [1]. An important area of LED lighting development is agricultural illumination, where the appropriate light spectra should be engineered to meet specific plants' needs, improving photosynthesis process and growth. In particular, the blue region of the spectrum is strongly absorbed by photosynthetic pigments, while red light and NIR light play a key role in controlling the plant physiological processes [3].

In this work, the optical properties of Ce^{3+} and Sm^{3+}-doped $Ca_2Sr(PO_4)_2$ phosphate are presented, which exhibits both blue and red light range emission with excitation- dependent tunability. The material was synthetized via a solid-state reaction method, receiving a polycrystalline phase as a final product, crystallizing in the *R3cH* space group. The broad excitation band in the 250–360 nm range was observed, corresponding to the 4f → 5d transition of Ce^{3+}. Additionally, multiple Sm^{3+} excitation lines are present with the most visible at around 403 nm, corresponding to $^6H_{5/2} \rightarrow {}^6P_{3/2}$ transition. The emission spectrum under 365 nm excitation consists of a broad band at around 410 nm and narrow emission lines in 550 – 750 nm region, corresponding to transitions of Ce^{3+} and Sm^{3+}, respectively. Both the emission intensity ratio and a fine spectral shape depend on the excitation wavelength, resulting leading to the spectral shift. Furthermore, temperature-dependent measurement and luminescence kinetics were studied to provide insight into excitation-dependent emission tunability and to evaluate material's potential as an LED phosphor for stimulating plant growth and development.

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Upconversion-based FRET for Next-Generation In-situ (Bio)Sensing

Materials for the Future

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Keywords: upconversion, nanomaterials, energy transfer, sensing

Förster resonant energy transfer (FRET) is a phenomenon of distance-dependent energy transfer between a donor and an acceptor fluorophores, widely used to probe molecular interactions and enable sensitive optical detection. It has become a basic and broadly adopted tool in bioanalysis and molecular sensing. Unfortunately, conventional fluorophores used in FRET, suffer from photobleaching and spectral crosstalk under typically UV photoexcitation, limiting their applicability, robustness and sensitivity in the *in-situ* diagnostics [1].

Upconverting nanoparticles (UCNPs), photoexcited with near-infrared light and emitting at shorter wavelengths, provide background-free detection and are suitable for point-of-care diagnostics, even without prior sample purification [2]. Nevertheless, UCNP-based FRET (UC-FRET) phenomenon is constrained by short Förster distances and structural factors such as dopant distribution, concentration, and the multi-donor nature of the UCNPs. To address these challenges, we synthesized Tm^{3+}-doped UCNPs and optimized thulium ions concentration for efficient energy transfer to organic dye acceptors anchored on their surface and compared several UC-FRET quantitative evaluation strategies [3].

Our results show that nanoparticle brightness is not the main factor governing FRET efficiency and that luminescence-ratio analysis provides the lowest detection limits and simplest technical efforts. We also applied this strategy for multiplexed detection, demonstrating effective sensing and distinction of multiple analytes using the same donors. These findings highlight UCNP chemical architecture engineering as a practical route to improving UC-FRET sensitivity and expanding multiplexing capabilities, advancing the design of upconversion-based platforms for next-generation (bio)sensing.

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When Buildings Age: Can Demolition Wood Become a Material of the Future?

Materials of the Future

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Keywords: demolition wood, circular economy, structural reuse, mechanical properties

The construction sector produces large volumes of demolition waste, including structural wooden elements that are usually incinerated. Simultaneously, there is growing pressure to reduce the climate and environmental impacts of construction, caused by conventional energy-intensive materials like concrete, steel and synthetic polymers. This raises an important question: can wood recovered from old buildings become a low-carbon material resource for the future?

The material properties and performance of demolition wood are, however, poorly understood. Prolonged loading and environmental exposure can change wood's mechanical and fracture behaviour in more complex ways than a simple loss of strength. In this study the properties of aged pine wood from different parts of a demolished building were compared with fresh pine using three-point flexure tests and spectroscopy – to assess changes in strength, brittleness and chemistry over time.

The results show that aged demolition wood can retain strength in comparison to fresh wood with modulus of elasticity values from about 7190 MPa in roof samples up to 9900 MPa in dense wall samples, compared with 7780 MPa for fresh wood, but exhibited brittle failure. The results suggest potential for reuse if its fracture behaviour and heterogeneity are better understood and explicitly included in design and grading approaches.

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Adhesion Behaviour of Melt-Extruded Copper Droplets on Glass Substrates

Materials of the Future

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Keywords: copper droplets, adhesion, glass substrate, debonding, melt extrusion

Copper structures deposited on glass substrates are of increasing interest for applications in microelectronics, sensors, and transparent electronic devices. Additive manufacturing techniques such as melt extrusion enable the direct formation of metallic features on glass without the need for subtractive etching, offering a potentially more material-efficient and environmentally friendly fabrication route. This approach represents a promising direction in the development of modern materials and manufacturing technologies. The ability to directly create conductive metallic structures on glass substrates opens new possibilities for advanced electronic, optoelectronic, and sensor devices. In particular, the use of inorganic intermediate layers combined with additive deposition techniques may enable more reliable metal-glass interfaces and support future scalable fabrication of functional microelectronic components.

In this work, copper droplets were deposited onto borosilicate glass substrates via melt extrusion. Molten copper was extruded from a heated nozzle and allowed to form individual droplets on the glass surface. In selected samples, the glass substrate was additionally coated with a vitreous enamel layer acting as an intermediate adhesion-promoting layer. The adhesion of the deposited copper droplets was evaluated through mechanical shear tests, in which the force required to detach individual droplets from the substrate was measured. Based on the obtained detachment forces, the apparent adhesion was determined, and the results were analysed using statistical methods to assess the variability and reliability of the measured adhesion behaviour.

Amphiphilic Gold Nanoclusters as a Probe for Correlative Light and Electron Microscopy

Materials of the Future

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Keywords: Correlative Light and Electron Microscopy, Aggregates, Metal nanocluster

Metal nanoclusters (NCs) with a size of approximately 3 nm exhibit quantum-confined electronic states that give rise to unique optical and chemical properties. Among them, gold nanoclusters (AuNCs) have emerged as highly promising multifunctional probes due to their intrinsic biocompatibility, strong nonlinear optical responses, and photostability [1]. A major challenge in modern bioimaging—particularly in the visualization of samples is the lack of probes that perform in both fluorescence microscopy and electron microscopy. This limitation hinders the development of efficient Correlative Light and Electron Microscopy [2] (CLEM) workflows, which require probes that are simultaneously luminescent and electron-dense.

In this work, we utilize the dual functionality of crown-ether-encapsulated Au_{25}NCs, which combine with near-infrared luminescence, amphiphilicity, and high electron density, enabling their use as CLEM probes. We synthesized amphiphilic crown-ether-stabilized AuNCs [3] and used them to label amyloid aggregates, i.e., spherulites. Fluorescence microscopy validate staining of spherulites and electron microscopy provides high-resolution images of the clusters. This study demonstrates that crown-ether-capped Au_{25} nanoclusters represent a powerful class of multimodal imaging probes, enabling fluorescence imaging and electron microscopy. Their tunable optical properties, combined with robust electron contrast, open new ideas for high-precision, multiscale analysis of biological structures.

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Balancing Mesomorphism and Blue Emission in Donor-Acceptor Terphenyls Via Saturated N-Heterocycles

Materials for the Future

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Keywords: materials, fluorescence, donor-acceptor

Fluorescent organic materials play a pivotal role in contemporary optoelectronic technologies, including light-emitting diodes, sensing platforms, and advanced display systems, where efficient light emission must often be combined with controlled molecular organization. Among established molecular design strategies, donor-acceptor systems are particularly effective in promoting strong fluorescence through intramolecular charge-transfer interactions. However, the incorporation of powerful nitrogen-containing electron donors, while advantageous for enhancing emission intensity, may simultaneously disturb molecular packing and suppress the formation of ordered liquid-crystalline phases. This structural disruption can compromise anisotropic properties that are critical for direction-dependent optical performance.

To address this challenge, we investigate an approach based on tuning donor geometry and conformational rigidity than altering donor strength alone. Specifically, flexible diethylamino end groups are compared with conformationally restricted six-membered nitrogen heterocycles (piperidine and piperazine). Although these substituents exhibit comparable electronic donor characteristics, their distinct spatial organization significantly influences intermolecular interaction and phase behavior. Our results demonstrate that constraining the donor structure enables the preservation of intense blue fluorescence while promoting stable nematic and smectic mesophases. These findings underscore the importance of molecular shape as a governing factor in the integration of optical functionality with supramolecular order, offering a rational framework for the development of next-generation multifunctional organic materials.

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BEYOND POLYAMIDES: TAILORING LM-PAEK PARTICLE MORPHOLOGY FOR HIGH-PERFORMANCE POWDER BED FUSION

Materials of the Future

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Keywords: LM-PAEK, Cryogenic Milling, Particle Morphology, Feedstock Engineering, PBF-LB/P

Laser-based Powder Bed Fusion of polymers (PBF-LB/P) is increasingly used for highperformance industrial parts; however, its applications are limited by a narrow polymer portfolio dominated by PA12. Super Engineering Polymers (SEPs), specifically the Polyaryletherketone (PAEK), represent the next frontier. While some SEPs are commercially available as powders, this Low-Melt PAEK (LM-PAEK) is supplied as coarse granules that require conditioning to ensure compatibility with the PBF-LB/P recoating process. LM-PAEK is promising due to its thermal stability (T_m = 280.4°C, T_g = 156°C) and suitability for mid-temperature applications.

The preliminary reduction of the supplied LM-PAEK via mechanical fractionation by sieving to achieve a particle distribution below 350 µm indicated that the powder is chemically stable. Although initial flowability via GranuDrum on the fractioned powder indicated that the cohesive index (CI) significantly exceeds the PBF-LBP requirement of 0 < 24, confirming that fractionation is insufficient for PBF-LB/P. Furthermore, the PSD analysis by Sympatec HELOS/BR 4470 C setup clearly indicated that the powder is unimodal, but some particles are larger than the setup's detection range.

To achieve the PBF-LB/P requirement of unimodal 20–80 µm range, cryogenic milling via RETSCH SM300, and integration of flow agent are scheduled. These are critical to achieving good flowability and reducing the cohesive index for PBF-LB/P purposes.

COAXIAL 3D BIOPRINTING OF HYDROGELS CONTAINING MICROALGAE

Materials of the Future

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Keywords: 3D printing, biomaterials, engineered living materials, microalgae

Coaxial 3D printing allows the creation of core-shell structures, which can be deeply modified, increasing their usefulness for bioactive materials that contain microorganisms.

The purpose of this work was to improve the bioprinting process for coaxial structures, which uses different inks to construct the inner core and outer shell. Starting with the synthesis of GelMA (methacrylate gelatin) with a DoF of 50–55%, moving on to the preparation of multicomponent bioink, and finishing with 3D printing and crosslinking.

The outer shell ink, which is mostly formed of GelMA, was infused with microalgae, while the core was created using Pluronic F127. Because of the differences in parameters between the two mixtures, determining parameters such as internal (~125 kPa) and external pressure (~3.0 bar) and printing speed (~6 mm/s) was an important part of the research. UV irradiation was paired with a chemical crosslinking agent to achieve the desired stability of the final structure, which was then evaluated using optical microscopy. Lastly, to assess future possibilities, cytotoxicity was checked, and the results show a lack of negative impact on the viability of the cells.

Those outcomes support further development in this area and show high potential for tissue engineering and biotechnological uses.

Composition–Property Relationships in Bio-Based Gel Electrolytes for Electrochromic Applications

Materials for the Future

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Keywords: gel electrolyte, natural polymers, electrochromic device, ionic conductivity

Electrochromic devices (ECDs) enable reversible modulation of light transmission under an applied electric field and are widely used in smart windows, displays, and energy-efficient systems. The performance of ECDs strongly depends on the electrolyte, which must provide high ionic conductivity, optical transparency, and long-term stability.

This study aimed to develop and compare gel electrolytes based on hydroxyethylcellulose, sodium alginate, xanthan gum, glycerine, sorbitol, and $LiClO_4$ for application in glass/ITO/WO_3/gel/ITO/glass structures. Physicochemical properties (density, mass stability, ionic conductivity) and optical parameters (transmittance, optical contrast ΔT, optical density ΔOD, switching times) were evaluated. The highest ionic conductivity (approximately 32 mS/cm) and the best electrochromic performance were obtained for gel 1, which exhibited an optical contrast up to 16.5% at 800 nm and fast bleaching kinetics ($t_{b90\%}$ = 3 s).

The results demonstrate that gel composition, particularly glycerine content and gelling agent ratio, critically influences ion mobility and optical modulation. These findings contribute to the development of stable, biodegradable, and efficient gel electrolytes, supporting further advancement of sustainable electrochromic technologies.

Covalent Organic Frameworks For Metal Recovery

Materials for the Future

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Keywords: Covalent Organic Frameworks (COFs), Capacitive Deionization (CDI), metals recovery, batteries

Covalent Organic Frameworks (COFs) are an innovative class of crystalline, porous materials that form strong covalent bonds between organic building blocks. In the result, highly ordered structures are created with tunable pore sizes and large surface areas [1, 2]. The growing production of batteries for use in portable devices and electric vehicles poses a challenge to sustainability and the environment [3]. Therefore, battery recycling is becoming increasingly important and valuable. The role of COFs in this field is an emerging area of interest because of the unique properties of those materials. COFs could be used for efficient recycling processes, potentially aiding in the selective extraction and recovery of valuable metals: Co, Ni, Mn, and Li (typical battery composition). The objective of the experiment was to investigate the feasibility of using electrodes fabricated from imine bond-based COFs to sift metal ions with the capacitive deionisation process (CDI). The conducted research shows that COFs are promising cathode materials for the recovery of metal ions. These materials could be applied in the recovery of manganese ions, for which they exhibited the best performance. The results of this study also indicate that, by applying appropriately designed process conditions, a separation effect can be achieved.

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Cultivation of Microalgae in a Medium Containing Sodium Bicarbonate – Growth Kinetics

Materials of the Future

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Keywords: Microalgae, Chlamydomonas reinhardtii, sodium bicarbonate

Microalgae are a diverse group of unicellular eukaryotic microorganisms widely distributed in freshwater and marine environments. Most species contain chlorophyll and use sunlight as an energy source to convert carbon dioxide into biomass and oxygen through photosynthesis. The ability of microalgae to continuously produce oxygen and valuable bioproducts can be utilized in various fields of biomedicine and bioengineering.

Since microalgae produce oxygen most efficiently in the absence of an organic carbon source, this study aims to determine the appropriate optimal concentration of sodium bicarbonate to support their growth.

C*hlamydomonas reinhardtii* was grown in a Tris-minimal liquid medium containing $NaHCO_3$ as a source of inorganic carbon (10–50 mM). Initial cell concentrations were 1×10^5 and 5×10^5 cell/ml. The light/dark cycle was 12/12 hours.

The results showed that the optimal $NaHCO_3$ concentration for *C. reinhardtii* growth was 20–30 mM in Tris-Minimal medium. Under these conditions, the specific growth rate reached 0.326 day^{-1}, with a doubling time of 2.13 days. No microalgae growth was observed at 10mM, while at 50 mM the growth rate was significantly reduced (0.196 day^{-1}). At higher concentration (5×10^5), the doubling time increases.

Microscopic observations confirmed that under optimal conditions, the cells exhibited strong chlorophyll autofluorescence for up to 30 days. No bacterial contamination was detected.

Future work will focus on photobioreactor cultivation with continuous monitoring of oxygen production by microalgae under the optimal $NaHCO_3$ concentration.

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Development of a Sand-Based Helical Coil Thermal Energy Storage System for Future Biopolymer PCM Studies

Materials of the Future

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Keywords: silica sand, helical coil heat exchanger, biopolymer, phase change material, phase equilibria

Latent heat thermal energy storage (LHTES) using phase change materials (PCMs) is a promising solution to reduce the mismatch between energy supply and demand. Compared to sensible heat storage, LHTES offers higher energy density and operates at nearly constant temperature during phase change. However, the application of LHTES is often limited by the low thermal conductivity of most PCMs, which slows heat transfer and requires improved heat exchanger designs. Therefore, a reliable experimental setup is necessary to evaluate thermal performance. This study presents a laboratory-scale thermal energy storage (TES) system equipped with a helical coil heat exchanger. Silica sand is initially used as the TES material to establish a reference and to calibrate the heat transfer behavior of the system before introducing biopolymer-based PCMs. The helical coil configuration is selected due to its simple design, easy fabrication, and low cost. Theoretical analysis indicates that the helical geometry provides good heat transfer performance. The validated sand-based system serves as a baseline for future studies aimed at quantifying the performance improvement achieved by biopolymer PCMs. The system was tested at two operational heat source temperatures, 80°C and 70°C, with each charging cycle repeated to assess repeatability and thermal stability. For the 80°C heat source, the TES charging process increased the storage temperature from 25.8°C to 71.4°C,exhibiting a stable and repeatable thermal profile. The temperature deviation across measurements ranged between ±0.5°C and ±1.8°C. For the 70°C heat source, the TES temperature increased from 27.73°C to 63.57°C, with a similar charging trend, while the measurement deviation ranged from ±0.8°C to ±3.5°C. For both heat source temperatures with 10.5 liters of sand, the charging process required less than 3 hours to reach the desired temperature range. These results show that the system works reliably for testing bio-based materials. This setup can be used as a solid starting point for developing and testing sustainable biopolymer PCMs which can be applied as novel energy solutions supporting the shift toward greener technologies.

DIRECT GROWTH OF CARBON NANOFIBERS ON CARBON CLOTH FOR HIGH-PERFORMANCE ALKALINE ELECTROCATALYSIS

Materials of the Future

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Keywords: electrocatalysis, water splitting, carbon nanofibers, chemical vapor deposition

Hydrogen production through alkaline water electrolysis is a promising pathway for energy systems. However, large-scale implementation is limited by reliance on expensive noble-metal catalysts for the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER). In this work, carbon-cloth (CC) supported carbon nanostructures were synthesized on transition-metal catalysts based on Ni, Ni-Fe, and Co-Cu compounds. Catalyst precursors were thermally treated in H_2 to form metal nanoparticles (Me-NPs) that subsequently promoted chemical vapor deposition (CVD) growth of carbon nanostructures.

During CVD at 650°C in a H_2/C_2H_4 atmosphere, carbon cloth samples with Me-NPs were decorated with carbon nanofibers (CNFs). Electrocatalytic performance of the electrodes was evaluated in 1 M KOH by comparing HER and OER linear sweep voltammetry (LSV) curves for Me-NPs and corresponding Me-np/CN anchored to CNFs.

The Ni-Fe composition (Ni_1Fe_1) showed improved performance after CVD-assisted carbon growth, achieving η_{10}(HER) = 196 mV compared with 271 mV for annealed Me-NPs without carbon structures. Similar trends were observed for OER, indicating improved charge-transfer properties and structural stability, due to encapsulation of metal nanoparticles within the carbon matrix.

These results demonstrate that CVD-grown CNFs with metal nanoparticles enhance catalytic activity and durability, offering a scalable route to precious-metal-free electrodes for hydrogen production.

ECR Relaxation Studies of Selected Oxide Materials Containing Fe And Mn

Materials of the Future

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Keywords: Electrical conductivity relaxation; oxygen transport kinetics; Fe-Mn oxide materials

Understanding oxygen transport and surface reactivity in transition-metal oxides is essential for their application in high-temperature energy and electrochemical technologies.

In this work, electrical conductivity relaxation (ECR) was employed to investigate the oxygen exchange behavior of selected iron and manganese-containing oxide materials over the temperature range of 800–1000°C under oxidizing (air) and neutral (N_2) atmospheres. ECR measurements were used to extract the chemical diffusion coefficient of oxygen (D_{chem}) and the chemical surface exchange coefficient ($k/chem$), which describe bulk oxygen mobility and surface reaction kinetics, respectively. For example, for a sample of $CuFe_2O_4$ measured at a temperature of 800°C in a nitrogen atmosphere the following values were obtained: k = 3.17E-04; D = 2.03E-01; k/D = 1.56E-03. For a sample of $CuFe_2O_4$ at a temperature of 800°C in an air atmosphere the following values were obtained: k = 4.31E-04; D = 3.69E-01; k/D = 1.17E-03. Diffusive effects play a similar role in both the reduction and regeneration of the catalyst due to similar D values.

In general, higher temperatures may enhance oxygen transport, whereas changes in the gas atmosphere may alter relaxation behavior, reflecting differences in oxygen vacancy concentration and surface exchange mechanisms. These findings demonstrate that ECR is a powerful tool for probing oxygen kinetics in complex oxides and provide insights relevant to the design of materials for applications.

Electrospinning of Poly(Vinyl Alcohol)/Alginate Blends for the Production of Sustainable Nanofibers

Materials of the Future

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Keywords: sodium alginate, poly(vinyl alcohol), nanofibers

Electrospinning is a novel technique for the production of nanofibrous materials characterized by high porosity and a large surface-to-volume ratio, making them attractive for biomedical, environmental and agricultural applications. Among natural polymers, sodium alginate (SA) gained attention due to its biodegradability, biocompatibility and high availability. However, the electrospinning of pure alginate is challenging because of its polyelectrolyte nature, high solution conductivity and limited chain entanglement, which lead to jet instability and bead formation.

To overcome these limitations, poly(vinyl alcohol) (PVA) is commonly used as a supporting polymer. PVA improves the spinnability of alginate-based solutions by enhancing chain entanglement and promoting intermolecular hydrogen bonding. As a result, the addition of PVA enables the formation of continuous nanofibers with high SA content while maintaining the fibers' biodegradable character.

This work investigates the development of electrospun nanofibers composed of PVA and SA. The effect of polymers' ratios and concentrations on fiber formation, morphology and average fiber diameter is investigated. An optimized PVA/alginate system enabled stable electrospinning and the formation of uniform, bead-free nanofibers. The study shows how adjusting the solution composition influences fiber formation and morphology, providing practical guidance for the development of biodegradable PVA/alginate nanofibrous materials.

Acknowledgments

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Electrospun Fibers with Anthocyanins as Freshness Indicators in Intelligent Food Packaging

Materials of the Future

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Keywords: electrospinning, intelligent packaging, natural deep eutectic solvents, anthocyanins

Intelligent packaging is a modern form of smart packaging that records and informs about changes occurring in the product. Anthocyanins are natural pH indicators that can be incorporated into a polymeric matrix and applied as freshness indicators for food products. The use of polymeric fibers instead of films enables better gas penetration into the material and thus greater sensitivity. This study attempts to fill the research gap by assessing the suitability of NADES-extracted and ethanol-extracted anthocyanins for electrospinning applications. The effect of the composition of the spinning solution on the electrospinning process of poly(ethylene oxide) (PEO)-based fibers with the addition of anthocyanin-rich extracts and sodium alginate (Alg) was investigated. Durable mats were successfully obtained for fibers with the addition of ethanol-based extracts, although these fibers were covered with numerous beds. The obtained mats responded to changes in environmental pH by exhibiting a visible color change. Tests were carried out on solutions containing extracts obtained from red cabbage leaves using NADES, a 50% ethanol solution, and mixtures of NADES with ethanol in various ratios. The results provide insights into how the physicochemical features of NADES--based systems may affect fiber formation, advancing the field by defining critical limitations.

Functionalization of Activated Carbon With H_2O_2/HNO_3 – Dependence of Product Properties on Process Parameters

Materials for the Future

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Keywords: carbon material, oxidation, heteroatom content, porous structure

Activated carbon is a porous carbon material widely used, among other applications, as an adsorbent in water and air purification processes. In recent years, there has been significant interest in exploring new application areas for this material, particularly as a catalyst support or as a heterogeneous catalyst itself. In this context, adsorption, catalytic, and hydrophilic–hydrophobic properties play a crucial role. These properties can be modified through functionalization, which involves increasing the number of functional groups on the surface of activated carbon. In this study, the effect of oxidation temperature and time using H_2O_2/HNO_3 on the porous structure and the degree of surface oxidation of activated carbon was analyzed. It was observed that increasing the reaction temperature and time resulted in a decrease in pore volume, accompanied by an increase in the number of oxygen-containing functional groups on the surface. The obtained results indicate that oxidation parameters play a key role in controlling both the porous structure and surface chemistry of activated carbon, enabling its rational design for targeted catalytic and adsorption applications.

Impact of Ultrasonic Assistance on Microstructural Evolution and Geometric Features of LPBF-Fabricated 316L Stainless Steel

Materials of the Future

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Keywords: Laser Powder Bed Fusion, Ultrasonics, Microstructure, Field-Assisted Additive Manufacturing

Laser Powder Bed Fusion (LPBF) enables complex metallic component fabrication but often suffers from microstructural limitations due to rapid solidification. This project successfully developed and integrated an ultrasonic vibration (USV) module designed to control the melt pool through acoustic streaming and cavitation effects.

The USV module is now fully operational and capable of USV-assisted LPBF fabrication. To validate performance, 316L stainless steel samples were produced under standard and assisted conditions. Evaluation involved porosity analysis, hardness testing, and Electron Backscatter Diffraction (EBSD) to compare grain refinement and crystallographic textures across the different processing modes.

Results demonstrate the module's stability and effectiveness. Baseline parameters produced a fine grain size of ASTM 9.5, while USV-assisted samples achieved even finer ASTM 9.7 and higher density of low-angle grain boundaries, signaling cellular-dendrite refinement. Relative density remained above 99%, while hardness was maintained at 228 HV, matching the value of the control samples, confirming that the ultrasonic field modifies grain structure without degrading mechanical strength or density.

This confirms the USV-assisted module works as intended. Having established reliable operation of the module, project focus shifts to process parameters optimization. This work provides a new capability for manufacturing high-reliability components with controlled microstructures, potentially minimizing the need for extensive post-processing treatments.

In-Situ Resource-Based Additive Manufacturing in Architecture: Design Exploration of a 3D Printed Observatory in Iceland

Materials for the Future

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Keywords: in-situ materials, 3D printed construction, additive manufacturing in architecture, sustainable

The objective of the thesis was to develop a conceptual architectural design of a building constructed using additive manufacturing technology and in-situ materials. The project is based on a review of existing large-scale 3D printing implementations and an analysis of material composition and technological parameters used in contemporary architectural applications.

Additive manufacturing is increasingly investigated in architecture as a method for reducing construction waste and enabling site-specific, resource-efficient construction strategies. A key research direction is the use of locally available materials as an alternative to conventional construction resources.

Based on a literature review, an analysis of available projects and material solutions used by companies constructing buildings using 3D printing, as well as industry consultation, material assumptions and process parameters were defined. Two material systems were adopted: an earth-based mixture intended for above-ground elements, consisting of local soil, water, natural fibers, and optional stabilizers such as lime or cement (compressive strength approx. 1–5 MPa), and a concrete mixture intended for underground elements, containing cement, fine aggregates, and stabilizing admixtures (compressive strength approx. 20–35 MPa depending on the exact composition).

Technological parameters were defined as a result of industry consultations and include a layer height of 30 mm, controlled curing intervals between layers, and horizontal reinforcement every 10 printed layers. The proposed manufacturing process assumes the use of a large-scale crane-type 3D printer.

The result of this work is a conceptual design of an observatory located in Iceland, integrating both material systems. The project demonstrates the potential of additive manufacturing in construction, while also highlighting the need for further experimental validation of material behavior and process parameters.

Investigation of MXene-Supported Metal Catalysts for Methanol Electrooxidation

Materials of the Future

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Keywords: MXenes, Methanol Electrooxidation, Metal–Support Interactions, Density Functional Theory (DFT)

Fuel cells are promising energy conversion devices that can efficiently convert chemical energy into electricity with low emissions. Among them, direct methanol fuel cells (DMFCs) are attractive due to the high energy density and easy handling of methanol. However, their practical application is limited by slow methanol electrooxidation kinetics and catalyst poisoning, which require the development of more efficient and durable electrocatalysts.

Recent research suggests that engineering metal–support interactions can significantly influence catalytic activity and stability. MXenes, a class of two-dimensional transition metal carbides and nitrides, have emerged as promising catalyst supports because of their high conductivity, tunable surface chemistry, and strong interaction with supported metals. In this study, density functional theory (DFT) calculations are used to investigate methanol oxidation pathways on oxygen-terminated titanium carbide MXenes with different layer thicknesses.

The results indicate that MXene thickness and surface termination significantly influence intermediate stabilization and the energy barrier of the CO + OH coupling step, which is identified as a key step in the reaction mechanism.

These findings demonstrate that MXene-supported catalysts provide a tunable platform for controlling catalytic performance. Furthermore, integrating DFT data with machine learning approaches enables efficient screening of catalyst candidates, offering a predictive strategy for designing cost-effective and durable electrocatalysts for sustainable fuel cell technologies.

LINKING OXYGEN AND HYDROGEN ELECTROCATALYSIS IN CARBON-BASED ELECTRODES FOR POWER-TO-HYDROGEN SYSTEMS

Materials of the Future

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Keywords: multifunctional electrocatalysis, carbon nanostructures, energy storage and conversion systems

The efficiency of Power-to-Hydrogen and related Power-to-X technologies is limited by electrode kinetics, with the oxygen evolution reaction (OER) being the primary bottleneck in water electrolysis. While the hydrogen evolution reaction (HER) is inherently faster, the overall performance relies on the synergy between both reactions. To address this limitation, noble-metal-free, multifunctional carbon-based electrocatalysts were developed for OER, HER, and the oxygen reduction reaction (ORR) crucial for the performance of zinc-air batteries. Carbon nanostructures (CNSs) were synthesised in situ on electrochemically activated carbon cloth, where the activation step parameters precisely control nanostructure growth, morphology and surface properties. Experimental results demonstrate that even a brief 1-minute electrochemical pre-treatment of the substrate prior to the main CNSs synthesis significantly enhances electrocatalytic activity, yielding a two-fold increase in ORR limiting current and a 30 mV reduction in overpotential. Furthermore, at 100 mA/cm², the overpotentials for OER and HER were lowered by 70 mV and 50 mV, respectively.

This engineering approach allows for tuning of OER kinetics while preserving activity towards HER and ORR, demonstrating the significant potential of these carbon electrodes for integrated Power-to-Hydrogen and renewable energy storage systems.

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Multichromism – How To Control the Color Change

Materials of the future

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Keywords: multichromism, color change, multicolor, physicochemistry

Multichromism is a general term for the phenomenon of color change, normally reversible, induced by an external stimulus. There are several ways of how to force a multichromic molecule to change its color. For example, if the stimulus is heat, the process is called thermochromism; if the color changes under the influence of radiation, we call it photochromism; when absorbance varies from the type of solvent, one calls it solvatochromism.

Multichromism is a very useful phenomenon as it enables one to precisely control color of the molecule. What is worth noting, multichromism is a feature of rather small molecules whose chemical structure is simple (in comparison to other conventional, organic dyes), which is their huge advantage.

In our research, we focus not only on investigating if the compound exhibits multichromism, but also how the process of color change works, for example, what can affect the change its speed or if there are any competitive processes. Our latest work has revealed how solvatochromism and photochromism interpenetrate each other and how does this affect a multichromic molecule [1]. The conducted research is a valuable contribution to understanding the behaviour of multichromic pigments, like spiropyrans, which is crucial if we consider their further development and commercialization.

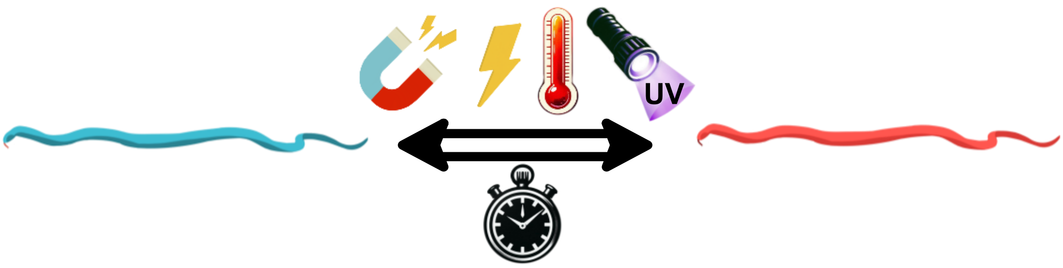

Fig. 1. Schematic representation of a multichromism phenomenon

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Nanostructured Materials Based on Silver Nanoparticles Capped by New Multicharged Cationic Surfactants

Materials of the Future

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Keywords: silver nanoparticles, dicephalic cationic surfactants, capping agents, zeta potential

Silver nanoparticles (AgNPs) exhibit a broad range of technological potential, particularly in biomedical applications, including antimicrobial agents, diagnostic probes, and drug nanocarriers [1]. A key aspect in the synthesis of stable colloidal AgNPs is the selection of an effective capping agent that prevents agglomeration while controlling nanoparticle size and morphology. Multicharged cationic surfactants are considered particularly efficient capping agents, combining adsorption onto nanoparticles surface enhanced by positively charged hydrophilic groups with steric stabilization provided by hydrophobic alkyl chains. Dicephalic surfactants, containing two hydrophilic groups and a single hydrophobic tail, due to their structural diversity enable more efficient stabilization and more precise control over AgNPs morphology compared with conventional linear cationic surfactants [1]. In this study, newly synthesized multicharged cationic surfactants – 2-alkyl-N,N,N,N',N',N'-hexamethylpropan-1,3-ammonium dibromides (C_n-DcNMe$_3$Br, where n = 10, 12, 14) – were employed [2]. Zeta potential is a key physical parameter of nanoparticles that reflects the electrical properties of their charged interfaces. Because it indicates the magnitude of electrostatic interactions between nanoparticles, the zeta potential is commonly used as an indicator of charge-induced colloidal stability. Obtained zeta potential values indicate the formation of stable AgNPs capped with dicephalic cationic surfactants. The investigated surfactants effectively stabilize the studied colloidal systems.

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OPTICAL PROPERTIES OF GRAPHENE QUANTUM DOTS OBTAINED VIA ONE-POT GREEN HYDROTHERMAL SYNTHESIS

Materials for the Future

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Keywords: carbon dots, graphene quantum dots, photoluminescence, hydrothermal process

Carbon dots (CDs), and in particular graphene quantum dots (GQDs) due to their strong photoluminescence, chemical stability and low toxicity, are an attractive and rapidly developing class of carbon nanomaterials. Their properties make them ideal materials for optoelectronics, bioimaging, and use as sensors. It is therefore very important to choose the type of synthesis and precursor materials, which directly affect the size and surface chemistry, and thus the optical response of the materials.

In this work, graphene quantum dots were synthesized via a one-pot green hydrothermal method using graphene oxide as a carbon precursor and hydrogen peroxide as an oxidizing-cutting agent. The obtained dispersions were purified by dialysis to remove residual molecular species and subsequently isolated as solid material by lyophilization. The optical properties of the GQDs were investigated using UV-Vis absorption spectroscopy and photoluminescence spectroscopy, while the surface chemical composition and distribution of functional groups were analyzed by X-ray photoelectron spectroscopy (XPS).

The synthesized GQDs exhibit strong green photoluminescence with excitation-dependent emission. The XPS analysis has confirmed the presence of oxygen-containing surface groups.

The results reveal a clear link between the surface chemistry and the optical properties of hydrothermally synthesized GQDs.

Optimizing Cellulose Extraction from Coffee Ground Waste: A Review of Recent Advances

Materials of the Future

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Keywords: coffee waste, cellulose extraction, optimization, sustainable materials, biocomposites

A vast, underutilized resource for cellulose, a natural polymer that is essential for packaging, and eco-friendly biomaterials, is coffee grounds waste from cafe and residences. Each year, billions of tons of discarded coffee grounds are deposited in landfills, thereby exacerbating waste management issues.

Isolating cellulose from this accessible residue provides a means to convert common waste into valuable sustainable products. Traditional extraction techniques frequently exhibit excessive chemical consumption, significant wastewater production, and diminished cellulose purity, impeding industrial scalability.

This paper examines current advancements in pre-treatment and extraction techniques, beginning with fresh collection, cold storage at –8°C, and oven-drying at 105°C for 30 minutes, to mitigate limits and improve yield, purity, and environmental sustainability. Refined techniques integrate drying with alkali boiling (e.g., NaOH), acid hydrolysis (e.g., H_2SO_4 or HNO_3), and bleaching (e.g., H_2O_2 or $NaClO_2$), achieving cellulose yields of 25–40% at 80–90% purity.

These technologies use ultrasonic or cavitation to create micro- and nano-cellulose for produce biodegradable packaging. They support the zero-waste valorization of coffee grounds, which advances circular economies and green manufacturing around the world.

OPTO-MECHANICAL ESTIMATION OF APPARENT ELASTIC MODULUS OF MYELIN TUBES BY OPTICAL TRAPPING

Materials of the Future

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Keywords: multilamellar lipid membrane, interlamellar coupling, optical trapping

Multilamellar lipid membranes represent an important class of self-assembled soft materials whose collective mechanical properties remain not sufficiently understood under localized optical forcing. Although the bending rigidity of single lipid bilayers have been extensively characterized, far less is known about how stacked cylindrical assemblies such as myelin tubes respond to highly focused light-induced stress.

Here, we demonstrate that tightly focused optical trapping generates controlled and reversible radial deformations in myelin tubes, allowing for the direct extraction of their apparent bending modulus in the 10^{-19} to 10^{-18} J range.

Using a continuum Helfrich model and analyzing real-time deformation dynamics, we show that the mechanical response depends on interlamellar coupling and molecular incorporation within the bilayer structure. In dye incorporation modulates collective elasticity, providing a tunable molecular handle over macroscopic mechanical behavior.

These findings establish optical trapping as a quantitative probe of multilamellar membrane mechanics and introduce myelin tubes as a mechanically adaptive soft platform. Beyond fundamental membrane mechanics, this work opens pathways toward optically reconfigurable soft photonic elements, including waveguiding structures and soft responsive materials whose geometry and mechanical stiffness can be dynamically controlled by light.

Photoinduced Phase Transitions in Polar Nematic Phases: Design and Synthesis of Multifunctional Azo-Dopants

Materials of the Future

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Keywords: liquid crystal, polar nematic phases, azo-dopants, photoisomerization

The discovery of the ferroelectric nematic (NF) [1] and the heliconical (NTBF) [2] phases have fundamentally redefined the design rules for liquid crystalline materials, paving the way for non-linear photonic systems with unprecedented electro-optic response [3]. While the dielectric control of these phases is being extensively explored, their photo-modulation remains a largely uncharted area, posing significant challenges for both organic synthesis and condensed matter physics.

In this work, we demonstrate that the photoisomerization of the azo-dopants can be utilized to induce drastic changes in the phase sequence of polar liquid crystals. Under UV irradiation (*trans* → *cis* isomerization), the rod-like geometry of the dopant is disrupted, leading to the destabilization of the polar order (Fig. 1). This allows for the precise, light-induced induction or suppression of target polar phases (NF, Nx, NTBF, or polar smectics) at a given temperature. The process is fully reversible upon exposure to longer wavelengths (*cis* → *trans* isomerization).

The presentation will cover the molecular engineering and synthesis of these novel azo-mesogens, their mesomorphic characterization, and systematic studies on their miscibility and photo-switching kinetics.

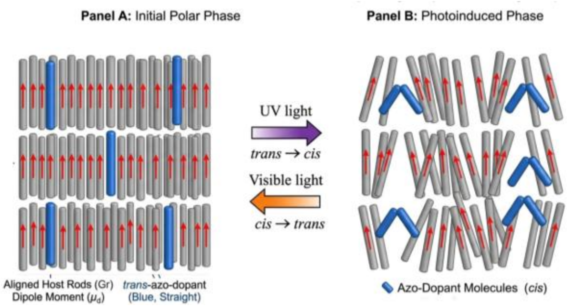

Fig. 1. Photoinduced phase transtion in Ferroelectric Liquid Crystal

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PHYTO-MEDIATED SYNTHESIS OF SILVER NANOPARTICLES FROM *TRIGONELLA FOENUM-GRAECUM* EXTRACT: STRUCTURAL CHARACTERIZATION AND EVALUATION OF DUAL BIOLOGICAL ACTIVITIES

Materials for the Future

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Keywords: Green synthesis, Anti-microbial activity, nanoparticles

In the current work, fenugreek Seeds extract was used to create silver nanoparticles by a green synthesis approach, which offers the bioactive element required for the reduction of silver ions to silver nanoparticles, using $AgNO_3$ solution and fenugreek plant seed aqueous extract, which functions as a capping, stabilizing, and reducing agent under ambient conditions. The solution color shift from colorless to dark brown, together with the first excitonic peak of the UV-vis spectra at 430 nm, all supported the production of silver nanoparticles. The distinctive peaks of the N-H amide and C-O stretching groups were detected at 1687 cm^{-1} and 1084 cm^{-1} by FTIR analysis. As an antibacterial agent, produced Silver nanoparticles were examined against *E.coli*, *Bacillis subtilus, Pseudomonas aurignosa* and *Staphylococcus aureus*. Maximum antibacterial activity was shown against *E.coli* with inhibition zone of 7.8 mm. It was shown to be effective since the inhibition zone of these bacteria was larger when silver nanoparticles were used than when 1mM silver nitrate was used alone. Thus, the process of creating silver nanoparticles from plant extract move us closer to using non-toxic components as antibacterial agents.

Preparation, Structural Phase Transition and Second Harmonic Generation Switching of the Hybrid Organic-Inorganic Perovskite $[DIPEA]_3Pb_2Br_7$

Materials of the Future

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Keywords: Synthesis, structural characterization, hybrid organic-inorganic perovskites (HOIP), temperature-induced structural phase transitions, nonlinear optics, lasers, second harmonic generation (SHG), temperature switchability of SHG

Hybrid organic–inorganic lead halide perovskites have emerged as promising materials for next-generation solar cells, light-emitting diodes, lasers, and electro-optic switches. The first-order structural phase transitions occurring in these compounds enable switching between distinct levels of integral SHG intensity. Temperature-driven switching in such materials allows their application as thermally controlled electro-optic elements, a research area that continues to gain significant momentum [1, 2].

The present study focused on the identification of a functional crystalline SHG switch. A key stage of the investigation involved the synthesis of the perovskite $[DIPEA]_3Pb_2Br_7$ (DIPEA = diisopropylammonium). Subsequently, comprehensive structural characterization was performed using SC-XRD and PXRD techniques. The NLO properties of the material were also examined, with particular emphasis on its SHG switchability.

The results demonstrate that the material exhibits a switchable SHG-Low-High-Low phase transition occurring between a low-temperature phase with space group *Pc* and a high-temperature phase with space group *Cm*. The phase transition takes place at approximately 238 K and is accompanied by a small thermal hysteresis of about 4 K. The SHG-Low-High switching behavior is particularly desirable because all temperature-dependent phases of the material remain non-centrosymmetric. Moreover, only a limited number of reports describe materials exhibiting this type of switching at such relatively high temperatures. An additional factor underscoring the material's potential contribution to the advancement of thermally driven switching systems is its favorable crystal morphology and relatively large crystal size.

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PROPERTIES OF POLY((R)-3HYDROXYBUTYRATE-CO-(R)-3-HYDROXYHEXANOATE) USING INJECTION MOLDING TECHNOLOGY

Materials of the Future

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Keywords: biodegradable polymers, PHB copolymers, injection molding, thermoplastic materials

Poly(3-hydroxybutyrate-co-3-hydroxyhexanoate) (PHBHHx) is a microbial based, biodegradable and biocompatible copolymer belonging to the polyhydroxyalkanoate (PHA) family. It is usually produced from vegetable oils or fatty acids via the β-oxidation process, while biosynthesis from sugars has also been achieved using recombinant strains of the hydrogen-oxidizing bacterium Cupriavidus necator. Due to its flexible structure and favorable material properties, PHBHHx exhibits a wide range of applications across multiple fields. It is for example biomedical engineering, packaging, agriculture, eco-friendly disposable products, and 3D printing. Because of these characteristics, PHBHHx is considered as a promising alternative to conventional petroleum-based polymers.

The obtained using injection molding technique samples were characterized for tensile strength, thermal properties (differential scanning calorimetry as well as thermogravimetry) and structure – fourier transformed infrared spectroscopy.

In this research we have demonstrated the feasibility of processing PHBHHx using injection molding for industrially available technology which opens a possibility of use the PHBHHx in large scale.

RADICALS IN ACTION – THE POSSIBLE USE OF NEW RADICAL COMPOUNDS

Materials of the Future

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Keywords: radicals, OLED, electronics, SMM

Along with the development of technology the natural resources of materials are decreasing, thereby the need of new substitutes is rising. Organic radicals - made from abundant elements - have attracted significant attention due to their open-shell structure, which enables applications in various fields of material science. Some are used in OLED displays, others exhibit electrical conductivity making them suitable for flexible electronics or display magnetic properties that make them candidates for building blocks of single-molecule magnets.

The main goal of our research was to synthesize stable radicals, which would be possible to use in some of the fields above. Recently we obtained a new phenoxazine radical system containing two 10H-phenoxazine derivatives (2,4,6,8-tetra-tert-butyl-10H-phenoxazine and 1-hydroxy-2,4,6,8-tetra-tert-butyl-10H-phenoxazine linked by hydrogen bond) and biscatechol derivative (4,4′-(1,1-Cyclohexanediyl)di(1,2-benzenediol), which in the alkaline pH change the form into semiquinone radical. The EPR studies confirmed the presence of radicals and XRD experiments confirmed the structure of phenoxazine radical and biscatechol precursor. Both compounds are characterized by high stability and may be of potential use as functional materials.

Spontaneous Formation of Photonic Structures in PS-PMMA Polymer Blends

Materials of the Future

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Keywords: photonic crystals, polymer blends, self-assembly, light amplification

Photonic crystals are materials with a periodically varying refractive index in one or more dimensions. This causes unusual light interactions, such as wavelength and angular transmission dependence. Consequently, these structures serve as optical filters, waveguides, and optical logic gates.

Self-assembly methods for preparing photonic structures are widely studied because, unlike conventional lithography, they enable economical large-scale production. Phase segregation and structuring during solvent evaporation in heterogeneous polymer mixtures have been explored. However, few studies describe the optical properties of the resulting structures, particularly in PS-PMMA systems. Our research demonstrates that altering the relative polymer concentrations controls the size of the resulting photonic structures. This enables a tunable photonic crystal platform, which we evaluated using light amplification techniques to achieve amplified spontaneous emission, random lasing, and well-defined structures facilitating single-frequency narrow-band emission.

This work establishes a new branch of photonic crystal synthesis. The findings open further investigation into how parameters like interfacial tension and solvent evaporation rate impact structure size and morphology, ultimately providing a long-sought tool for the straightforward, tailored fabrication of photonic structures.

Stability and Self-Cleaning Properties of Superhydrophobic Glass Coated with Halloysite Clay Nanotubes, Titanium Dioxide, and Silver-Titanium Dioxide Nanocomposite

Materials of the Future

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Keywords: Self-cleaning, superhydrophobic surfaces, spray-coating, halloysite nanotubes

Nature provides remarkable examples of surfaces that strongly repel water, such as lotus leaves and insect wings, which remain clean due to their micro and nonoscale structures. Inspired by this natural phenomenon, researchers are developing superhydrophobic materials that mimic such structures to achieve similar anti-wetting and self-cleaning properties.

Although titanium dioxide-based coatings are widely studied for anti-wetting coatings, they often have limited stability during sunlight exposure. The integration of abundant, low-cost halloysite nanotubes (HNTs) with titanium dioxide and silver-titanium-dioxide offers a promising alternative to fabricate a robust and eco-friendly multifunctional coatings, yet this approach remains underexplored.

Superhydrophobic nanostructured coatings fabricated using titanium dioxide, silver-coated titanium dioxide, and halloysite clay nanotubes achieved a contact angle of 159.35° ±2.7° and a sliding angle of 8°, demonstrating excellent stability and self-cleaning properties.

The use of scalable and low-cost nanotubes through a simple spray-coating process provides a more environmentally friendly alternative to conventional fabrication of anti-wetting surfaces. The demonstrated durability under harsh physical, chemical and thermal conditions highlights the coating's suitability for practical applications. These findings advance the design of multifunctional coatings and support future development toward industrial adoption.

STRAIN TUNABILITY OF G-FACTORS AND 18-BAND K·P DESCRIPTION FOR SELECTED HALIDE PEROVSKITES

Materials of the Future

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Keywords: perovskites, g-factor, strain, kp model, DFT

Condensed matter physics seeks to understand how electromagnetic interactions determine material properties. Semiconductor physics focuses on modeling halide perovskites, crystalline compounds that have attracted tremendous interest [1] for solar cells [2], LEDs, and photodetectors due to their exceptional optoelectronic properties. A key parameter for spintronics is the Landé g-factor, which describes how electron spins respond to magnetic fields.

Despite extensive research on perovskites for photovoltaics, accurate descriptions of their magnetic response remain incomplete. Previous models were too simplified to capture band structure complexity or strain effects on spin. This study addresses this gap by developing an 18-band k·p model for $CsPbX_3$ perovskites (X = Br, Cl, I), parameterized using density functional theory calculations.

We demonstrate that the 18-band model significantly improves agreement with experimental g-factor values and reveal substantial strain tunability – the absolute change from unstrained values exceeds 0.75 for certain compounds and deformation modes.

These findings establish strain engineering as a practical tool for controlling spin properties in perovskite materials, advancing their potential for spintronic devices and quantum technologies [3] where precise magnetic response is essential. The enhanced theoretical understanding enables more accurate predictions of electronic, spin, and optical properties needed for next-generation applications.

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Structural, Mechanical and Optical Performance of $PbTiO_3$ Reinforced Polyester Nanocomposites

Materials of the Future

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Keywords: nanocomposites, lead titanate, polyester matrix, sol-gel synthesis

Polymer matrix ceramic nanocomposites are studied because nanoscale ceramic fillers can enhance the mechanical and functional behavior of polymers. Polyester reinforced with ferroelectric lead titanate ($PbTiO_3$) nanoparticles is a promising system due to the stability and electrical properties of $PbTiO_3$ combined with the lightweight nature of the polymer. $PbTiO_3$ nanoparticles were synthesized via a sol–gel process and incorporated into polyester by solution casting at different filler contents. X-ray diffraction confirmed the formation of crystalline $PbTiO_3$ with an average crystallite size of 45.84 nm. Scanning electron microscopy showed dispersion of nanoparticles within the polymer matrix, with partial agglomeration at higher loadings. Fourier transform infrared spectra displayed Ti-O-Ti and Pb-O vibrational bands, verifying the presence of $PbTiO_3$ within the composite. Mechanical testing revealed that nanoparticle loading influenced polymer behavior. Tensile strength increased from 25.63 MPa for neat polyester to 28.13 MPa at 2 wt.% $PbTiO_3$, while elongation at break increased from 4.53% to nearly 14%, indicating improved ductility. Higher filler content reduced strength, likely due to agglomeration and weaker interfacial bonding. Optical measurements showed light absorption improved by approximately 104% compared with neat polyester. Polyester/ $PbTiO_3$ nanocomposites with low nanoparticle content demonstrate potential for lightweight structural, coating, and optoelectronic applications.

STRUCTURE AND MECHANICAL PROPERTIES OF A NEW HIGH-ENTROPY ALLOY $Al_{12}Co_{27}Cu_{7}Fe_{27}Ni_{27}$ PRODUCED BY INDUCTION MELTING

Materials of the Future

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Keywords: high entropy alloys, induction melting, casting, microstructure

High-entropy alloys (HEAs) are a relatively new group of materials whose rapid development began in 2004. Early studies already demonstrated that such materials may exhibit interesting properties and therefore constitute a potential alternative to currently used engineering materials.

One of the promising materials in this group is the AlCoCuFeNi alloy, which exhibits very good corrosion resistance and favorable magnetic properties. However, alloys of this type are difficult to manufacture due to the presence of elements with a very wide range of melting temperatures. In this work, the authors present the results of investigations of a new alloy, Al12Co27Cu7Fe27Ni27, based on this system but characterized by a different structure and properties. The alloy was produced using a semi-industrial induction melting process with specially adapted technology, which constitutes one of the general objectives of the research.

The developed alloy exhibits a single-phase structure with large grains (average size of approximately 1.5 mm). In contrast to the equiatomic alloy, it shows very good plasticity during a static tensile test, reaching up to 110% elongation to failure, compared with only 0.9% elongation observed for the equiatomic alloy.

The conducted studies demonstrate that non-equiatomic high-entropy alloys may also exhibit attractive properties and represent a promising research direction. Even such a complex alloy can be successfully produced using industrially applicable methods, which may open the way for wider application of these materials.

Synthesis of Methacrylated Sodium Alginate as a New Material for Volumetric Printing

Materials of the Future

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Keywords: alginate, hydrogel, 3D printing, volumetric

Volumetric 3D printing is an alternative to classic layer-by-layer fabrication, enabling fast, single-step fabrication of complex structures. Sodium alginate is widely used in biomedical engineering due to its biocompatibility, yet its limited photo-responsiveness restricts its application in light-based volumetric printing [1]. To address this limitation, this work develops methacrylated alginate using glycidyl methacrylate as the functionalizing agent as a new volumetric-printing material. To date, volumetric printing has been demonstrated mostly with acrylates, thiol-enes, epoxies, and gelatin inks.

The study optimizes the synthesis to enhance degree of substitution (DS) and evaluates the material as a photoreactive ink. In optimized conditions, the modified alginate reached a DS of 44% compared to 18,7% and 25% reported previously [2, 3]. ALGMA inks at 2–4% (w/v) were assessed for printability. Preliminary tests in DLP-printer showed that the 2% ink cured rapidly and exclusively within illuminated regions, with complete polymerisation in ~3 s. The absence of off-target polymerization and the uniform curing profile indicate sufficient optical clarity for controlled light propagation, confirming suitability for volumetric fabrication.

To our knowledge, no methacrylated alginate system has been validated for volumetric fabrication. This synthesis provides a new platform for volumetric and emerging 4D biofabrication.

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THERMOSENSITIVE PNIPAM HYDROGEL MATERIALS: FROM MICROSPHERES TO COAXIAL 3D PRINTING

Materials of the Future

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Keywords: thermoresponsive hydrogels, PNIPAm, membrane emulsification, coaxial 3D printing

Thermosensitive hydrogels have attracted significant interest in recent years due to their ability to change their physicochemical properties as a response to temperature. One of the most commonly studied thermosensitive polymers is poly(N-isopropylacrylamide) (PNIPAm), which shows a characteristic lower critical solution temperature (LCST), causing reversed structural changes in hydrogels. Because of this property, is widely used in biomedical materials and smart hydrogel systems.

The study presents the development of PNIPAm based hydrogel materials at different structural scales: from microspheres to 3D printed structures. In the first stage, membrane emulsification was used to produce polymer microspheres with a controlled size distribution. The morphology and size distribution were analyzed using optical microscopy and a particle size analyzer based on laser diffraction.

Next, PNIPAm hydrogels were used for coaxial printing of tubular structures. The outer layer uses thermosensitive material, while the core contained Pluronic F127. The structures were characterized using optical microscopy and scanning electron microscopy. Microrheology and cytotoxicity tests were also performed.

The results confirm that PNIPAm hydrogel materials, both in the form of microspheres and 3D printed structures, show clear changes in shape under the influence of temperature.

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Tuning Mesomorphic, Spectral and Nonlinear Optical Behavior in Chalcogenophene Triads: the Role of Oxygen, Sulfur, and Selenium

Materials of the Future

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Keywords: liquid crystals, chalcogenophenes, fluorescence, nonlinear optics

Chalcogenophene-based liquid-crystalline materials are promising functional systems due to the combination of self-organization, tunable electronic structure, and attractive optical properties. In this work, we present a series of rod-like bichalcogenophene derivatives incorporating furan, thiophene, or selenophene units and different terminal substituents. The aim of the study was to determine how heteroatom exchange and peripheral modification affect molecular organization, mesomorphic behavior, and optical response.

The compounds were synthesized using modular coupling-based strategies and characterized by spectroscopic methods, thermal analysis, and polarized optical microscopy. Their absorption and fluorescence properties were examined together with phase behavior to establish structure-property relationships across the series. The results show that both the chalcogen atom and terminal functionality strongly influence mesophase formation, thermal stability, and emission characteristics. Sulfur- and selenium-containing analogues exhibit more pronounced mesomorphic behavior than the corresponding oxygen derivatives. In addition, preliminary nonlinear optical studies indicate that these materials may also display promising NLO activity, further expanding their functional potential.

Overall, the presented results highlight bichalcogenophene-based mesogens as versatile platforms for the development of multifunctional soft materials combining liquid-crystalline order, luminescence, and nonlinear optical response.

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Green Transformation

ORAL PRESENTATION

BEYOND THE MERIT-ORDER: POWER PRICE AND DISPATCH IN THE POLISH DAY-AHEAD POWER MARKET

Green transformation

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Keywords: day-ahead electricity market, negative power prices, merit-order, Poland

The merit-order principle is a widely used heuristic for explaining the price formation in liberalized power markets in Europe. It assumes that the day-ahead price of the electricity is set by the power plant with the highest marginal cost, needed to meet the demand.

However, in case of the polish market around 70% of power is traded as OTC (Over The Counter), therefore the day-ahead price does not fully reflect the power dispatch, since many units are scheduled independently from the market signals This study identifies the anomalies in price formation taking into account actual dispatch of individual units and historical bidding curves. A particular interest is devoted to large combined heat and power units, which are mainly dispatched based on the heating demand. The research shows that higher participation in the market and increased load-following flexibility could decrease the day-ahead prices.

The findings justify the importance of introducing the power trading obligation (pol.obligo giełdowe) planned for July 2026 and the value of transparency in the power market.

Biopolymer Materials with Increased Resistance to UV Radiation

Green transformation

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Keywords: polylactide, UV radiation, biopolymers, thermoplastics

In response to increasing ecological awareness, interest in biomaterials such as polylactide (PLA) is growing. PLA is a biodegradable, thermoplastic polymer that is widely used in such fields as medicine (e.g., absorbable surgical sutures), agriculture, and the packaging industry [1]. However, PLA is sensitive to UV radiation, which significantly limits its use in conditions of exposure to atmospheric factors due to the deterioration of its mechanical properties as a result of the degradation of the polymer's molecular structure [2].

The main goal of the research was to determine if organosilicon derivatives with benzophenone groups could serve as a remedy to this problem [3, 4]. Additionally, the ground raw sunflower shells were used as the natural filler.

The results demonstrate that some of these derivatives can effectively influence the resistance to atmospheric conditions. This can be seen as no decrease or a slight decrease in impact strength and tensile strength after a controlled aging process in an aging chamber, while, for reference, a significant decrease in these values was observed. This confirms that benzophenone and its derivatives can be successfully used as UV-blockers for biopolymers and could lead to new applications for PLA.

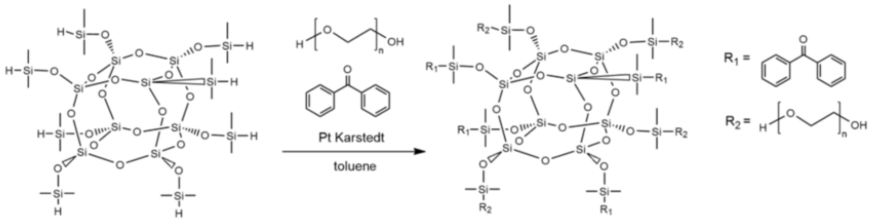

Fig. 1. The synthesis of the hydrogenosilicate derivative

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Chitosan-Polyphenol Based Films Containing Berberis Vulgaris Fruits Extract: Preparation and Characterization

Green transformation

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Keywords: chitosan, *Berberis vulgaris*, polyphenols, active packaging

Biopolymer-based materials are increasingly considered as sustainable alternatives to conventional plastic packaging. Among these materials, chitosan has attracted considerable attention due to its biodegradability, biocompatibility, and excellent film-forming ability [1]. The incorporation of plant-derived polyphenols into chitosan matrices can enhance the physicochemical and functional properties of active packaging materials [2]. In this study, a polyphenol-rich extract from *Berberis vulgaris* fruits, obtained using NADES is incorporated into chitosan matrices to fabricate composite films through the solvent-casting technique. To evaluate the effect of different components on film properties, films based on pure chitosan, chitosan containing NADES, and films enriched with *B. vulgaris* extract are investigated. Mechanical properties are analyzed to determine tensile strength and flexibility, while the release behavior of polyphenolic compounds is examined in different food simulants, including aqueous and ethanolic media (10%, 20%, and 50%). The obtained results indicate that the presence of NADES and plant extract influences the mechanical strength of the films and enables controlled diffusion of bioactive compounds. Further characterization, including FTIR, SEM analysis, antioxidant and antimicrobial activity tests is employed to investigate molecular interactions and the functional performance of the developed films. This study provides insight into structure-property relationships of chitosan-polyphenol-based films and highlights their potential as biodegradable active packaging materials.

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Economic Viability of Pumped-Storage Hydropower Under Wind and Solar Expansion in European Day-Ahead Electricity Markets

Green Transformation

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Keywords: Price arbitrage, pumped-storage hydropower, renewable energy, day-ahead markets

The rapid growth of wind and solar generation is reshaping European day-ahead price patterns, increasing flexibility needs while changing the revenue potential of long-duration storage. Pumped-storage hydropower (PSH) is a leading flexibility option, yet its economic viability under renewable expansion remains unclear. This study evaluates the arbitrage value of hybridizing PSH with co-located wind and PV across 28 European countries under 2024 market conditions. A mixed-integer linear programming model co-optimizes hourly dispatch of a 1 MW PSH unit with co-located renewable generation. Results show that: (1) under 2024 day-ahead price conditions, break-even investment remains below typical new-build PSH costs in all examined countries, suggesting that energy-only arbitrage alone was insufficient to support new PSH without additional revenue streams. (2) Profit-maximizing configurations are typically reached at moderate co-located capacities, with PV-leaning or balanced mixes outperforming wind-heavy ones; Sweden and Norway are least profitable, whereas Bulgaria, Greece, Hungary, and Romania perform best. (3) Storage-duration sensitivity shows strong diminishing returns: the median gain in break-even investment is about 35% when extending duration from 2 to 3 h, but falls to only about 2.5% per added hour beyond 6 h. These findings provide a cross-country benchmark for PSH valuation in high-renewable power systems.

FAULT TOLERANT CONTROL FOR MICROMOBILITY

Green Transformation

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Keywords: micromobility, fault tolerant control, brushless DC motors

Significant part of a green transformation is transport based on electric energy, which is locally zero-emission. Electromobility is not only electric cars as it is frequently thought, but also multitude of capsule vehicles, for instance, scooters and hoverboards. In such applications, BLDC motors are mostly used, and that is the reason why safe operation of these drives is so important.

Brushless DC motors are simple machines that convert an electric energy into a rotational speed of the shaft. In opposition to simple DC motors BLDC motors do not contain brushes, which are considered to be a weak point of the drives. Whereas, registering position of the shaft is required. Fault tolerant control of BLDC motor in case of position sensor error consists of an estimation the position using remained sensors. Unsophisticated algorithm of detection sensors fault and estimation of wanting information can be implemented in low-cost microcontroller. Such an additional solution enables sustained operation of any BLDC drive.

Increasing the Efficiency of Photovoltaic Installation by Utilizing Lost Energy for Thermal Purposes

Green Transformation

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Keywords: PV installation, efficiency improvement, waste energy, CHP

The growing demand for energy and the need to reduce greenhouse gas emissions have increased interest in renewable energy sources. Among them, photovoltaic technology is widely used for decentralized electricity generation in residential buildings, making the improvement of PV system efficiency an important research topic in sustainable energy systems.

This study investigates methods for increasing the efficiency of a photovoltaic system designed to meet the electricity demand and partially support domestic hot water preparation in a single-family house. The research is motivated by the possibility of utilizing energy that is typically lost due to the inverter activation threshold, thereby improving the overall performance of the system.

Laboratory measurements of photovoltaic module parameters under variable irradiance conditions were conducted to assess the influence of solar radiation intensity, and the presence of a charge controller on the energy yield.

The results indicate that an appropriately designed PV installation, combined with the use of otherwise unused low-power energy for thermal purposes, can increase overall system efficiency and improve economic performance. These findings support the development of integrated residential energy systems that combine electricity generation with thermal energy utilization, enabling more efficient use of renewable energy.

Microbiome-Driven Nutrient Mobilization from Agro-Industrial Waste Streams through Plant–Microbe Interaction Scenarios for Biofertilizer Development

Green Transformation

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Keywords: Agro-industrial waste valorization, plant growth-promoting rhizobacteria (PGPR), rhizosphere microbiome, nutrient mobilization, circular nutrient cycling, biofertilizer formulations

Agro-industrial wastes are substantial reservoirs of macro- and micronutrients; however, conventional waste management often removes valuable biological fractions, exacerbating soil nutrient depletion and limiting crop productivity. Plant growth-promoting rhizobacteria (PGPR) offer a promising strategy for nutrient recycling through microbiome-based biofertilizer formulations that enhance nutrient bioavailability and plant performance.

This study investigates rhizosphere microbiome dynamics in plants supplemented with waste-derived nutrient sources – blood & bone meal, spent mushroom substrate, coffee grounds, feathers, ash, and biochar – combined with PGPR inoculants introduced via two strategies: soil colonization and plant-mediated infection. The research addresses the gap between the intrinsic nutrient potential of agro-industrial residues and their effective utilization to restore soil fertility. We hypothesize that integrating waste-derived nutrient matrices with functionally selected microbial consortia will create favorable conditions for plant growth and nutrient mobilization.

Current work focuses on high-throughput screening of key PGPR functional traits, including IAA biosynthesis, ACC deaminase activity, and Zn and K solubilization, to identify candidate strains for biofertilizer development.

The obtained results will enable targeted selection of multifunctional strains for evaluation with diverse waste substrates. Planned pot experiments will determine optimal strain–substrate combinations under both inoculation scenarios. Ultimately, this project aims to establish performance criteria for waste-specific biofertilizer formulations, advancing microbiome-based strategies that support sustainable nutrient cycling and a circular bioeconomy in agriculture.

Next-Generation Sequencing Strategies For Drought-Resilient Crops: Insights From Rye Genomics

Green Transformation

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Keywords: next-generation sequencing, drought tolerance, molecular breeding, high-performance computing

Climate instability and increasing frequency of drought events are reshaping global agriculture and threatening food security. Sustainable agricultural systems, aligned with the European Green Deal, depend on developing climate-tolerant, disease-resistant crops that require fewer inputs of energy and water. Advances in next-generation sequencing (NGS) have transformed crop breeding by enabling genome-wide insights into genetic variation and stress responses.

Wild relatives of crops represent a largely untapped source of genes and traits for stress tolerance. Rye remains particularly valuable, as its natural resilience has long contributed to the improvement of major cereal crops. To investigate this potential, we conducted single-nucleotide–level analysis of genetic diversity and drought-responsive gene expression in wild and cultivated genotypes generating large-scale DNA and RNA sequencing datasets that require substantial computational resources.

GPU-accelerated bioinformatic pipelines running on the high-performance computing infrastructure of the Wrocław Centre for Networking and Supercomputing enabled efficient whole-genome analysis and demonstrated that rye constitutes a valuable reservoir of genetic diversity and drought-adaptive traits for molecular breeding.

These findings bridge genomics, agriculture and high-performance computing, highlighting the potential of wild rye for developing climate-resilient crops. Our work demonstrates how NGS-driven biotechnology can accelerate crop improvement and contribute to sustainable agricultural systems under environmental change.

OPTIMIZATION OF FUNGAL CELLULASE-MEDIATED TEXTILE WASTE VALORIZATION

Green Transformation

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Keywords: fungal cellulase, textile waste, cotton-polyester blends, circular economy

The abundance of textile waste around the world has raised environmental concerns and highlighted the urgent need for innovative circular solutions in the textile sector. Cotton-polyester blends are among the most widely used textile materials, with cotton accounting for more than one-third of total textile waste. A biotechnological approach focused on cellulolytic enzymes enables the selective and efficient processing of cotton-polyester textile waste. This study explores the optimisation of cellulase production from textile waste using three different strains of Aspergillus mold. Cotton-polyester textile blends with varying ratios were used as low-cost substrates for both solid-state cultivation and submerged fermentation in three different nutrient media. The Mandels–Weber medium was identified as the most effective for cellulase production. The cellulases produced by the selected fungal strains were extracted and applied to the enzymatic hydrolysis of textile waste, converting cellulose into fermentable sugars and enabling the recovery of polyester fibers suitable for reuse. This work demonstrates the potential for a viable biotechnological pathway for the valorisation of mixed textile waste. By generating fermentable sugars and recovering synthetic fibers simultaneously, the presented approach supports resource efficiency and contributes to the advancement of circular economy strategies in the textile industry.

Performance Analysis of Thermal Energy Storage Materials and Working Fluids in ORC System Under Various Operating Conditions

Green Transformation

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Keywords: ORC, TES, power generation, fluctuating energy sources

Intermittent and fluctuating heat sources, such as waste heat or solar thermal energy, pose integration challenges in energy systems due to mismatch between supply and demand. To mitigate this variability, thermal energy storage (TES) can temporarily store excess of energy during surplus periods for later use when demand exceeds supply. Among possible applications, it can be used with organic Rankine cycle (ORC), which may be applied in low and medium temperature range, and is especially competitive when compared to conventional power cycles in a small scale. While share of the photovoltaics and wind-based power increases, the heat-based cycles (such as ORC) will remain an important fixture of the energy mixture, especially accounting for the waste heat.

This study presents the results of the modeling simulation of ORC system integrated with TES. The simulation was conducted for charging and discharging process under various operating conditions. The comparison was made between various types of storage materials and working fluids, to facilitate the method of their selection. The results obtained will help in their integration with fluctuating energy sources.

Quantifying Urban CO_2 Sinks: Advances in In-Situ Observations, Remote Sensing, and Biospheric Modeling

Green Transformation

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Keywords: urban CO_2 sinks, eddy covariance, remote sensing, climate neutrality

Urban green spaces, such as parks, street trees, and unmanaged vegetated patches, play a vital role in maintaining the environmental health of cities by absorbing carbon dioxide from the atmosphere. While cities are widely recognized as major sources of emissions, these “green lungs” act as natural carbon sinks that help mitigate the local carbon footprint. However, the exact amount of CO_2 captured by urban vegetation remains difficult to quantify, due to the complex mixture of biogenic and anthropogenic signals originating from traffic and industrial activities. This review synthesizes recent advances in the quantification of urban carbon sinks using *in situ* flux measurements, remote sensing, and biospheric modeling approaches. Our analysis of case studies from Łódź, Berlin, and Barcelona shows that combining data from different measurement techniques, such as LiDAR and ground-based eddy covariance observations, can effectively reduce uncertainties in carbon accounting. These findings contribute to the advancement of the field and provide urban planners with tools to assess progress toward climate neutrality by 2050 on the basis of empirical data rather than generalized estimates.

ROOFTOP SOLAR: INSTALLATION PRACTICES IN TANZANIA

Green transformation

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Keywords: Rooftop Solar, installation practices, energy storage, cost reductions

The transition toward renewable energy has positioned rooftop solar systems as effective solutions for reliable and sustainable power generation. By combining photovoltaic modules, battery energy storage, and limited grid connectivity, these systems reduce dependence on conventional electricity sources and enhance energy autonomy. However, inconsistent installation practices and sizing methods can affect overall performance and cost efficiency.

Evaluations of rooftop solar systems (4.96 -8.77KW,5.12 -20kWh storage) in Tanzania revealed that, at an electricity cost of USD 0.14/kwh, adopting solar reduced expenses by 70–98%. With an average investment of USD 9,600 per system, the setups achieved a 4–5 year payback and an LCOE of about USD 0.08/kWh is about 40% lower than the grid tariff, demonstrating strong economic performance and durable energy reliability.

Hybrid inverters were grid-linked but operated in non-exporting modes, demonstrating strong performance even without feed-in incentives. System efficiencies improved with proper alignment of panel capacity and storage sizing, enabling users to minimize grid dependency while maintaining stable power availability.

The findings confirm that well-designed rooftop solar systems significantly decrease energy expenditure, while improving reliability. Establishing standardized installation and monitoring practices could further optimize system output and support large-scale adoption in urban and semi-urban settings. Such solar solutions represent a practical pathway toward resilient, low-carbon, and self-sustaining energy infrastructures.

The Role of Clustering and Dimensionality Reduction in Methane PLUME Detection Using Hyperspectral Data

Green Transformation

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Keywords: minimum noise fraction, matched filter, background modeling

As part of the Paris Agreement, the European Union committed to becoming the first climate-neutral society by 2050. The Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS) were introduced to support this goal. These efforts respond to the urgent need for improved monitoring and reduction of greenhouse gas emissions, particularly in light of the continuous rise in atmospheric concentrations. Despite advancements in detection algorithms, accurately determining the spatial extent of gas plumes remains a significant research gap. This study attempts to assess the impact of data clustering in a reduced dimensional space on the effectiveness of methane detection using a columnwise matched filter. An important aspect of this research is the comparison of background modeling based on both Principal Component Analysis (PCA) and the Minimum Noise Fraction (MNF) transform. The proposed methodology involves performing image clustering based on these techniques, which aims to extract homogeneous land cover classes and enable a more precise estimation of background statistics. The results verify the hypothesis that adaptive background modeling based on such identified clusters allows for a more effective elimination of false positives and improves the precision of mapping the gas cloud boundaries.

The Role of Pumped Hydro Storage in the Context of Poland's Energy Transition

Green Transformation

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Keywords: energy transition, pumped hydro storage, power system flexibility, renewable integration

Poland's power sector is undergoing a fast transition as variable renewables expand and coal's role declines. In such systems, maintaining reliable and affordable electricity increasingly depends on flexibility resources that can manage short-term volatility and seasonal peak-risk.

This research reviews Poland's transition pressures and the role of storage as a flexibility portfolio in recent years, focusing on two observable stress signals: rapid growth of renewable curtailment and rising winter-peak adequacy sensitivity under electrification. The motivation is that annual energy shares can mask stress-hour constraints that determine costs and security of supply.

The main finding is that Poland's emerging bottleneck is a joint flexibility–adequacy constraint, evidenced by curtailment rising from 8.4 GWh in 2022 to about 1,378 GWh in 2025, alongside increasing winter-peak exposure.

In this context, pumped hydro storage (PHS) remains strategically important as Poland's only system-scale storage technology in meaningful energy volumes (about 8 GWh total storage energy, with more than 90% provided by PHS), while battery storage can scale faster to provide short-duration balancing and fast-response services. These results support protecting and modernizing PHS for multi-hour shifting and adequacy-grade support, scaling batteries for short-duration services, and enabling bankable revenue stacking aligned with grid constraints and curtailment.

TRANSPARENT BIPV SYSTEMS IN THE ENERGY TRANSITION OF PUBLIC BUILDINGS IN TEMPERATE CLIMATES

Green Transformation

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Keywords: photovoltaic glazing, energy simulation, energy transition, building-integrated photovoltaics

Contemporary buildings are increasingly designed as active components of the energy system, capable not only of reducing energy demand but also of generating electricity. One emerging approach is the integration of transparent photovoltaic systems (BIPV) into building envelopes, enabling simultaneous daylight provision and on-site energy production.

The performance of such systems depends strongly on climatic conditions and glazing parameters. While previous research has focused mainly on high-irradiance regions, temperate climates remain less investigated. The results are based on a preliminary literature review [1] and annual energy simulations comparing a BIPV glazing solution with conventional glazing in a modelled office room in Poland [2].

The results demonstrate that photovoltaic glazing reduces solar gains by approximately 17%, lowering cooling demand but increasing heating and lighting energy use due to reduced visible light transmittance. A key finding is the achievement of a positive net annual electricity balance in the majority of analysed cases while maintaining thermal comfort within standard limits [2].

These findings confirm the potential of transparent BIPV systems to support the energy transition of public buildings in temperate climates and constitute an initial stage of the ongoing doctoral research conducted by the author.

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UNDERSTANDING POLLUTANT WASH-OFF FROM URBAN FOLIAGE UNDER REAL AND SIMULATED RAINFALL

Green Transformation

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Keywords: air phytoremediation, leaf morphology, precipitation, urban vegetation

Urban vegetation is widely recognized as a nature-based solution for improving urban air quality, as plant leaves capture particulate matter (PM) and associated trace elements (TEs) from the atmosphere. However, this retention is often temporary because rainfall can wash deposited pollutants from leaf surfaces. Understanding rainfall-driven wash-off is therefore essential for accurately evaluating the long-term effectiveness of urban greenery in mitigating air pollution.

Because natural rainfall varies in intensity and duration, many studies use simulated rain to examine wash-off processes, yet the comparability of these methods remains unclear. This study compared the effectiveness of natural and simulated rainfall in removing PM and TEs from 17 plant species – including trees, shrubs, and herbaceous plants – in an urban park in Wuhan, China.

Simulated rainfall generally removed greater amounts of PM and TEs across most plant groups, whereas natural rainfall was more effective for certain evergreen species and was associated with increased foliar Cu and Zn concentrations. Leaf morphological traits, such as surface texture and waxiness, strongly influenced wash-off efficiency.

Overall, the results show that simulated rainfall does not fully replicate natural wash-off dynamics and emphasize the need to incorporate environmental variability when assessing the air pollution mitigation potential of urban vegetation.

WEATHER-DRIVEN ELECTRICITY CONSUMPTION REGIMES IN RESIDENTIAL BUILDINGS: A CLUSTERING-BASED PATTERN ANALYSIS

Green Transformation

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Keywords: electricity consumption, meteorological variables, HDBSCAN clustering, pattern analysis

Weather conditions play a key role in shaping electricity demand dynamics in residential energy systems. Meteorological variations significantly influence household electricity usage patterns. Traditional demand studies often rely on aggregated or linear approaches that may fail to capture complex and non-linear consumption regimes associated with changing meteorological conditions. Most existing studies apply clustering techniques such as K-means, while density-based algorithms that automatically determine the number of clusters, such as HDBSCAN, are rarely applied in electricity demand research. In addition, relatively few studies directly include meteorological variables such as clustering inputs. This study aims to identify hidden electricity consumption regimes dential electricity consumption data for Vancouver, Canada, with 29,231 hoassociated with meteorological conditions. The analysis uses the Hourly Energy Usage: Buildings in British Columbia dataset from Kaggle, containing three years of resiurly observations. Electricity consumption together with meteorological variables, including humidity, atmospheric pressure, and weather conditions, were used as clustering inputs. After removing days with gaps longer than one hour and duplicate records, the HDBSCAN unsupervised clustering algorithm implemented in Python identified distinct consumption regimes. The results reveal multiple weather-dependent electricity demand patterns. They highlight the usefulness of density-based clustering for improving electricity demand analysis and forecasting.

Green Transformation

POSTERS

Advancing Microplastics Characterization through Digital Image Processing Using Vector-Based Fractal Dimension Analysis

Green Transformation

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Keywords: Microplastics, Structural complexity, Fractal dimension, Resolution-independent geometry, Vector-based morphology

Microplastic characterization in municipal tap water has largely focused on particle abundance, polymer composition, and size distribution, while geometric structural complexity remains insufficiently quantified. This study investigates structural complexity as an additional morphological descriptor for microplastics isolated from municipal tap water in Wroclaw, Poland. Tap water samples were collected from 5 residential buildings following standardized flushing protocols and processed using oxidation digestion, density separation, and vacuum filtration. Retained particles were imaged using scanning electron microscopy (SEM). Particle contours were manually vectorized into scalable vector graphics (SVG) format and reconstructed using cubic Bézier curves to enable resolution-independent arc length computation. Structural complexity was quantified using fractal-derived metric defined as the ratio between integrated contours length and end-to-end distance. Results indicate that fibre class particles generally exhibit low and narrowly distributed FD values, consistent with near linear geometries, whereas fragment class particles display higher and more variable complexity, reflecting irregular and degraded morphologies. These findings suggests that particle type influence geometric irregularity and demonstrate the feasibility of incorporating vector-based geometric analysis into MPs morphology assessment. Th propose workflow provides a reproducible approach for quantifying particles complexity in microplastics research.

Aquatic Macrophytes Exposed to Ibuprofen: From Physiological Stress to Phytoremediation Potential

Green Transformation

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Keywords: ibuprofen, macrophytes, phytotoxicity, phytoremediation

Ibuprofen (IBU) is one of the most widely used pharmaceuticals, and it is frequently detected in municipal wastewater. Conventional sewage treatment systems have been found to be ineffective in completely removing IBU, resulting in its continuous release into surface waters. While numerous studies have documented the toxic effects of IBU on aquatic animals, knowledge regarding its impact on aquatic plants remains limited. This study evaluated the effects of different IBU concentrations (5, 10, 20 and 50 mg/L) on three species of aquatic macrophytes: *Lemna minor*, *Elodea canadensis*, and *Myriophyllum spicatum*. During a three-week exposure experiment, plant growth and physiological responses were analyzed, including biomass production, chlorophyll a and b content, and total protein concentration. Preliminary results indicate that IBU negatively affects growth and metabolic parameters of the studied aquatic plants. However, among the tested species, *Lemna minor* showed the highest tolerance, maintaining active growth even at a concentration of 20 mg/L. Subsequent research will examine whether floating macrophytes can not only tolerate, but also absorb or transform IBU. Confirmation of active IBU degradation would support the potential use of aquatic macrophytes in nature-based systems aimed at reducing pharmaceutical pollution.

Beyond Zero: Biomethane-Fueled Allam Cycle for Negative Emissions and Noise Reduction in Maritime Transport

Green Transformation

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Keywords: Mobile BECCS, Allam Cycle, Maritime Transport, Hydroacoustic Pollution

The maritime transport sector faces an urgent need to decarbonize to meet the IMO 2050 strategy and the Fit for 55 package goals. Current alternative fuels, such as LNG and methanol, only reduce greenhouse gas emissions and are considered merely transitional solutions. Furthermore, traditional low-speed piston engines generate significant underwater noise pollution, severely impacting marine ecosystems as recognized by the Marine Strategy Framework Directive (MSFD). There is a critical research gap regarding integrated propulsion systems that not only eliminate emissions but actively remove carbon dioxide while mitigating hydroacoustic pollution. This feasibility study proposes replacing conventional marine engines with a supercritical Allam–Fetvedt cycle fueled by liquefied biomethane, aiming to achieve negative emissions (Mobile BECCS) and a drastic reduction in underwater noise. By coupling a closed-loop supercritical CO_2 turbine with pure oxygen combustion, the system inherently captures 100% of carbon emissions without energy-intensive scrubbing. This approach advances the field by shifting the maritime decarbonization paradigm from “zero-emission” to “negative-emission”, offering a holistic solution that addresses both climate change and marine environmental protection.

Changes in Nocturnal Air Temperature Trends in Poland

Green Transformation

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Keywords: night-time air temperature, climate change, building energy demand, diurnal temperature range

Climate change influences air temperature patterns that affect environmental conditions and energy use in buildings. Differences between daytime and night-time temperatures play an important role in passive cooling and thermal comfort strategies.

However, long-term changes in nocturnal air temperature trends in Poland remain insufficiently quantified, despite their potential impact on building energy performance.

Here we show long-term trends in night-time air temperature based on meteorological observations from 5 locations across Poland.

Analysis of historical air temperature records reveals a consistent increase in minimum daily temperatures over recent decades. This increase is accompanied by a gradual reduction in the diurnal temperature range, indicating that night-time temperatures rise faster than daytime temperatures in several locations. The observed trends suggest changing thermal conditions during night hours, which may reduce the effectiveness of passive night cooling strategies in buildings.

These findings highlight the importance of considering changing nocturnal temperature patterns in climate-responsive building design. Understanding trends like that supports the design of energy-efficient buildings and their HVAC systems.

Cold Wind Droughts: When Low Wind Power Events Meet High Winter Electricity Demand

Green Transformation

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Keywords: variable renewable energy, shortage events, energy meteorology, power system resilience

In future power systems dominated by variable renewable energy (VRE), weather conditions will play a crucial role in shaping electricity generation. Photovoltaic generation is limited in winter, while wind turbines typically generate relatively more electricity. Despite this seasonal complementarity, prolonged periods of low wind and solar generation can occur, known as VRE droughts.

In Poland, winter electricity demand is strongly correlated with low temperatures. Moreover, the growing use of heat pumps and electrode boilers further increases this temperature sensitivity. Therefore, analysing periods of low wind generation coinciding with cold events (*cold wind droughts*) is essential for assessing the risk of critical energy shortages.

Analysis of historical wind generation and population-weighted temperature data for Poland (2016–2019) shows that the longest wind drought lasted 7–8 days and occurred in late July 2016, while the longest cold wind drought lasted 2–3 days. In addition, at temperatures between 0–5°C and below 0°C, the probability of wind drought occurrence reaches 12.7% and 23%, respectively.

The results further indicate that even relatively short cold wind drought events may pose a risk during winter periods of elevated demand. They should therefore be considered in future power system resilience assessments.

This work was supported by the National Science Centre (Narodowe Centrum Nauki) as part of project no. 2022/47/B/ST8/01113 titled: Method to quantify the energy droughts of renewable sources based on historical and climate change projections data.

Comparative Analysis of Case Studies of Godrej Group and Ramky Attero: a Perspective on Implementation of Digital Product Passports in Circular Economy

Green Transformation

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Keywords: Circular Economy, Digital Product Passport, Supply Chain, System Dynamics Modelling

The transition toward a Circular Economy (CE) from a linear "take–make–dispose" economic model entails improved material traceability, lifecycle transparency, and systematized stakeholder integration across supply networks. Digital Product Passports (DPPs) have manifested as a digital governance tool capable of enabling such systemic transformation. This study explores the implementation potential of DPPs within the circular economy frameworks of Godrej Group, a diversified Indian conglomerate with strong manufacturing and consumer goods presence, and Ramky Attero, a leading e-waste recycling and resource recovery enterprise in India. The research paper examines how DPPs can function as integrative digital infrastructures integrating upstream production ecosystems with downstream waste recovery systems.

The study adopts a mixed approach comparative analysis of case study approach supported by a system-dynamics-assisted analytical framework. DPPs are postulated as dynamic digital repositories that synthesize product-level data including carbon footprint, material composition, origin, repairability, recyclability, reuse potential, and end-of-life pathways. Through contextual scrutiny of Godrej's manufacturing and supply-chain systems along with Ramky Attero's waste processing and material recovery ecosystem, the research estimates how DPP integration could strengthen Extended Producer Responsibility (EPR) compliance, enhance lifecycle transparency, and facilitate closed-loop material flows. Analytical modeling is utilized to map feedback loops between data transparency, regulatory alignment, and circular performance outcomes.

The findings recommend that DPP implementation can significantly lower information asymmetry across value chains, augment regulatory traceability, and boost secondary material recovery rates. Within Godrej's manufacturing ecosystem, DPPs are expected to enhance sustainable product design, eco-labelling, and reverse logistics integration. Within Ramky Attero's recovery operations, DPP-enabled data flows can enhance material identification accuracy, increase recovery yield, and boost resource valuation in secondary markets. The study illustrates that DPP structural dimensions viz: transparency, standardization, interoperability, and stakeholder accessibility are positively interdependent with measurable circularity indicators such as resource recovery efficiency, waste diversion rates, and lifecycle environmental impact reduction.

The research is limited to two organizational case studies within the Indian context, which may afford limited generalizability across sectors and geographies. Notwithstanding, the study contributes to circular economy scholarship by assimilating digital governance theory with industrial sustainability practices. It proposes CE discourse within emerging economies by presenting a dual-perspective model that connects manufacturing-led circularity with waste-recovery-driven circular systems.

For practitioners, which include waste management enterprises, manufacturing firms, and policymakers, the study positions DPPs as a strategic digital architecture for augmenting EPR enforcement, supply-chain traceability, and material flow optimization. It establishes key implementation barriers such as data governance complexity, digital infrastructure readiness, cost of system integration, and multi-stakeholder coordination challenges. The findings afford actionable insights for sectoral standardization initiatives, phased DPP adoption, and public–private digital infrastructure partnerships. By augmenting accountability, transparency, and lifecycle visibility across production and recovery ecosystems, DPPs facilitate responsible consumption, improved recycling systems, and environmental stewardship. With respect to developing economies, such integration strengthens regulatory governance, aids sustainable industrial transformation, and contributes to broader societal transitions toward resource efficiency and ecological resilience.

Concepts for Improving The Energy Efficiency of a Chlorobenzene Production Plant

Green Transformation

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Keywords: energy efficiency, pinch analysis, process simulation

Chlorobenzene production is an important part of the chemical industry, as this compound is widely used as an intermediate in the synthesis of solvents, agrochemicals, and specialty chemicals. The process is based on the exothermic chlorination of benzene and multistage separation in column apparatuses, which involves significant energy consumption and process emissions. Under conditions of increasing regulatory and decarbonization pressure, installations of this type are becoming the subject of optimization analysis.

Although the literature includes studies on heat integration, pinch analysis, and the environmental assessment of chemical processes, there is still no integrated review that applies these tools directly to chlorobenzene production plants.

As a result of the simulations, it was found that the highest energy consumption occurs in the plant's separation section. Heat integration makes it possible to reduce heating energy demand by 30–60%, depending on the assumed boundary conditions.

In a broader context, the conducted research is expected to enable the development of a framework that will provide the basis for future simulation analyses and the quantitative evaluation of modernization scenarios. Reducing energy demand will contribute to the design of more sustainable industrial plants.

From Christmas Trees to Clean Water

Green Transformation

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Keywords: biomass, ethinylestradiol, activated carbon

Water purification has always been a key issue in the field of environmental engineering. Of particular concern is the removal of hormones, including synthetic estrogens, which affect the life of aquatic organisms. In many countries, the concentration of 17α-ethinylestradiol exceeds European water quality standards by several times, and the presence of this hormone has been detected in surface waters on all continents.

Therefore, it is necessary to develop an effective and economically feasible method for its removal. In this study, an adsorbent (activated carbon) was prepared from waste biomass in the form of discarded Christmas trees. Chemical activation was applied separately using either acid or base, and the efficiency of the resulting materials was evaluated through static adsorption experiments. The highest removal efficiency, 30%, was achieved with the sample activated with acid at a 3:1 mass ratio (activator:biomass) without prior carbonization. Moreover, it was found that surface functional groups play a more significant role in adsorption than the development of porous surface area. These results highlight the need for further research on the analysis and modification of surface functional groups, which may allow the production of more efficient activated carbons from low-cost sources in the future.

From Earth to Space: Extremophilic Bioleaching for Sustainable Critical Raw Material Recovery

Green Transformation

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Keywords: metal recovery, bioleaching, extremophilic microorganisms, extraterrestrial resources

Clean Energy Transformation and development of advanced technologies rely on accessibility of critical raw materials, which in the European Union are limited and dependent on imports. To address these challenges, circular economy and biotechnology-based approaches to metal recovery from industrial waste are becoming increasingly important. Alongside the rapid growth of the space industry, research is required on new technologies enabling their *in situ* use in extreme extraterrestrial environments. One of the promising methods is bioleaching using extremophilic microorganisms, naturally adapted to functioning in extreme environmental conditions on Earth.

The aim of the study was to analyse the possibility of recovery of selected critical raw materials from end-of-life lithium-ion batteries and Mars regolith simulant using extremophilic volcanic microalgae. Under laboratory conditions, the potential of bioleaching and metals bioaccumulation was evaluated.

The study has shown that bioleaching with microalgae exhibits significant potential in terms of biotechnological critical raw materials recovery from waste materials as well as from extraterrestrial material. This proves that extremophilic microorganisms-based technologies can support sustainable, low-emission raw materials economy and can provide the foundation for extraterrestrial resource extraction technologies in space in the future.

From Mining Waste to Resources: Assessing the Metal Recovery Potential of Post-Mining Heaps

Green Transformation

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Keywords: mining waste, post-mining heaps, metal recovery, circular economy

The growing demand for mineral resources, driven by the energy transition and the development of advanced technologies, is increasing pressure on primary mineral deposits. At the same time, limited access to new deposits encourages the search for alternative and more sustainable sources of valuable raw materials. In this context, mining waste is increasingly recognized as a potential secondary resource.

Despite Europe's long mining history, many waste heaps remain poorly studied for their resource potential. Evaluating their composition may reveal opportunities for recovering valuable metals while simultaneously reducing the environmental burden associated with long-term waste storage.

The aim of this study was to assess the potential of a selected post-mining heap in Poland as a secondary source of recoverable metals. A sample collected from a waste heap at a former nickel and chrysoprase mine in Szklary was analyzed using scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) to characterize the morphology and elemental composition of the material.

The results confirmed the presence of hematite and gold, indicating the potential for recovering valuable elements from the studied waste material. These findings highlight the importance of mining waste as a secondary resource and support the development of circular economy strategies.

Hourly Water Production Patterns in Polish Utilities: Implications for the Country's Power System

Green Transformation

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Keywords: Water production, Energy demand, Water utilities, Demand-side flexibility

With the growing share of variable renewable energy sources in the Polish power system, the temporal structure of electricity demand becomes increasingly important. While much attention has been devoted to generation-side variability, demand patterns in infrastructure-intensive sectors such as water utilities remain equally relevant in system-level assessments. Using hourly water production data from multiple utilities across Poland, with annual production volumes ranging from 458 to approximately 4000 dam^3, this study analyzes temporal production patterns and examines their alignment with national hourly electricity load. The results show that water utilities exhibit pronounced daily and weekly cycles. Water production patterns display moderate to strong positive correlations with national system load, with Pearson coefficients ranging from 0.27 to 0.67. At the same time, the similarity of temporal profiles across utilities suggests a structurally consistent demand pattern within the water utility sector despite differences in scale. The frequent presence of water storage capacity and potential operational flexibility within water supply facilities, may provide a basis for coordinated demand-side response strategies aimed at improving system flexibility under increasing renewable penetration.

IMPACT OF CATION SYMMETRY ON THE ENVIRONMENTAL BEHAVIOUR OF QUATERNARY AMMONIUM SALTS

Green Transformation

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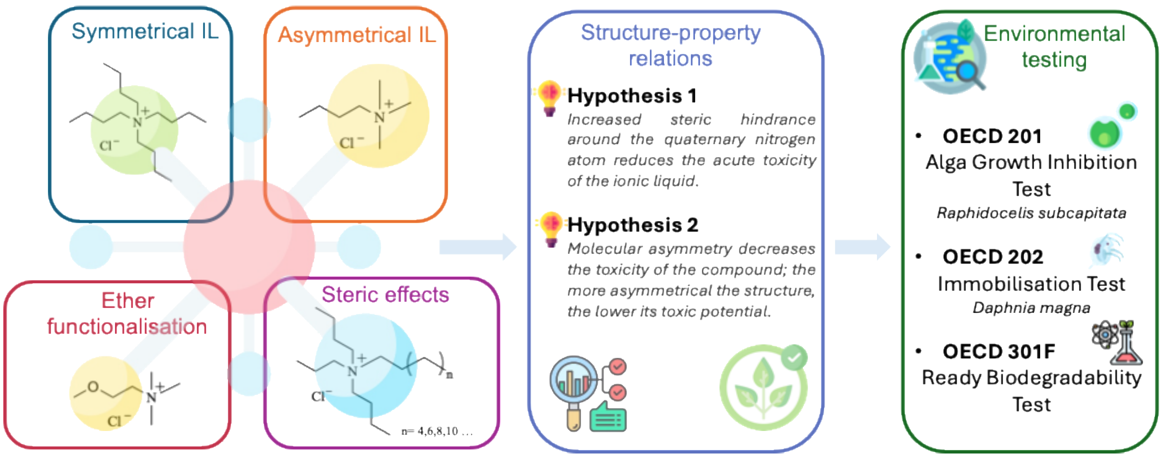
Keywords: Quaternary Ammonium Salts, Toxicity

Sustainable chemical research increasingly prioritises the principles of green chemistry, aiming to minimise environmental impact while preserving functional efficiency. Quaternary ammonium salts (QAS), including ionic liquids, surfactants, and deep eutectic solvents are widely used in numerous industrial sectors. As a result of their extensive and growing use, global consumption of QAS is steadily increasing, leading to their growing presence in wastewater. The environmental persistence and bioaccumulative potential of QAS have raised concerns about their toxicological profiles, making such considerations central to the design and regulatory assessment of these compounds.

Previous studies have largely focused on key structural determinants, including the type of amine core, the length of the alkyl chain, and the type of the anion. Despite the well-characterised development of both symmetrical and asymmetrical QAS, the influence of cationic molecular symmetry on environmental fate and toxicity remains largely unexplored.

In this study, structure-toxicity relationships were investigated with emphasis on cation symmetry as a molecular-level descriptor that modulates environmental behaviour.

Recognising symmetry as a critical structural parameter provides a novel framework for the environmental classification of QAS. Integrating this parameter into rational design strategies may enable the development of quaternary ammonium-based compounds with optimised functionality while minimising ecological risk.



Impact of Ionic Liquid Presence on Piston Expander Efficiency

Green Transformation

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Keywords: pressure expander, Ionic Liquid, waste pressure energy recovery

Gas expanders are main devices which are applied for reducing the gas pressure to the desired level. During the pressure reduction, usually, change of gas temperature occurs, which from thermodynamical point of view is not desired and leads to reduced efficiency. To improve the efficiency of this process, interstage heat exchangers are implemented to bring the outlet gas temperature to inlet temperature level. Here, use of ionic liquid (IL), as a working substance is proposed.

The IL is already industrially applied in piston compressors, where it reduces the temperature change of pressurized gas and eliminates the occurrence of so-called “dead volume” of compressor. Despite industrial application of IL compressors, no research is available on IL implementation in piston expanders.

Proposed research aims to evaluate the impact of IL application in piston expanders on working parameters of machine for various technological gases and fill the existing research gap.

Improved efficiency of the gas expander could lead to increased waste pressure energy recovery in industrial systems which corresponds to reduced demand for primary energy carriers and reduced greenhouse gases emission, furthermore offering economical savings on power consumption.

Ionic Covalent Organic Frameworks as Electrocatalysts for Fuel-Forming Reactions

Green Transformation

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Keywords: covalent organic frameworks, electrochemical carbon dioxide reduction, hydrogen evolution reaction

The development of energy conversion technologies is crucial to reducing the impact of global warming. Electrochemical water splitting and electroreduction of CO_2 are both fuel-forming reactions that can be powered by green energy. However, the practical implementation of these processes requires the use of appropriately designed electrocatalysts.

In this study, ionic covalent organic frameworks (iCOFs) were developed as electrocatalytic materials for electrochemical reduction reactions. ICOFs are porous, crystalline materials, composed of organic blocks, with ion-transporting moieties [1]. Owing to their high surface area and tunable electronic properties, they provide a promising platform for catalyst design. A series of iCOFs was prepared via solvothermal reaction between aromatic dialdehyde building blocks and nitrogen-rich diamine linkers, followed by cobalt impregnation. The obtained materials were analysed in terms of their morphology and chemical composition. The electrocatalytic activities of the resulting electrodes towards the hydrogen evolution and electrochemical CO_2 reduction reactions were investigated. The results demonstrate a high potential of iCOFs as inexpensive and efficient electrocatalysts.

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Less Material, Less Carbon: The Case for Parametric Optimization

Green Transformation

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Keywords: parametric design, structural optimization, embodied carbon, marine infrastructure

Heavy infrastructure – bridges, quays, and foundations – carries a disproportionate environmental burden due to the carbon intensity of marine-grade concrete and steel, which often carries a 20–50% GWP premium over standard materials. While parametric design has revolutionized building architecture, its application as a carbon-reduction tool in heavy marine engineering remains largely unquantified in current literature.

This study addresses this gap by integrating an automated Grasshopper–BIM–FEM workflow to optimize a pile-supported ferry quay in Norway as a case study. By systematically exploring structural configurations under full Eurocode and durability constraints, the parametric approach achieved a 12% reduction in concrete volume and a 27% reduction in steel mass relative to conventional design methods – results consistent with benchmarks in structural optimization literature, where 10–15% material savings under full code compliance represent a practically significant outcome, yet this approach remains unexplored in port infrastructure.

The findings suggest that computational optimization offers what may be termed an “instant carbon payback” – permanent embodied carbon savings generated through digital rather than material investment. Scaling such workflows is essential for meeting IPCC AR6 climate goals, providing a tangible pathway for the green transformation of the global maritime sector.

Modelling the Social Dynamics of Energy Communities: An Agent-Based Perspective

Green Transformation

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Keywords: ABM, energy communities, business models, innovation

The green energy transition creates opportunities for greater energy independence and local empowerment. One way to support this shift is the development of Energy Communities (ECs), understood as locally governed entities that jointly produce and share energy. Despite their potential, ECs remain underdeveloped in Poland, partly due to the absence of well-defined and socially aligned business models.

This study demonstrates how an Agent-Based Model (ABM) can serve as a simulation tool to analyze alternative EC management models. The research combines survey data from 984 respondents, capturing psychological traits and current attitudes toward EC participation, with a structural simulation framework that models dynamic social interactions over time.

The ABM architecture, unlike static survey analysis, enables the exploration of how different governance and business model configurations affect individuals' willingness to join by accounting for peer effects, social influence and heterogeneous preferences, and by running "what if" simulations that reveal which models gain popularity under varying social conditions.

By illustrating how ABM supports the evaluation of EC business models before real-world implementation, the study highlights its value as a decision-support tool for policymakers and local stakeholders engaged in energy transition.

Monitoring and Smart Maintenance of Power Converters

Green Transformation

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Keywords: power electronics, condition monitoring, smart maintenance, fault detection

Power converters are present very often when the electrical energy transfer is required. The transition between alternating current (AC) and direct current (DC) helps to properly supply power grids with energy from renewable sources, various electronics, electric vehicle motors, and much more. During everyday use of converters, their power electronic components undergo a wear-out process that will eventually lead to catastrophic failure. The smart maintenance, in this context, means taking repair actions in the close-to-failure condition, omitting the aftermath caused by an uncontrolled power electronics fault. Moreover, condition monitoring of the power converter should provide the cause of degradation so the system can be improved in order to waste fewer components and resources in the future. Multiple diagnostic methods regarding various improper converter operation causes are present in the literature. However, not enough attention is put on the multiple degradation processes happening at once. The author has investigated the two common degradation phenomena in the AC/DC converters, DC-link capacitance drop and uneven AC voltage. The designed voltage unbalance and capacitance detection methods take into consideration both phenomena appearing at once in order to avoid false diagnostics. By doing so, the power converter during maintenance can be repaired and also improved.

More Than Soot: the Role of Hydrogen in Plasma-Assisted Methane Pyrolysis

Green Transformation

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Keywords: methane coupling, microwave plasma, acetylene, ethylene

Methane, a potent greenhouse gas, is an abundant yet underutilized resource that can be produced from renewable biogenic sources. Converting methane into value-added chemicals through electrified pathways, such as plasma-assisted processes, may be a sustainable alternative to conventional conversion routes, as they can be powered using renewable energy. However, the influence of hydrogen on methane pyrolysis using plasma remains insufficiently studied. This research investigates the effect of hydrogen addition on methane conversion to acetylene and ethylene in a microwave plasma reactor operated at 600-1200 W, 30-60 SLM, and H_2:CH_4 ratio of up to 6:1. Under all conditions, ratios greater than or equal to 4:1 exhibited improved performance: conversion increased from ca. 30% (without H_2) to 40%, combined acetylene and ethylene yield from 20% to 44% and selectivity spiked from 69% to 100%. Acetylene was the substantially dominant product across all ratios, and soot formation was notably unobservable starting from 5:1. Furthermore, optical emission spectroscopy proved increased H radical density with an increased H_2:CH_4 ratio, potentially explaining the trend in conversion. These findings indicate that H_2 addition could lead to more versatile plasma-assisted methane valorization with selectivity towards C_2 compounds, advancing the investigation of plasma-assisted pyrolysis onto new tracks.

Operational Flexibility of SMEs under Evolving Distribution Tariffs: A Structural and Cognitive Perspective

Green Transformation

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Keywords: electricity distribution tariffs, SME operational flexibility, tariff literacy, decision-support systems

The rapid growth of renewable generation and electrification has transformed European electricity networks into congestion-prone systems, where distribution tariff design increasingly shapes economic behavior. Between 2018 and 2025, estimated congestion costs in Europe rose from €1.2 to €5 billion annually, highlighting structural inefficiencies in grid operation and cost allocation.

Despite regulatory progress toward more cost-reflective tariffs, small and medium-sized enterprises (SMEs) remain weakly integrated into flexibility mechanisms. This study examines how dynamic and capacity-based tariff signals interact with SMEs' operational structures, managerial cognition, and risk governance. A CAWI survey among SMEs in Poland, Bulgaria and Romania operationalizes three dimensions: (1) technological process rigidity and operational risk, (2) tariff literacy and strategic positioning of energy within firms, and (3) demand for decision-support systems (DSS) under cost uncertainty.

The findings indicate that process continuity significantly constrains declared flexibility, while low tariff literacy correlates with delegating energy decisions outside strategic management and with higher perceived cost destabilization.

Results suggest that SMEs prioritize predictability and risk reduction over pure cost optimization, implying that DSS adoption is driven more by uncertainty buffering than profit maximization. The study advances smart grid research by integrating structural, cognitive, and governance dimensions into a unified model of SME flexibility under evolving distribution pricing.

POOL BOILING HEAT TRANSFER COEFFICIENT: INFLUENCE OF THE BUNDLE EFFECT

Green Transformation

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Keywords: pool boiling, bundle effect, subatmospheric pressure, water

Modern cooling technologies are essential for everyday life, yet many conventional systems consume significant energy and contribute to greenhouse gas emissions. Consequently, research increasingly focuses on efficient heat transfer technologies using natural working fluids such as water, including systems operating under subatmospheric conditions.

As the boiling heat transfer coefficient decreases with decreasing pressure, multi-tube configurations (tube bundles) are often used to enhance heat transfer performance. Interactions between neighbouring tubes may significantly influence boiling heat transfer, leading to the so-called bundle effect. Vapor bubbles departing from the bottom tube rise and interact with the top tube, activating additional nucleation sites on its surface [1–3]; this effect was also confirmed in our previous experiments on two interacting tubes under subatmospheric pressures of 3–5 kPa [4].

In our previous study on tandem tubes, the maximum bundle effect reached 2.8 at a vapor pressure of 3 kPa and 3.94 at 5 kPa, while the presence of an additional liquid column was identified as a factor limiting the bundle effect. Therefore, the aim of the present study is to investigate whether increasing the number of tubes in the configuration (e.g., two or three tubes) enhances or limits the bundle effect.

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PRODUCTION PROCESS AND SAFETY ASSESSMENT OF HIGH NITROGEN CONTENT AMMONIUM NITRATE FERTILIZERS ENRICHED WITH SELECTED MICRONUTRIENTS

Green Transformation

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Keywords: ammonium nitrate, nitrogen fertilizers, thermal analysis, safety assessment

Ammonium nitrate (AN) remains an industrially important compound, but its use is associated with significant safety concerns. Consequently, fertilizers based on AN are subject to strict regulatory requirements and handling restrictions. The incorporation of micronutrient additives into AN-based fertilizers raises questions regarding their influence on the thermal stability of these materials [1–4].

The addition of micronutrients to high-nitrogen AN fertilizer granules may alter both the decomposition behavior and overall stability of the final product. In this study, Cu, Mn and Zn compounds were mechanically homogenized with ammonium nitrate and dolomite, a stabilizing filler commonly applied in AN fertilizers. Both inorganic sulfate salts and EDTA chelates were investigated.

Thermal analysis using thermogravimetry coupled with differential thermal analysis and mass spectrometry showed that mixtures containing 0.2 mass% of micronutrients showed highest thermal stability due to the relatively high fraction of stabilizing filler, whereas most systems containing 1 mass% exhibited reduced stability. The results demonstrate that both the type of micronutrient and its form significantly affect decomposition characteristics, phase transitions and other physicochemical properties of AN-based granules.

These findings contribute to a better understanding of micronutrient incorporation in AN fertilizers and provide guidance for the safer design of micronutrient-enriched fertilizer systems.

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Reaching Remote Positions: Dynamic TDGs and H-Bonded Templates as Tools for Transannular C–H Activation

Green Transformation

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Keywords: C-H activation, selectivity, transient directing groups, H-bonding templates

Carbon–hydrogen (C–H) bonds are among the most ubiquitous structural motifs in organic chemistry. Their inherent chemical inertness – arising from low polarity and high bond dissociation energy – renders the direct transformation of C–H bonds into C–C or C–heteroatom linkages a formidable challenge in synthetic chemistry [1]. While transition metal catalysis has emerged as a primary solution, achieving high regioselectivity remains a critical hurdle. Traditionally, this is addressed by incorporating directing groups (DGs) that coordinate the catalyst in proximity to the target bond.

To overcome the limitations of permanent DGs, the **transient directing group (TDG)** [2] approach has been developed. This strategy enables the *in situ* generation of a directing moiety (e.g., an imine) from a simple additive, eliminating the need for additional protection and deprotection steps. Consequently, TDG strategies streamline synthetic pathways, enhancing both step-economy and the overall sustainability of the process. Alternatively, **hydrogen-bonding templates** [3] leverage weak, non-covalent interactions to organize the substrate in a specific conformation, utilizing internal recognition sites to guide the catalyst. Although these methodologies rely on fundamentally different molecular interactions, both represent powerful and efficient alternatives to conventional multi-step functionalization protocols.

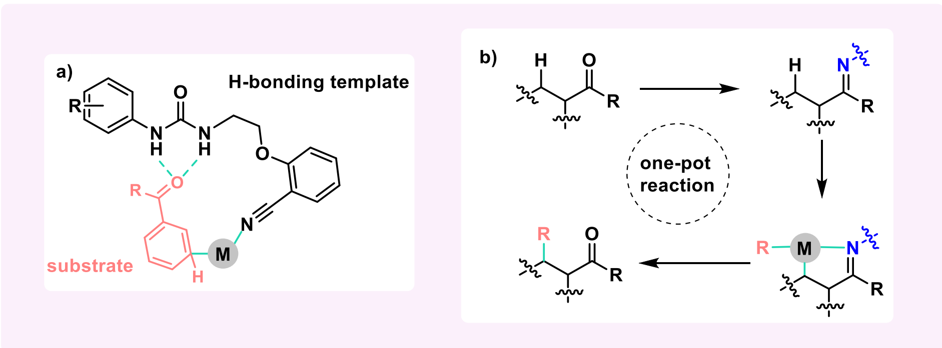

Fig. 1. C-H activation using an H-bonding template (a), and a transient directing group (b)

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REGIOSELECTIVE PALLADIUM-CATALYZED C–H ACTIVATION OF AROMATIC AMINES ENABLED BY NOSYL PROTECTION

Green Transformation

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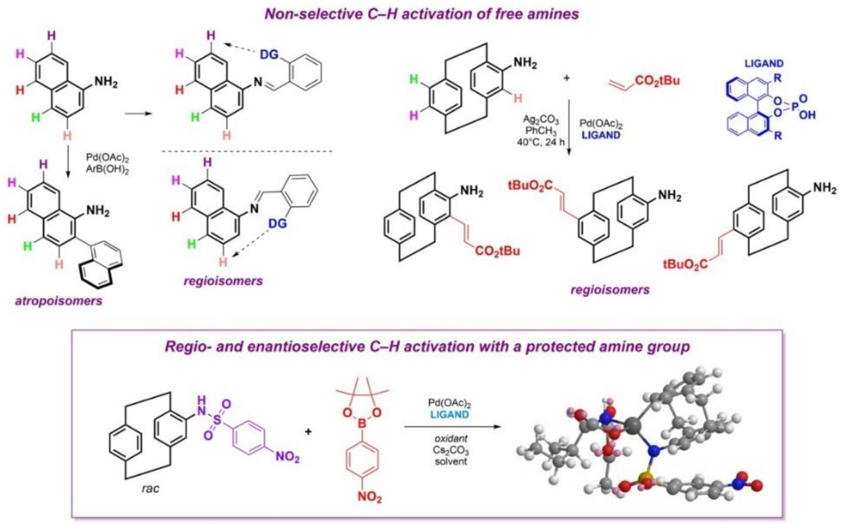
Keywords: C–H activation, aromatic amines, palladium catalysis, directing groups

C–H bond activation reactions, particularly those catalyzed by palladium complexes, represent an important tool in modern organic synthesis, enabling the direct functionalization of relatively inert C–H bonds and thereby shortening synthetic routes. The functionalization of aromatic amines is of particular interest due to their role as key precursors of biologically active compounds, agrochemicals, and functional materials [1]. However, C–H activation of aromatic amines remains challenging because the strongly coordinating amino group can deactivate palladium catalysts or promote undesired pathways. Consequently, strategies that control coordination between the substrate and the metal center are required [2].



In this work, we demonstrate that permanent protection of the amino group with a nosyl group effectively suppresses its coordinating ability, enabling efficient C–H activation with high regioselectivity. These results indicate that tuning the coordination properties of the substrate represents an effective strategy for controlling palladium-catalyzed C–H activation processes and may provide a useful approach for the selective functionalization of aromatic amines.

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STIMULATION OF MICROBIAL ACTIVITY IN MICROBIAL FUEL CELLS USING WASTE VEGETABLE OILS AS A CARBON SOURCE

Green Transformation

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Keywords: MFC, WCO, Oil composition, Bio-electrochemical analysis

Waste cooking oils (WCOs), generated by the food industry, contain high-energy compounds such as lipids and fatty acids capable of enhancing microbial metabolism in microbial fuel cell (MFC). This study evaluates the effect of different WCOs on microbial activity and electrochemical performance in single-chamber air-cathode MFC.

The waste sunflower oil, waste rapeseed oil, waste palm oil, and industrial waste mixtures of sunflower and rapeseed oils were used as a source of carbon. The electrochemical activity was characterized using real-time power density, polarization curves, electrochemical impedance spectroscopy, and cyclic voltammetry. Treatment efficiency was assessed by measuring chemical oxygen demand (COD) removal.

The highest power density among the WCOs was achieved using the industrial waste mixture of sunflower and rapeseed oils (1.02 ±0.11 W m^{-3}) followed by waste palm oil (0.98 ±0.95 W m^{-3}), waste rapeseed oil (0.84 ±0.12 W m^{-3}), and waste sunflower oil (0.60 ±0.22 W m^{-3}).

The results indicate that various types of waste cooking oils can be used as a fuel in MFC system. The complexity of these oils determines the electroactive biofilm maturing time and the maximum power performance.

STUDIES ON THE PHASE COMPOSITION OF SELECTED HARD COALS AND THEIR ASHES

Green Transformation

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Keywords: hard coal, ash, phase composition, XRD

Coal ash is the main solid byproduct of coal combustion in power plants. This waste material is used as a valuable secondary raw material. Knowledge of its phase composition allows for the development of ash management methods. This type of raw material is typically used for land reclamation (backfilling mines, embankment construction, road bases). However, depending on its composition, ash can also be used as a cement additive (high-silica ash) or as an additive in the production of aerated concrete (high-calcium ash), thereby reducing CO_2 emissions associated with the production of this type of raw material.

In this study, a diffraction analysis of ash from selected coal types was performed. The phase composition was determined, and examples of possible applications for this type of secondary raw material were provided.

STUDY ON PHYSIOLOGY OF YARROWIA LIPOLYTICA YEAST TO USE LIGNOCELLULOSIC BIOMASS AS A CARBON SOURCE FOR LIPID BIOSYNTHESIS

Green Transformation

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Keywords: microbial lipids, *Yarrowia lipolytica*, lignocellulosic biomass, yeast

The sustainable production of bio-based chemicals from renewable resources is a central goal of modern biotechnology. Lignocellulosic biomass, an abundant and inexpensive plant-derived material, represents a promising feedstock for microbial lipid production. The oleaginous yeast *Yarrowia lipolytica* is an established model for eukaryotic lipid metabolism and is widely used as industrial platform for fatty acid biosynthesis.

Despite its biotechnological potential, efficient growth and lipid production on lignocellulosic hydrolysates remain limited by poor xylose utilization and sensitivity to inhibitory compounds such as weak organic acids, phenolic compounds, and furan aldehydes. A comprehensive understanding of the metabolic and regulatory networks underlying carbon assimilation and inhibitor tolerance is lacking. This study addresses this gap by investigating native xylose transport and catabolism after activation of a cryptic pathway, and by identifying adaptive changes arising from laboratory evolution under hydrolysate stress. Engineered and evolved strains are characterized to define genetic and transcriptional determinants of improved performance.

Our research focuses on preparing hydrolysates from various plant materials and using them as raw medium for the production of lipids. Significant data will include comparative growth kinetics, lipid yields, inhibitor tolerance profiles, and genome-wide mutation and expression patterns. The project is expected to identify critical metabolic nodes and regulatory mechanisms governing carbon assimilation and stress response. These findings will advance fundamental understanding of *Y. lipolytica* metabolism and provide a rational basis for developing robust cell factories for sustainable lipid production from renewable lignocellulosic feedstocks.

Turning Celery Root Pomace into Value: Sustainable Extraction of Pectic Polyanions

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Keywords: pectin, celery root pomace, natural deep eutectic solvents, waste valorization, analysis of variance

Plant-based food processing generates large quantities of by-products that remain underutilized despite their potential as sources of valuable bioactive compounds. Pectins, complex acidic heteropolysaccharides, are widely used due to their functional properties and health-promoting potential. Within the framework of green transformation and circular economy strategies, plant processing residues are increasingly explored as renewable sources of functional biopolymers [1]. Celery root pomace, a by-product of the agri-food industry, represents a promising yet insufficiently studied source of pectic polysaccharides. Efficient recovery of these compounds requires sustainable extraction approaches and systematic optimization of process parameters [2].

This study evaluates the influence of extraction parameters on the recovery of polyanionic saccharides from celery root pomace and applies Design of Experiments (DoE) combined with Response Surface Methodology (RSM) to optimize the extraction process and determine relationships between extraction conditions and the physicochemical properties of the obtained pectic polyanions. The results contribute to the development of sustainable biomass valorization strategies and support the transformation of agri-food by-products into high-value functional materials. This approach aligns with circular economy principles and promotes the efficient use of renewable biological resources.

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The work was supported by the National Science Centre, Poland, under the research project “Processes of obtaining polyanionic saccharides from native agricultural waste, including Ohmic heating-assisted extraction in environmentally safe solvents” no. UMO-2023/51/B/ST8/02851.

Unlocking Europe's Lithium: Solvent Extraction for a Green Energy Future

Green Transformation

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Keywords: Lithium recovery, solvent extraction, brine processing, Europe lithium sources

The increasing demand for lithium driven by the rapid development of renewable energy technologies and electric vehicles highlights the need for new and sustainable lithium sources in Europe. Brines represent a promising resource, although their relatively low lithium concentrations and the presence of impurities pose challenges for efficient recovery. This study investigates the applicability of solvent extraction as a hydrometallurgical method for lithium recovery from European brines. The extraction process was optimized using a binary synthetic brine system by selecting an appropriate organic phase composition, suitable stripping agents, and evaluating the influence of the phase ratio on extraction performance. In addition, a precipitation step was developed to remove calcium and magnesium impurities prior to extraction. The optimized extraction system enabled effective lithium recovery and concentration from low-lithium brines after impurity removal. These results demonstrate the potential of solvent extraction for processing European brine resources and contribute to the development of more sustainable lithium supply chains supporting the European green energy transition.

Lem Next Gen Science Forum at Wrocław Tech

April 28-29, 2026

Smart Cities and Society of the Future

ORAL PRESENTATION

Assessing the Socio-Economic-Environmental Sustainability of the Hamedan Traditional Bazaar as an Urban System

Smart Cities and Society of the Future

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Keywords: Traditional bazaar; Sustainability; Urban morphology; Hamedan; Iran

Within the Iranian urban framework, the bazaar emerges as a multifunctional institution that significantly influences the economy, socio-cultural practices, and urban planning. Despite existing scholarly efforts, systematic assessments that integrate social and environmental sustainability into urban morphology remain scarce, particularly concerning Hamedan, one of Iran's most ancient cities. This research investigates the sustainability of the traditional Hamedan bazaar and explores the impact of institutional anchors on its spatial and functional characteristics. The methodology includes morphological mapping, pedestrian network analysis, and fieldwork, with a particular emphasis on the Jameh Mosque and the central square as pivotal nodes for land utilisation, social activities, and environmental conditions. The findings indicate that the courtyard of the Jameh Mosque exhibits high social sustainability owing to pedestrian activity and religious events, whereas the peripheral corridors show environmental decline attributable to vehicular traffic and climatic factors. The bazaar acts as a connective fabric of civic, commercial, and religious spaces but remains susceptible to environmental challenges. Integrating sustainability principles into urban morphology provides a heritage-sensitive planning framework suitable for historic cities. The study recommends pedestrian-centred urban design, the adaptive reuse of caravanserais as socio-economic hubs, and the development of climate-resilient micro-infrastructure to enhance long-term sustainability.

Design and Dynamic Analysis of a Protective Tunnel Structure Under Extreme Blast Loading

Smart Cities and Society of the Future

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Keywords: atomic shelter, metro, blast load, numerical modelling

Civil engineering increasingly focuses on protecting critical infrastructure from extreme and unpredictable events, such as powerful explosions. This field involves studying how large-scale structures, like underground tunnels, react to the massive pressure generated by a blast. By understanding these forces, engineers can design safer urban environments that serve the public in both peace and times of crisis.

Despite rising global geopolitical tensions, the design of specialized shelters remains an underdeveloped area in modern civil engineering. There is a clear research gap in how to effectively adapt existing metro infrastructure for civil defense purposes. This study addresses this need by exploring innovative numerical modeling methods to evaluate the protective capabilities of underground tunnels against conventional and nuclear threats.

Research demonstrates that soil damping plays a critical role in the structural resilience of tunnel casings, significantly reducing the effective impact of blast loads on the lining.

These findings provide a technical foundation for developing “dual-use” infrastructure, where everyday transportation systems are engineered to function as high-capacity life-saving shelters. By integrating blast resistance into standard civil projects, this work advances the field of shelter engineering and informs the political debate on national security and urban resilience.

FROM SMART CITY TO SMART EDUCATION: WROCŁAW UNIVERSITY OF SCIENCE AND TECHNOLOGY AS A LIVING LAB OF URBAN RESILIENCE

Smart Cities and Society of the Future

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Keywords: living labs, urban resilience, resilient campus, WrocławTech, smart city, New European Bauhaus

Smart cities are more than technology – they are societies where education, engagement, and resilience enable communities to thrive. Universities play a central role in this transformation. At Wrocław University of Science and Technology (WrocławTech), this reflects the philosophy of Stanisław Lem: a trust in human reason and the proactive design of systems that anticipate future crises. In this framework, the campus is envisioned as a laboratory for applied futurology, where engineering ingenuity converges with ethical stewardship and socio-environmental resilience.

This study examines WrocławTech as a living lab for urban resilience (2015–2025) using open-source data. The analysis evaluates infrastructure, spatial design, architecture and participatory initiatives through New European Bauhaus (NEB) principles: sustainability, inclusiveness, and aesthetics. Despite these advancements, WrocławTech's resilience strategies remain largely unexplored, highlighting a critical research gap.

Findings highlight WrocławTech strengths and opportunities in green-blue infrastructure, renewable energy, passive design strategies, accessibility, mobility, and circular economy initiatives.

These results inform innovative management models and practical strategies while supporting in-depth analysis of presented areas at WrocławTech and other urban contexts. They also provide a foundation for comparative studies, advancing the understanding of how smart education drives the development of resilient communities.

Hybrid Drone Distribution: Sustainable Models for Urban Last-Mile Delivery

Smart Cities and Society of the Future

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Keywords: drone logistics, last-mile delivery, distribution models, urban sustainability

Parcel lockers have become a key part of urban delivery systems across Europe, with Poland being one of the leaders in their adoption. With nearly 45,000 parcel locker machines operated by multiple logistics providers, Poland has the highest parcel locker density in Europe and offers a unique and mature infrastructure for exploring next-generation delivery innovations. Integrating drones into these existing parcel locker networks could make urban deliveries faster, cheaper, and more environmentally friendly.

However, there is currently no clear management framework for how drones and parcel lockers can work together effectively, especially in the Polish market condition. Most existing research focuses on drone delivery to homes, leaving the drone-to-locker model largely unexplored.

This study applies a structured literature review to examine the key variables that shape such a system, including locker locations, drone capacity, delivery demand patterns, and urban zone characteristics in Polish geography. Special attention is given to how these variables differ across direct and third-party logistics channels.

Preliminary findings from the literature review reveal a clear absence of dedicated management frameworks for drone-to-locker systems, and identify locker spatial density, channel type, and demand variability as the most critical variables influencing system design. These insights form the conceptual foundation for developing future management models aimed at supporting logistics companies and policymakers in moving toward smarter, greener, and more efficient urban last-mile delivery in Poland.

Interdisciplinary Integration in Human-Centred Street Design: Bridging Policy and Implementation

Smart Cities and Society of the Future

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Keywords: human-centred street design; sustainable urban mobility; participatory planning; interdisciplinary governance

Urban streets are among the most extensive and durable urban infrastructures, shaping mobility, environmental performance, and social life. While contemporary visions of "smart cities" emphasise digital optimisation, electrification, and autonomous vehicles, street redesign often remains anchored in technocratic road-engineering standards and fragmented administrative routines, leaving car-dependent structures largely intact.

This research addresses the gap between sustainability agendas and the processes through which streets are planned and delivered. It asks how interdisciplinary integration can reorganise street transformation as a coherent, adaptive, and participatory process rather than a one-time construction task. Building on urban design theory, environmental psychology, and project management frameworks inspired by iterative development models, the study develops a conceptual model embedding behavioural research, stakeholder engagement, staged testing, and post-implementation evaluation. Emerging evidence from ongoing case overview and case study shows that smart technologies can enhance sustainability goals when integrated within broader spatial and governance strategies, for instance in climate-responsive engineering, adaptive lighting, and nature-inclusive infrastructure.

Preliminary analysis suggests transformative outcomes depend less on technological upgrades and more on governance capacity to align spatial, social, and organisational dimensions from early stages. By reframing streets as socio-ecological infrastructures, the study advances debates on sustainable urban futures beyond purely technological paradigms.

Marketplaces as Social Infrastructure in Future Cities

Smart Cities and Society of the Future

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Keywords: marketplaces, social infrastructure, smart cities, urban resilience

Contemporary discourse on smart cities emphasizes digital infrastructure and data management, marginalizing social foundations. Urban marketplaces provide spaces for social exchange, trust, and community engagement, revealing the relational dimension of urban life.

Despite interest in technologies, the social role of marketplaces remains underexplored. Marketplaces are social infrastructure, generating social capital, reinforcing community resilience, and stabilizing local economic relations. As "third places," marketplaces foster regular encounters, trust, and social ties. In the context of commercialization, they are central to the urban social system. Functional diversity and high usage intensity underpin the vitality of public spaces. The hybrid character of marketplaces – combining commercial, social, and service functions – fosters inclusiveness and interactions across social and age groups.

The research focuses on the relationship between spatial structure and social interactions in European marketplaces. The study applies a mixed-method approach, combining spatial analysis with field observations and behavioral mapping conducted in selected marketplaces. The results indicate that spatial configuration, accessibility, and functional diversity significantly influence the intensity and quality of social interactions. The findings demonstrate that the urban intelligence of future cities is relational, depending not only on technological systems but also on the quality of social infrastructure that supports adaptation, cooperation, and urban stability.

Operationalising the Customer-Centric Mindset: a Behavioural Assessment Framework for Organisational Diagnosis

Smart Cities and Society of the Future

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Keywords: customer-centricity, assessment, organisational development, organisational diagnosis

Customer-centricity is widely recognised as a vital driver of strategic differentiation; however, it is often described as an abstract cultural aspiration rather than an organisational capability that can be accurately assessed and developed.

This study presents a behavioural assessment framework, designed by experts Christopher Brooks, Michael Brandt and Rodrigo Perea, to transform this mindset into a measurable and diagnosable organisational capability in B2B environments.

The research utilises a 70-item psychometric instrument based on seven behavioural traits with extensive empirical support. These traits are synthesised into three decision-making axes: Orientation, Approach and Abundance.

The methodology involved testing a sample of 60 specialists, enabling the generation of specific behavioural profiles (sub-types) that reveal biases in corporate culture.

By applying a structured scoring system, this framework facilitates the formalisation of knowledge regarding customer value to make informed decisions focused on real results.

The results provide leaders with a data-driven diagnostic tool to bridge the gap between strategic ambition and operational reality, promoting the co-creation of value and trust within complex industrial ecosystems.

Scaling Excellence: An Agent-Based Analysis of Experience-Driven Team Formation

Smart Cities and Society of the Future

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Keywords: agent-based modelling, IT team performance

The team assembly process is a foundational step in project execution, significantly impacting long-term success. In contemporary business environments, particularly the competitive IT sector, organizations must balance operational effectiveness with innovation to remain viable.

Agent-based modelling facilitates the analysis of complex team dynamics. However, existing studies often overlook realistic corporate constraints, such as limited human resources. Furthermore, research has historically focused on network topology rather than the impact of collaboration dynamics on measurable performance. This research addresses this gap by investigating the influence of the probability of choosing an incumbent (p) on collective effectiveness and innovativeness.

Simulation experiments reveal that during initial organizational growth, the optimal balance between these metrics is achieved at a p-range of 40–60%. Conversely, as organizations mature, overall innovativeness declines significantly, regardless of the rate at which newcomers are integrated.

This research advances computational social science by demonstrating how seniority-based hierarchies can be integrated into team assembly models to better predict organizational adaptability. By bridging the gap between network theory and corporate constraints, the study provides a framework for simulating productivity-innovation trade-offs. It suggests that as organizations mature, maintaining a competitive edge requires shifting from personnel adjustments toward actions promoting collective creativity.

Smart City Solutions in Oslo, Helsinki and Amsterdam: A Comparative Analysis and Potential Application in Wrocław

Smart Cities and Society of the Future

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Keywords: Smart City, Sustainable Mobility, Urban Transport Policy, Wrocław

This study analyzes selected smart city mobility solutions implemented in Oslo, Helsinki and Amsterdam to examine their potential relevance for Wrocław, Poland. To maintain a clear analytical scope, the research focuses specifically on the domain of sustainable urban mobility. Using a comparative case study approach combined with policy benchmarking, the paper evaluates selected policy instruments and transport strategies supporting sustainable mobility in the three cities.

Key initiatives examined include Mobility-as-a-Service (MaaS) platforms developed in Helsinki, car-free urban zones introduced in Oslo, and cycling-oriented mobility policies widely implemented in Amsterdam. The analysis compares the objectives, governance mechanisms, and policy tools associated with these initiatives and contrasts them with the strategic priorities outlined in Wrocław's urban mobility and transport policy documents.

Rather than predicting quantitative outcomes, the study identifies key mechanisms and policy approaches that could inform future mobility planning in Wrocław. The findings suggest that elements such as integrated mobility services, demand-management measures, and stronger support for active transport may offer useful policy insights for cities seeking to advance sustainable mobility strategies.

SURVEILLANCE AND PRIVACY IN SMART CITIES – LEGAL AND PSYCHOLOGICAL PERSPECTIVES

Smart Cities and Society of the Future

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Keywords: smart cities, surveillance, privacy, safety

Smart cities use networks of sensors, Internet of Things (IoT) devices, and smart energy systems to improve urban efficiency, sustainability, and quality of life. These technologies enable real-time data collection for traffic management, energy optimization, and public safety. However, the growing use of surveillance tools, such as biometric facial recognition and behavioral data derived from energy consumption, raises concerns about privacy, autonomy, and public trust.

Rapid surveillance deployment highlights tensions between innovation and individual rights. While legal frameworks like the GDPR and the EU AI Act aim to regulate these risks, psychological research emphasizes the emotional effects of constant monitoring. This presentation combines technical expertise in mechatronics and renewable energy with legal and psychological perspectives to examine these interdisciplinary challenges.

Pervasive surveillance in smart cities may contribute to chilling effects, surveillance-related stress, and privacy cynicism, while also creating risks of function creep in the use of collected data.

By advocating for ethical governance and mediation in technological conflicts, this work advances human-centered urban innovation. It offers actionable recommendations for Polish and EU cities to balance automation benefits with the protection of fundamental human rights and psychological well-being.

Use of Satellite Data While Planning Green Infrastructure in Cities

Smart Cities and Society of the Future

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Keywords: Green Infrastructure, Satellite Data, Remote Sensing, NDVI, Urban Planning

Urban planning is increasingly relying on technological integration to ensure the health and sustainability of rapidly growing cities. Green Infrastructure (GI) acts as the biological foundation of urban environments, providing critical cooling and air purification services to city dwellers. Despite its importance, city planners often rely on outdated and expensive on-the-ground surveys that lack the scalability needed for modern climatic challenges. This research addresses this gap by proposing a monitoring system based on multi-spectral satellite data as a key tool in strategic planning.

The integration of NDVI analysis other data and special documents allows for the precise mapping of biomass health and the identification of heat-vulnerable zones, facilitating a direct shift toward evidence-based urban design. These results demonstrate that remote sensing can serve as a scalable “digital sense” for urban resilience, allowing cities to adapt dynamically to environmental shifts. This approach advances the field of landscape architecture by merging traditional geobotanical methods with real-time digital observation, providing a framework for managing urban ecosystems in the era of digital transformation.

Warsaw as a Smart City: Six-Domain Diagnosis and Governance Trade-Offs Through the IMD Smart City Index

Smart Cities and Society of the Future

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Keywords: Smart City, Warsaw, governance, IMD Smart City Index

Smart city policies in the EU emphasize not only digitalisation, but also integrated improvements in mobility, environment, public services and social inclusion. This paper examines whether Warsaw can be considered a smart city and where the most important gaps remain. The study combines a six-domain framework (smart governance, economy, mobility, environment, living and people) with benchmarking based on the IMD Smart City Index and a review of Warsaw's strategic documents and digital public services. The analysis indicates a notable improvement in residents' perceptions captured by the IMD Index: Warsaw moved from 38th (2024, rating BBB) to 28th (2025) among 146 cities, suggesting growing satisfaction with selected smart solutions. At the same time, the governance dimension highlights political trade-offs typical for capital-city metropolitan systems: strong central coordination can accelerate citywide projects, but may also increase risks for transparency and citizen co-production. The presentation proposes a concise diagnostic dashboard linking index domains to local policy instruments, supporting evidence-based prioritisation for Warsaw's next smart-city cycle.

When Expressed and Private Opinions Evolve on Different Timescales: Insights from Agent-Based Models

Smart Cities and Society of the Future

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Keywords: agent-based model, social network, opinion dynamics, preference falsification

Computational social science is a rapidly growing interdisciplinary field at the intersection of the social sciences, mathematics, physics, and computer science that uses modeling to study complex societal phenomena. A key approach is agent-based modeling, in which populations are represented as interacting agents, linking individual behavior to collective outcomes. One important class of problems concerns situations where what people say in public does not match what they believe in private, a phenomenon known as preference falsification. Agent-based models that assign each individual both a private belief and an expressed opinion are commonly used to study how such mismatches evolve in social networks. However, most existing expressed–private opinion (EPO) models treat private and expressed changes as occurring on the same timescale and consider only limited forms of response to social influence. To address this gap, we introduce a generalized EPO model and show that changing the relative rate at which agents update their private versus expressed opinions can qualitatively alter collective behavior, depending on the assumed response to social influence. The results hold on artificial and empirical social networks, demonstrating robustness across different social structures. Overall, they provide a more realistic basis for studying preference falsification dynamics in networked societies.

Who Decides How a City Recovers? Flood, Governance, and Collaborative Regeneration in Lądek-Zdrój

Smart Cities and Society of the Future

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Keywords: flood recovery, urban regeneration, stakeholder governance, climate resilience

Floods are among the most disruptive natural hazards affecting cities in Central Europe, increasingly intensified by climate change. Post-disaster recovery processes therefore become critical moments that shape not only physical reconstruction but also social relations, governance structures, and long-term urban resilience.

This study examines the case of Lądek-Zdrój, a historic spa town affected by severe flooding in September 2024, and explores how different stakeholders – local authorities, residents, planners, and institutions – negotiate visions of post-disaster urban regeneration. The research draws on the author's engineering thesis and a design concept developed within the Wrocław University of Science and Technology Urban Innovation Centre project.

Author's experience highlight that post-disaster recovery is not only a technical planning challenge but also a process shaped by conflicts over decision-making power, access to resources, and competing visions of the town's future.

The case demonstrates that collaborative governance and inclusive planning processes can transform disaster recovery into an opportunity for innovation and urban resilience. Understanding stakeholder dynamics in such contexts is essential for shaping more adaptive and participatory models of urban regeneration in the face of increasing climate risks.

Lem Next Gen Science Forum at Wrocław Tech
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Smart Cities and Society of the Future

POSTERS

Hydrological Analysis of the 2024 Flood Events in South Poland

Smart Cities and Society of the Future

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Keywords: SCS–CN curve methodology, Geographic Information System, remote sensing, rainfall data

Extreme weather events are becoming more frequent and intense due to ongoing climate change. In September 2024, Storm Boris brought record-breaking rainfall, leading to catastrophic floods across Poland and Central Europe. Understanding the mechanisms of these events is essential for the effective protection of populations and infrastructure in the future. This study focuses on the Biała Lądecka river basin in southern Poland, where gauging stations failed during the flood peak. To reconstruct the events that occurred while the data remained unrecorded, a hydrological model based on the SCS–CN method was developed to simulate the flood wave dynamics. This approach required calibrating numerous physiographic parameters and integrating various precipitation sources – ranging from a single rain gauge and spatial interpolation (IDW) to satellite-based datasets. The analysis revealed that despite the multi-parameter complexity of the model, the precision of precipitation data exerts the most crucial influence on its sensitivity and the accuracy of flood wave reconstruction during crisis situations. These findings provide the knowledge necessary to enhance future resilience against the increased frequency of extreme events. They will enable better forecasting of hydrological disasters, allowing for earlier adaptation and the reinforcement of regional infrastructure against future flooding.

OPTIMIZATION OF THE BUILDING FORM TO IMPROVE ENERGY AND MATERIAL EFFICIENCY

Smart Cities and Future Societies

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Keywords: Sustainable Architecture, Building Optimization, Mathematical Modeling, Architectural Design

This research presents a rigorous framework for optimizing the geometry of single-family residential buildings with the aim of minimizing the external surface area of the building envelope under specified design constraints. The analysis focuses primarily on hip-roof houses, while also extending the investigation to hip-roof buildings with L-shaped plans. Several optimization scenarios are considered: fixed volume, fixed footprint ratio, fixed slenderness ratio, fixed floor area, and constrained building height. For each case, explicit formulas for the optimal geometric proportions are derived, providing architects and engineers with practical guidelines for improving material efficiency, reducing construction costs, and enhancing energy performance.

To demonstrate the practical relevance of the theoretical results, selected case studies of existing houses are examined, highlighting both common inefficiencies in typical designs and examples that approach the derived optimal configurations.

The results indicate that square-based footprints combined with balanced slenderness ratios generally yield the most surface-efficient forms, whereas elongated or excessively flattened proportions lead to significantly higher material and energy demands. The inclusion of L-shaped configurations further illustrates how deviations from compact geometry affect envelope efficiency. Overall, the work demonstrates how mathematical modeling can support architectural decision-making and contribute to the design of energy-efficient, cost-effective, and sustainable residential buildings.

SMART WATER CITIES: INTEGRATING TECHNOLOGY AND SOCIETY

Smart Cities and Society of the Future

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Keywords: urban water management, water city index, blue-green infrastructure, socio-economic resilience, urban governance

Contemporary cities face increasing pressures in managing water due to urbanization, population growth, and climate change. The “water city” concept treats water not only as infrastructure but as a strategic resource supporting social, economic, and environmental development.

Despite substantial investments, links between technical solutions and socio-economic outcomes remain underexplored. The Water City Index 2025, covering 218 Polish cities (8 metropolises, 58 county-level, 152 medium towns), aggregates over 40 quantitative and qualitative indicators from 2020–2024. Weighted averages and subindex rankings were used to evaluate system efficiency, retention, network digitalization, governance, pricing, and community engagement.

The analysis identifies leading cities, such as Łódź (top in the metropolitan “livability” subindex) and Gdynia, which combine modern retention and digital systems with active social participation and rational pricing.

Wrocław also ranks highly, reflecting recent investments. These integrate technical and social strategies, improving climate resilience, enhancing quality of life and supporting long-term urban stability.

These findings emphasize the importance of integrated urban water management. Linking technology, governance, and blue-green infrastructure (BGI) is essential for adapting to extreme events like flash floods. Evidence provides practical guidance for policymakers and urban planners, showing that water managed as a collective resource strengthens urban attractiveness and ecological security.

Smart Wearable Shock Detection System for Real-Time Electrical Accident Prevention

Smart Cities and Society of the Future

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Keywords: electrical safety, wearable technology, smart infrastructure, automatic power isolation

Electrical accidents remain a major safety concern in modern urban and industrial infrastructure, particularly for electricians and utility workers exposed to live power systems. Immediate isolation of electrical supply after electrocution is critical, as delayed response significantly increases injury severity and fatality risk.

Conventional protection devices such as circuit breakers and residual current systems are designed to protect electrical circuits rather than human operators. Consequently, shock incidents may not be detected at the human-contact level, creating a gap in real-time worker protection and emergency response.

This study presents a smart wearable shock detection system that enhances electrical safety through human-centric monitoring and automated infrastructure control. The proposed solution integrates a wearable band equipped with vibration and voltage sensors, a microcontroller-based processing unit, RF wireless communication, relay-assisted circuit interruption, and GSM-enabled emergency alerts. When an electrical shock is detected, the system rapidly trips the connected circuit breaker and simultaneously notifies safety personnel.

Prototype implementation demonstrates reliable detection and fast automatic power isolation with minimal response delay, significantly improving worker protection.

The proposed approach strengthens smart-city safety infrastructure by integrating wearable sensing with responsive power control systems.

Time Series Analysis of Near Miss Events and Accidents in the Construction Industry Using Visibility Graphs

Smart Cities and Society of the Future

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Keywords: occupational safety, visibility graphs, near-miss events, occupational accident

Construction is one of the most dangerous industries, with dozens of workers losing their lives every day worldwide. Accidents at work have their precursors, known as near misses. Understanding the temporal dynamics of both event types is crucial for effective prevention. Despite growing availability of empirical data, classical statistical methods often fail to reveal complex relationships in accident time series. This study aims to identify dynamic patterns in accident time series in the construction sector using complex network theory, in particular visibility graphs.

119 monthly observations of accidents at work and near misses in the Polish construction sector from 2015 to 2024 were analyzed. The data were transformed into complex networks using natural and horizontal visibility graphs, supplementing the analysis with cross-correlation, seasonal-trend decomposition and stationarity tests. The distributions of graph degrees follow a power law (γ = 1,17 for natural visibility graphs of near misses; γ = 1,42 for accidents at work), which indicates the presence of long-range correlations. The relationship between near misses and accidents is predominantly synchronous, with the strongest correlation at lag 0 (r = 0.727), though significant correlations persist across all tested lags. The results indicate that accident processes have a complex, non-random dynamic structure.

Towards More Realistic Models of Pedestrian Motion

Smart Cities and Society of the Future

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Keywords: pedestrian motion, crowd dynamics, agent-based modelling, social force model

Understanding pedestrian movement is essential for designing safe and efficient urban environments. In modern cities, accurate modelling of crowd dynamics plays an important role in infrastructure planning, public space design, and evacuation safety. Mathematical and computational models allow researchers to analyse how individual behaviours lead to collective crowd patterns.

Agent-based models are widely used to simulate pedestrian behaviour because they represent each individual as an autonomous agent interacting with others and with the environment. A common framework for such simulations is the social force model. However, existing formulations often struggle to reproduce realistic behaviour in simple interaction scenarios, which can affect the reliability of large-scale crowd simulations.

Simulation experiments show that the proposed anticipatory model, which incorporates short-term prediction of other pedestrians' motion, produces trajectories and interaction patterns most consistent with experimental observations.

Improving the realism of pedestrian models is important for many applications related to the development of smart cities. More accurate simulations can support the design of safer public spaces, better evacuation procedures, and more efficient pedestrian infrastructure. The presented results demonstrate that incorporating mechanisms such as directional sensitivity and anticipation can significantly enhance the predictive capabilities of agent-based crowd models.

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Health Engineering, Future Medicine, and Biotechnologies

ORAL PRESENTATION

BIOTRANSFORMATION OF TESTOSTERON – HARD WORK OF FUNGI

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: steroids, biotransformation, hydroxy derivatives, cytochrome P-450 monooxygenase

Steroid biotransformation using filamentous fungi is an important area of biotechnology, offering selective and environmentally friendly routes to structurally complex derivatives. Microbial hydroxylation, in particular, enables regio- and stereoselective modifications that are difficult to achieve by classical chemical synthesis.

17α-Methyltestosterone is a synthetic androgen with both anabolic and androgenic activity, and structural modifications can significantly influence its biological profile, solubility, and bioavailability. However, efficient microbial systems for its selective hydroxylation remain insufficiently explored. The aim of this study was to screen a collection of 13 filamentous fungal species to identify a strain with the highest 17α-methyltestosterone biotransformation capacity, followed by process optimization and product identification.

Screening identified *Mucor hiemalis* AM 450 as the most effective strain, and optimization of medium volume, substrate concentration, and incubation time enabled preparative-scale transformation, yielding 7β-hydroxy-17α-methyltestosterone as the main product with a maximum yield of 39.64%.

Additionally, minor 6β-, 9β-, and 12β-hydroxy derivatives were detected, confirming regioselective hydroxylation mediated by a cytochrome P-450 monooxygenase, with the hydroxylation site dependent on substrate orientation in the active pocket. These findings establish a new microbial platform for selective steroid modification and provide a basis for developing biotechnological routes to bioactive steroid derivatives with potential pharmaceutical and veterinary applications.

COMMON PITFALLS AND RECOMMENDATIONS FOR USE OF MACHINE LEARNING IN DEPRESSION SEVERITY ESTIMATION

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: depression severity estimation, machine learning, affective computing.

The DAIC-WOZ dataset is a widely used benchmark for the task of depression severity estimation from multimodal behavioral data. Yet the reliability, reproducibility, and methodological rigor of published machine learning models remain uncertain. In this systematic review, we examined all works published through September 2025 that mention the DAIC-WOZ dataset and report mean absolute error as an evaluation metric. We found that published models suffer from poor documentation and methodology, and, *inter alia*, identified subject leakage as a critical methodological flaw. To illustrate its impact, we conducted experiments on the DAIC-WOZ dataset, comparing the performance of the model trained with and without subject leakage. Our results indicate that leakage produces significant overestimation of the validation performance. Without leakage, the model consistently performed worse than a simple mean predictor. Aside from poor methodological rigor, we found that the predictive accuracy of the included models is poor: reported MAEs on DAIC-WOZ are of the same magnitude as the dataset's own PHQ-8 variability, and are comparable to or larger than the variability typically observed in general population samples. We conclude with specific recommendations aimed at improving the methodology, reproducibility, and documentation of manuscripts.

Computational Photochemistry of Spiropyran Photoswitches as a Foundation for Designing Light-Controlled Therapeutics

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: photochemistry, TD-DFT, solvatation, fotoswitches

Molecular photoswitches are promising compounds that enable precise, time- and space-controlled modulation of biochemical activity, which opens up new possibilities in drug design and targeted therapies. Among them, spiropyran-merocyanine derivatives stand out for their photochemically regulated reactivity and strong dependence of spectral properties on the local microenvironment, making them promising candidates for future therapeutic applications.

Understanding the relationship between the structure, environment and photochemical reactivity of these systems is crucial, however, detailed data on the energetics of isomers, spectral signatures and the influence of specific environmental interactions are limited. Addressing that research gap, this work presents a computational analysis of NitroBIPS and methoxy-NitroBIPS, including modelling of ground and excited states, characterisation of reaction pathways, and microsolvation.

The performed benchmarks demonstrated that the selected TD-DFT methods reliably reproduce NitroBIPS spectra and allow for the identification of isomers most consistent with experimental observations. Furthermore, the obtained results show that local interactions with the solvent, especially nearby the nitro group, significantly modulate the position of the absorption bands and the photochemical response of methoxy-NitroBIPS.

These results provide the mechanism-based foundations required for the rational design of spiropyran systems with controlled properties and support the development of future light-controlled tools with potential therapeutic significance.

Development and Characterization of Bioinks Based on Photocurable Chitosan and Polydopamine Derivatives for 3D/4D Printing in Tissue Engineering

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: bioinks, chitosan, 3D/4D printing, tissue engineering

Tissue engineering increasingly utilizes advanced biofabrication techniques to produce biomimetic structures supporting tissue regeneration. Among these, 3D and 4D printing enable precise control over scaffold architecture and material functionality.

However, many bioinks still lack an optimal balance between printability, mechanical stability, and biological performance. This work presents the development of multifunctional bioinks based on photocurable chitosan and polydopamine derivatives designed for improved biological activity and suitability for 3D/4D printing.

The developed bioinks demonstrated enhanced printability, structural stability after photocrosslinking, and improved biological performance compared to conventional chitosan-based systems.

Polydopamine nanoparticles were obtained via the auto-oxidation of dopamine hydrochloride. Subsequently, chitosan was modified with methacrylic anhydride to obtain a photocurable derivative. Photocrosslinking of the obtained materials was then performed using different photoinitiators. A series of physicochemical analyses was conducted, including UV–Vis and FT-IR spectroscopy, as well as evaluation of mechanical and sorption properties. In addition, biological assessments were performed, including cytotoxicity, genotoxicity, antibacterial activity, and biodegradation studies.

These results indicate that photocurable chitosan–polydopamine bioinks represent promising materials for advanced biofabrication and future tissue engineering applications.

This work was carried out as part of the research project no. 2024/53/N/ST8/03283 funded by the National Science Centre, Poland.

Electric Stress as an Anticancer Strategy

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: electrochemotherapy, cellular stress, electroporation, cancer therapy

Electrochemotherapy (ECT) is an emerging anticancer modality that combines pulsed electric fields with chemotherapeutic agents to enhance drug uptake by tumor cells. By transiently permeabilizing the plasma membrane, electroporation facilitates intracellular delivery of otherwise poorly permeant molecules and has become an effective approach for local cancer treatment.

Recent advances indicate that ECT efficacy is not limited to enhanced drug transport but also involves electrically induced cellular stress. In particular, the duration of electric pulses – from conventional microsecond pulses to nanosecond electric fields – may influence intracellular responses and therapeutic outcomes. This work investigates how pulsed electric fields in the microsecond and nanosecond range, combined with anticancer agents, induce stress responses in cancer cells.

Accumulating evidence indicates that electrochemotherapy triggers a complex and time-dependent stress response characterized by reactive oxygen species generation, ATP depletion, and mitochondrial dysfunction, ultimately leading to apoptotic or necrotic cell death, including in drug-resistant cancer cells.

These findings support the concept that ECT acts not only as a drug-delivery method but also as a strategy exploiting electrically induced cellular stress. Understanding how pulse duration – from microseconds to nanoseconds – modulates these mechanisms may help optimize electroporation protocols and improve the effectiveness of electroporation-based anticancer therapies.

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Enhancing Hyaluronic Acid Recovery Using Ceramic Membrane Filtration

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Hyaluronic acid, Ceramic membrane, Membrane Filtration

Hyaluronic acid (HA) is a biopolymer produced via fermentation of *Streptococcus zooepidemicus* and used widely in cosmetic and pharmaceutical industries. Due to high water retention capacity, biodegradability, it is used to facilitate wound healing by keeping moisture and reducing inflammation.

The primary challenge in production of HA is the highly viscos fermentation broth, which limits mass transfer and complicates biomass removal. This study evaluates a 300 kDa ceramic membrane performance in separation and concentration, aiming to increase overall yield of HA while mitigating the barrier viscosity barrier encountered in traditional downstream processing. Samples were analyzed every for pH, absorbance at 600 nm, and HA concentration in feed, retentate, and permeate.

This research shows that ultrafiltration ceramic membranes provide a solution for dealing with highly viscous microbial products. By optimizing the primary recovery stage, this approach improves the sustainability of high pharmaceutical grade hyaluronic acid manufacturing.

Ethical Integration of Generative AI in Hospital Quality Management Systems: A Qualitative Exploration in the Middle East

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Generative AI Ethics; Hospital Quality Management; Human-AI Collaboration; Middle East healthcare

Hospital Quality Management Systems (QMS) are structured frameworks that integrate risk management, process standardization, and continuous improvement to ensure patient safety and regulatory compliance. The emergence of generative AI (GenAI) is transforming healthcare operations by offering new capabilities including real-time monitoring, predictive risk assessment, and automated documentation previously unavailable through traditional methods.

Despite this potential, integrating GenAI into hospital QMS raises critical ethical concerns around accountability, algorithmic bias, transparency, and data privacy. Existing ethical frameworks remain predominantly focused on clinical AI applications, leaving a significant gap in guidance specific to QMS workflows. This gap is especially pronounced in the Middle East, where fragmented regulation, heterogeneous infrastructure, and culturally distinct decision-making norms create context-specific challenges not addressed by Western-centric models.

Through thematic analysis of 20 semi-structured interviews with QMS professionals across Middle Eastern hospitals, this study identifies that ethical GenAI integration requires human oversight as a non-negotiable principle, robust data governance, algorithmic transparency, and culturally adapted implementation strategies incorporating family-centered decision-making and physician endorsement.

These findings advance the field by providing the first empirically grounded, context-specific framework for ethical GenAI adoption in Middle Eastern hospital QMS. The proposed socio-organizational approach combining governance structures, phased deployment, workforce training, and cultural adaptation offers healthcare administrators a practical roadmap that balances technological innovation with ethical stewardship. By foregrounding regional specificities rather than applying universal Western standards, this research contributes to a more equitable and trustworthy trajectory for AIdriven quality management in diverse healthcare systems.

From Soy Lecithin to Advanced Drug Delivery: Understanding the Extrusion of Highly Concentrated Lipid Systems in Variable Salt Concentrations

Health Engineering, Future Medicine and Biotechnologies

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Keywords: liposomes, extrusion, nanocarriers, energy consumption

Liposomes are phospholipid-based nanocarriers essential for modern medicine due to their high biocompatibility and drug delivery potential. Extrusion, a liposome formulation technique, is based on forcing mixed aqueous and organic phases through calibrated membranes to achieve uniform vesicle size.

While salt concentration is known to affect the critical quality attributes of liposomes, such as size or polydispersity index, its impact on the mechanical efficiency of the extrusion process remains under-explored. This study investigates the impact of the aqueous phase ionic strength on the extrusion process energy during liposome formation.

Our results show that highly concentrated lecithin/glycerin systems exhibit a significant salt-dependent increase in extrusion energy during liposome formation process. In contrast, lecithin formulations in propylene glycol remain energetically stable regardless of ionic strength. These findings suggest that propylene glycol acts as a rheological stabilizer, minimizing the impact of ionic changes on process efficiency.

These findings are consistent with the physical properties of glycerin and propylene glycol. Our research might be directly applied to the rational design of lipid-based nanocarriers, providing a basis for further studies aimed at bridging the gap between laboratory-scale formulation and energy efficient industrial production.

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Nanocarrier-Membrane Interactions: A Biophysical Basis for Engineering Future Drug Delivery Systems

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Keywords: Nanocarriers based on Dendrimer, Lipid Membranes, Drug Delivery Systems

The engineering of future nanomedicines requires a fundamental understanding of interfacial interactions that govern cellular internalization. This study investigates the adsorption of PAMAM dendrimer nanocarriers (PDN) and PDN covered by BSA corona onto artificial lipid membranes using QCM-D and complementary spectroscopic (FTIR, NMR, CD) and electrokinetic methods. The results show that dendrimers irreversibly adsorb on the artificial membrane. The obtained layer is viscoelastic, and to elucidate the molecular determinants of this interaction, we employed a multi-spectroscopic approach coupled with electrokinetic analysis. By correlating the carrier's molecular architecture with its membrane-disruptive potential, this research provides a framework for engineering safer biotechnologies. These insights are crucial for designing next-generation Drug Delivery Systems (DDS) that balance therapeutic efficacy against cytotoxic profiles in oncological applications.

Acknowledgements

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NEUROINFORMATICS IN THE DIAGNOSIS OF AUTISM

Health Engineering, Future Medicine and Biotechnology

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Keywords: neuroinformatics, Autism Spectrum Disorder, machine learning, neuroimaging diagnostics

Autism spectrum disorder (ASD) is a common neurodevelopmental condition characterized by diverse cognitive and behavioral patterns. Early and accurate diagnosis is critical but remains challenging due to the heterogeneity of symptoms. Neuroinformatics, combining neuroscience, data analysis, and artificial intelligence, offers tools to detect subtle neural patterns that may serve as early indicators of ASD.

Despite advances in clinical assessment, there is a lack of objective, data-driven biomarkers for early diagnosis. To address this, we analyzed EEG and fMRI datasets from over 500 participants, applying machine learning algorithms to identify distinctive patterns of brain connectivity associated with ASD.

Our results demonstrate that classification models can distinguish individuals with ASD from neurotypical controls with an accuracy exceeding 85%, highlighting specific neural circuits that are consistently altered.

These findings suggest that integrating neuroinformatics methods with traditional diagnostic approaches can enhance early detection and support personalized interventions. The study underscores the potential of large-scale data analysis and AI in neurodevelopmental research and provides a framework for future studies aiming to translate neural biomarkers into clinical practice.

OPTICAL TWEEZERS FOR CONTROLLED HYBRID SPHEROID FABRICATION

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: 3D cell culture, co-culture models, optical tweezers, tumor microenvironment

Three-dimensional *in vitro* cellular systems better recapitulate tumor architecture, microenvironmental gradients, and treatment responses than 2D cell cultures. Models that combine malignant and stromal elements are especially valuable for studying hematologic malignancies that interact with the bone-marrow niche. However, tools for study the early event of multicellular assembly at single-cell resolution remain limited.

A stepwise, transferable protocol was developed that couples standard agarose-based stromal spheroid formation with targeted single-cell manipulation by optical tweezers (OT). Mesenchymal stromal cell (MSC) spheroids were generated as a core scaffold, and individual B-cell lymphoma cells were captured and positioned on the spheroid surface using a 1064 nm optical trap. The approach permits real-time visualization of cell placement, controlled creation of hybrid spheroids, and quantitative measurement of the minimal cell–cell contact time required to establish an adhesive bond between cells.

Developed workflow enables reproducible assembly of hybrid lymphoma – stromal spheroids *de novo*, with precise control over the number and location of attached lymphoma cells. Our results show that OT manipulation provides temporal resolution of early adhesion events that bulk assays cannot resolve, and the platform is compatible with perturbations such as altered oxygenation and pharmacologic treatment to probe adhesion dynamics.

Combining established 3D culture techniques with optical trapping expands the experimental toolkit for hematopathology research by enabling controlled, minimally invasive construction of multicellular tumor models and direct measurement of nascent adhesion. This methodology offers a new avenue to investigate microenvironment-driven behaviors and to evaluate anti-adhesive therapeutic strategies in a physiologically relevant 3D context.

Polysaccharide Yield and Antioxidant Activity of Chemically Assisted *Hydnum Repandum* and *Tricholoma Equestre* Extraction

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Polysaccharides, Antioxidant Activity, Mushroom Extraction, Bioactive Compounds

Polysaccharides derived from edible and wild mushrooms have gained increasing attention due to their potential health-promoting properties, particularly their antioxidant activity. However, the efficiency of different extraction methods in recovering these bioactive compounds remains insufficiently explored for many wild species. This study investigated the effect of extraction solvents on the polysaccharide content and antioxidant activity of the fruiting bodies of Hydnum repandum and Tricholoma equestre. Alkali (NaOH) and acid (HCl) extraction methods were applied, and polysaccharide content was determined using the Dubois and DNS assays. Antioxidant activity of the extracts was measured using DPPH, ABTS, and H2O2 scavenging assays. The results indicated that both mushrooms contain significant levels of polysaccharides and exhibit notable antioxidant activity. Comparatively, T. equestre extracts displayed higher polysaccharide content and superior ABTS and H_2O_2 scavenging activities than H. repandum. In general, alkaline extraction yielded higher polysaccharide content and antioxidant activity. However, the choice of solvent had no significant effect on H_2O_2 scavenging activity. These findings suggest that T. equestre and H. repandum are valuable sources of bioactive polysaccharides, warranting further investigation for potential applications in functional food or nutraceutical product development.

Potential Mechanism of Lymphoid Cell Death Induced by Anti-MHC II Antibodies

Health Engineering, Future Medicine and Biotechnologies

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Keywords: monoclonal antibodies, MHC-II, apoptosis mechanism, FAS pathway

Monoclonal antibodies targeting tumor-associated antigens have become an important strategy in the treatment of hematological malignancies. These antibodies can selectively recognize cancer cells and trigger immune-mediated or direct cytotoxic mechanisms leading to tumor cell elimination.

Most clinically used monoclonal antibodies exert their anticancer activity through complement activation or antibody-dependent cellular cytotoxicity. However, some antibodies are capable of directly inducing apoptosis in malignant cells. In our institute, two monoclonal antibodies, B5 and E11, recognizing the DLA-DR antigen (canine MHC class II), have been developed and previously shown to induce strong pro-apoptotic effects in canine leukemia and lymphoma cell lines. The aim of this study is to investigate the molecular mechanisms underlying apoptosis induced by anti-DLA-DR antibodies.

Our results demonstrate that anti-DLA-DR antibody-mediated apoptosis is caspase-dependent and involves activation of the FAS receptor signaling pathway.

These findings provide new insights into the intracellular signaling mechanisms triggered by DLA-DR engagement. Understanding how anti-DLA-DR antibodies initiate programmed cell death may contribute to the development of more effective targeted immunotherapies for canine hematological malignancies. Moreover, elucidating these mechanisms may support future translational approaches and the design of antibody-based therapies applicable to human oncology.

Reactive Oxygen and Nitrogen Species in Cold Plasma Medicine

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: non-thermal plasma, dielectric barrier discharge, nanohydroxyapatite

Reactive oxygen and nitrogen species (RONS) are a group of highly reactive molecules that include both oxygen-derived species, such as hydroxyl radicals (•OH), superoxide (O_2^{-}•), hydrogen peroxide (H_2O_2), and singlet oxygen ($^1O_2$), and nitrogen-derived species, such as nitric oxide (NO), nitrogen dioxide (NO_2), and peroxynitrite ($ONOO^-$). These species play a crucial role in many chemical and biological processes because of their strong oxidative and redox activity. In aqueous environments, RONS can influence reaction pathways, modify surface functional groups, and regulate nucleation and crystal growth during nanoparticle formation.

Cold atmospheric plasma (CAP) is an efficient source of RONS generated under near-ambient temperature and pressure conditions. In this study, dielectric barrier discharge (DBD) plasma was applied to synthesize nano-hydroxyapatite (nanoHA), and the resulting nanoparticles were characterized using dynamic light scattering (DLS), scanning transmission electron microscopy (STEM), and X-ray diffraction (XRD). CAP-treated nanoHA exhibited smaller particle sizes and enhanced crystallinity compared with chemically synthesized controls. Cytotoxicity assays using L929 fibroblasts confirmed excellent biocompatibility of the obtained materials.

These findings indicate that RONS-mediated CAP synthesis provides a safe, tunable, and environmentally friendly method for producing high-quality nanoHA. By overcoming limitations of conventional approaches, this strategy may advance applications in tissue regeneration.

This research was funded in whole by the National Science Centre, Poland (Grant No. 2025/57/N/ST8/01864).

Remisio: An Integrated Digital Health Platform for Continuous Monitoring and Early Flare Detection in Inflammatory Bowel Disease

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: self-reported outcomes, remote patient monitoring, digital twin for medicine, patient engagement

Inflammatory Bowel Disease (IBD), including Crohn's Disease and Ulcerative Colitis, are chronic conditions requiring lifelong management with alternating periods of remission and relapse. Effective disease control depends on early detection of flare-ups and continuous monitoring of multiple health parameters. Digital health solutions offer promising opportunities to bridge gaps in traditional episodic care models.

Current IBD management relies on scheduled clinical appointments, creating critical surveillance gaps between visits where disease progression often goes undetected until emergency presentation. Existing digital tools lack comprehensive integration of patient-reported outcomes, dietary data, and clinical parameters into unified platforms that serve both patients and clinicians.

By transforming reactive episodic care into proactive continuous monitoring, this platform addresses a critical gap affecting 4.9 million IBD patients globally and establishes a scalable framework for chronic disease management beyond gastroenterology. The structured longitudinal datasets generated enable data-driven personalized medicine approaches while potentially reducing emergency hospitalizations through early intervention. This work demonstrates how comprehensive digital health solutions can fundamentally reshape chronic disease management paradigms.

We want to present project and implementation of *Remisio* platform developed as a functional prototype that is currently prepared for clinical validation through a pilot study involving 30 IBD patients

Respiration-Dependent Changes in ABP and CBFV Waveform Morphology Assessed Using Derivative Dynamic Time Warping

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: dynamic time warping, autonomic nervous system, cerebral blood flow, controlled breathing

Respiratory modulation introduces systematic changes in arterial blood pressure (ABP) and cerebral blood flow velocity (CBFV) waveforms morphology, which may persist beyond the fundamental respiratory frequency component. Understanding how respiration influences cardiovascular and cerebral hemodynamics is an important topic in physiological signal analysis and neuroengineering. This study aimed to apply the Derivative Dynamic Time Warping (DDTW) algorithm to quantify the influence of controlled breathing on cardiovascular and cerebrovascular signals morphology and to investigate these relationships using clustering and classification methods.

The dataset consisted of physiological recordings from 66 healthy adult volunteers (KB-170/2014 and KB-179/2023/N). ABP and CBFV signals were processed using filtering and extraction of cycle-based metrics (systolic phase onset, systolic phase peak, RR interval). Alignment costs between selected metrics were calculated using DDTW, and the resulting values were analyzed with clustering and machine learning approaches.

The results demonstrate that DDTW-based alignment costs vary systematically with breathing frequency ($p < 0.001$) and allow differentiation between breathing conditions (CatBoost classification accuracy: 88%). These findings indicate that DDTW-derived morphological metrics can capture respiration-related dynamics in cardiovascular and cerebrovascular signals, and remain sufficiently robust for machine-learning-based classification even after removal of the respiratory harmonic component.

SALT SPECIFIC EFFECTS ON PHOSPHOLIPID-BASED MYELIN FIGURES: PROSPECTS FOR BIOMIMETIC OPTICAL WAVEGUIDES

Health Engineering, Future Medicine, and Biotechnologies

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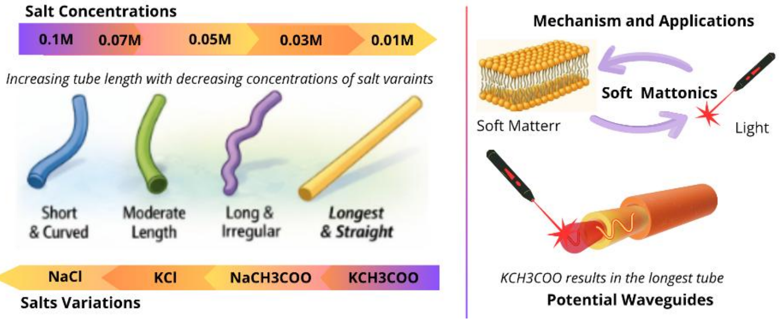
Keywords: Phospholipids, Multi-lamellar, Lyotropic Liquid Crystal, Waveguides

Physiologically relevant salts are crucial for membrane stability, osmotic balance and fundamental biological processes [1]. Specifically, Na^+ and K^+ ions are essential for maintaining axonal membrane potential during nerve impulse transmission. Axonal regions in nerves are further insulated by a phospholipid-rich, multilamellar lyotropic liquid crystal (LLC) myelin [2]. Myelin integrity is crucial for faster nerve signal transmission and proper cognitive function. Moreover, myelin being an LLC is a promising synthetic, tunable waveguide for soft matter photonics [3]. To obtain a stable, long-lived LLC that can serve as an *in vitro* potential waveguide, we performed salt-specific studies using varying salt concentrations (0.01 M to 0.1 M) of acetates and chlorides of K^+ and Na^+ on L-alpha phosphatidylcholine.

The polarized light microscopy studies revealed varying tube morphology across different salt types and concentration ranges, with the longest tubes reported in the presence of potassium acetate, highlighting the potential of phospholipid systems as biomimetic soft photonic materials capable of guiding light. This study aims to establish and validate prior salt case studies on a biomimetic membrane model through comparative analysis, supplemented with visual and statistical data to support the comparison and theoretical description.



(a) (b)

Fig. 1. a) A schematic illustration of ion-specific effects on the morphology of L-alpha-phosphatidylcholine, a lyotropic liquid crystal, under varying salt concentrations of acetates and chlorides of sodium and potassium. (b) Illustration of soft-matter photonics: the longest myelin tubes obtained in the presence of potassium acetate can serve as potential waveguides for future experiments

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Should Virtual Reality be Incorporated into the Standard Procedure for Venipuncture?

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: pediatric, virtual reality, venipuncture

Venipuncture in pediatric patients, particularly those with cancer, presents unique challenges due to small, fragile veins and high levels of procedural anxiety. Minimizing pain while maximizing first-attempt success is therefore a clinical priority. Immersive technologies such as virtual reality (VR) have emerged as nonpharmacological interventions for procedural pain, anxiety reduction, and patient education, but their role within routine venipuncture protocols remains underexplored. This study evaluated the key quality indicators which can help to implement immersive VR distractions during venipuncture in children with cancer as part of the standard procedure. Based on the current state of the art, VR use during venipuncture produced significant reductions in procedural pain and anxiety. Given the heterogeneity in headset and animation use, the focus should be on standardizing onboarding procedures for medical staff and sharing preparatory materials with parents before the visit 10 . Wider adoption could improve patient experience, reduce procedural distress, and complement existing pain-management strategies, but more studies are needed, taking into consideration a broader range of factors, with a focus on defining robust quality indicators to establish and monitor the implementation process effectively.

Simulation-Based Optimization of Patient Registration in a Family Medicine Practice

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: discrete event simulation, patient flow, healthcare management

Long patient waiting times at registration desks remain a persistent operational challenge in primary care, contributing to patient dissatisfaction and staff overload. A family medicine practice in Wrocław faced this problem directly, with recurrent congestion at its registration desk handling both walk-in and telephone contacts, and demand peaking sharply on Monday mornings.

To evaluate potential solutions before committing resources, a Discrete Event Simulation (DES) model was developed – an approach that tracks entities moving through a system over time, capturing stochastic arrivals and service durations, making it well-suited to identifying bottlenecks. The model was built from six weeks of observational data and used to compare two interventions: adding a part-time receptionist during peak hours, or shifting 40% of bookings online. Both substantially reduced waiting times, with mean wait dropping from 1.35 min to 0.32 min and 0.45 min, and maximum queue length decreasing from 26 to 6 and 9 patients respectively.

These results demonstrate that simulation models built from routine observational data can provide actionable guidance for small practices, offering a transferable, low-barrier framework for evidence-based operational decision-making in resource-constrained healthcare settings. The model further establishes a foundation for real-time data integration, enabling Digital Twin implementations for continuous operational monitoring.

Studies On Heat-Induced Generation Of Selected Betacyanin Dehydrogenated Derivatives From *Hylocereus Polyrhizus* Fruit Pulp Extract

Health Engineering, Future Medicine and Biotechnology

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Keywords: betalains, betacyanins, dehydrogenation, chromatography

Betalains are natural organic pigments classified into betacyanins and betaxanthins based on their structure and color. They are sensitive to factors such as temperature and pH which under selected conditions they may initiate decarboxylation or dehydrogenation reactions. Dehydrogenation of betacyanins can occur at two positions within the molecule: between carbon atoms C2 and C3 (creating the xan- form) and between carbon atoms C14 and C15 (forming the neo- form).

The main betacyanins previously isolated from *Hylocereus polyrhizus* (Weber) Britton & Rose fruit extract: betanin, phyllocactin, and hylocerenin, were heated at 70°C for up to 1 h in the presence of buffer solutions with pH values ranging from 3 to 6. The solutions before and after heating were analyzed using the LC-DAD-ESI-MS technique in SIM (Selected-Ion Monitoring) mode. Based on the obtained chromatograms and current literature, the generated dehydrogenated forms of betacyanins were identified, including 2,17-bidecarboxy-neobetanin and 2,17-bidecarboxy-phyllocactin. These compounds were generated in the presence of acetate buffer at pH 3.

The obtained results may serve as a basis for future isolation of dehydrogenated compounds which could subsequently be investigated for their potential antioxidant properties characteristic of betalains.

The research was funded by the National Science Centre, Poland (NCN) under project no. UMO-2021/41/N/NZ9/03046.

Surface Modification with DLC Coating as a Strategy to Improve Tribological Stability of Guided Growth Spinal Systems

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: tribocorrosive, spine implants, growth guidance system, diamond-like carbon

Early-onset scoliosis treatment requires simultaneous correction of spinal deformity while preserving growth potential. Growth Guidance Systems reduce the need for repeated revision surgeries; however, the presence of mobile screw–rod junctions promotes friction and wear, which may intensify under inflammatory conditions.

The aim of this study was to evaluate the tribological performance of the screw–rod junction of the SOCORE (NovaSpine) system manufactured from Ti6Al4V alloy. Two surface conditions were compared: passivated layer (PL) and diamond-like carbon coating (DLC). Tests were conducted in distilled water (DW) and in an acidic sodium lactate solution (ASL), simulating an inflammatory environment. The analysis included static and kinetic coefficients of friction, mass loss, wear morphology, wettability, and pH variations during testing.

The ASL environment significantly increased friction coefficients, particularly for PL specimens The DLC coating stabilized friction behaviour and maintained values close to those observed in DW. Mass loss for PL samples was approximately 0.05 g regardless of the medium, whereas DLC exhibited substantially lower values. The increased contact angle indicated reduced surface interaction with polar components. The results confirm that both the corrosive environment and surface modification significantly affect tribological processes in the screw–rod junction of the GGS system. The DLC coating provides effective tribological reinforcement, particularly under inflammatory conditions.

The Relationship Between Baroreflex, Cerebrovascular Reactivity, and the Blood-Brain Barrier Biomarkers in the Acute Stage After Brain Trauma

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: biomarkers, blood-brain barrier, cerebrovascular reactivity, baroreflex

Traumatic brain injury (TBI) is a major global public health concern, affecting approximately 50 million people annually. Blood-brain barrier (BBB) biomarkers provide objective measures of neuronal and glial injury. However, their relationship with key homeostatic mechanisms – cerebrovascular reactivity and autonomic nervous system (ANS) function remains unclear.

We analyzed 36 patients from the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) study (Perm. No. 514). ANS activity was assessed using baroreflex sensitivity (BRS), cerebrovascular reactivity via pressure reactivity index (PRx) and four serum BBB proteins (UCH-L1, Tau, NSE, and S100B) were measured repeatedly during days 1–3 post-injury.

Concentration of UCH-L1 ($p = 0.008$), Tau ($p = 0.035$), NSE ($p = 0.003$) and S100B ($p < 0.001$) decreased over time, while PRx improved ($p = 0.013$). BRS did not change significantly. PRx correlated with UCH-L1 ($r = 0.42$), Tau ($r = 0.34$), and S100B ($r = 0.43$) on day 2. Heatmap visualizations revealed that patients with low BRS and impaired cerebrovascular reactivity (high PRx) after 3 days had the highest BBB levels.

These findings suggest that BBB disruption and neuronal injury may be associated with impaired cerebrovascular reactivity and ANS dysfunction. Further studies are warranted to determine the prognostic significance of these observations.

Type I Interferon Signaling Shapes Microglial Activation After Ischemic Brain Injury

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: ischemic stroke, type I interferon, neuroinflammation, microglia

Ischemic stroke induces a robust neuroinflammatory response involving resident microglia and infiltrating peripheral immune cells. Microglia rapidly adapt their functional state after injury, yet the molecular pathways governing these responses remain incompletely understood.

Type I interferon (IFN-I) signaling is increasingly recognized as a regulator of neuroimmune processes and is activated in microglia after brain injury. However, its role in shaping microglial activation states, immunometabolic programs, and spatial interactions with infiltrating immune cells following ischemic stroke remains unclear.

We investigated the contribution of IFN-I signaling to post-stroke neuroinflammation using a mouse model of ischemic stroke, including IFNAR-deficient mice. Brain immune cells were analyzed by imaging mass cytometry and flow cytometry to define microglial phenotypes and their spatial organization at single-cell resolution.

Our data demonstrate that IFN-I signaling drives distinct, region-specific microglial activation states and modulates their interactions with infiltrating immune populations after ischemic injury.

These findings identify IFN-I signaling as a key regulator of the post-stroke neuroimmune microenvironment. By integrating spatially resolved approaches, this study uncovers neuroimmune features that are not accessible through dissociative techniques and provides mechanistic insight into immunometabolic regulation in ischemic brain injury.

UNIVERSALIZATION OF PROSTHETICS, DISTANT FUTURE OR TECHNOLOGY OF TOMORROW

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: 3D-printed prostheses, 3D limb scanning, modular upper-limb design, hybrid manufacturing

3D scanning and 3D printing are reshaping upper-limb prosthetics, enabling rapid, low-cost fabrication of individualized sockets and hand components directly from digital limb models. Handheld scanners and CAD workflows already support transtibial and upper-limb sockets produced in under 24 hours for a few hundred euros, with clinically acceptable fit and repeatable geometry. In parallel, modular hand and finger designs group users into a small set of anthropometric size families, allowing standardized joints, finger bodies and wrist units to be reused across many patients.

This work focuses on hybrid manufacturing strategies for such modular upper-limb systems, combining 3D-printed, scan-based sockets and adapters with standardized components that could later be mass-produced by injection molding or other high-throughput methods. Early studies on modular voluntary-opening hands and optimized finger linkages indicate that reducing unique part counts and fixing key interface dimensions can substantially cut cost and assembly time without sacrificing function. Within this framework, universalization of prosthetics becomes a matter of codifying digital design rules, standard size sets and validated materials so that personalized, scan-based prostheses can be delivered at scale in both high-income clinics and low-resource settings

Lem Next Gen Science Forum at Wrocław Tech
April 28-29, 2026

Health Engineering, Future Medicine, and Biotechnologies

POSTERS

A Multimodal Mobile Platform for Digital Phenotyping: Integrating Behavioral Surveys and Cognitive Games into the BRAVES-Cog Diagnostic Framework

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: digital phenotyping, neurobiomarkers, self-reported outcomes, cognitive gamification

Traditional clinic-based assessments offer important snapshots of cognitive status but are limited in temporal density, ecological context, and inclusivity for diverse neurotypes. While digital phenotyping enables non-intrusive quantification of behavior, the field lacks integrated platforms bridging real-world measures with high-fidelity neurophysiological signals (e.g., EEG/fNIRS).

The BRAVES-Cog mobile application addresses this challenge as a comprehensive data-harvesting hub designed for accessibility and neurodiversity. It systematically collects longitudinal phenotypic data through validated screeners covering lifestyle factors, physical activity, sleep quality, anxiety, and depression, alongside active cognitive performance data obtained from gamified assessments, including tasks such as the *Stroop*, *Flanker*, and *Trail Making* tests. These mobile-derived metrics are designed for multidimensional integration with high-fidelity laboratory measurements. By processing heterogeneous data streams using AI and advanced biosignal analysis, the platform identifies unique behavioral "fingerprints" (multivariate patterns across sleep, activity, and cognition) and neurobiomarkers.

We demonstrate the feasibility of high-frequency, real-world multimodal integration, enabling individualized temporal health profiles essential for personalizing therapy in brain and mental disorders. This work advances digital health by demonstrating how a mobile interface functions as a research-to-clinic translational tool, enabling structured, data-informed assessment of cognitive complaints in real-world settings.

Project entitled: *BRAVES-Cog: An integrated approach to the assessment and neuromodulation of cognitive deficits using multimodal behavioural, environmental, neurobiomarkers and biomedical signals (**B**rain **R**egulation, v**a**scular, **V**ocal, **E**ye & **S**timulation)* is funded under the 'Support for Research Teams 2025' programme of the Wrocław University of Science and Technology (No. 43WB_0009_25).

A Two-Stage Machine Learning Framework for High-Precision Identification and Functional Classification of Antimicrobial Peptides

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Antimicrobial peptides, Machine Learning, Random Forest, Prediction

Antimicrobial Resistance (AMR) represents a critical global health threat, necessitating the discovery of novel therapeutic agents. Antimicrobial peptides (AMPs) are key components of the innate immune system and serve as promising candidates for next-generation antibiotics due to their broad-spectrum activity. However, experimental discovery remains labor-intensive, and existing computational models often struggle with severe class imbalance.

This study proposes a two-stage hierarchical machine learning framework using Random Forest classifiers. To ensure data quality and reduce redundancy, CD-HIT screening was performed at an 80% sequence identity threshold. A random oversampling technique was subsequently implemented to balance both the binary (AMP vs. non-AMP) and multi-class (functional activity) datasets. The model achieved a mean 5-fold cross-validation accuracy of 87% for AMP identification (Stage 1) and a final functional classification accuracy of 92% (Stage 2), demonstrating high precision across all categories. Feature-importance analysis identified cysteine frequency as the primary biological driver of AMP prediction and a critical feature for determining functional activity.

These findings demonstrate that ensemble learning is a reliable approach for predicting peptide function directly from amino acid sequences. This framework provides a robust tool for the rapid, cost-effective screening of synthetic AMPs, potentially accelerating the development of targeted therapies against multidrug-resistant pathogens.

AM404 – THE MIRACULOUS METABOLITE OF PARACETAMOL?

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: AM404, paracetamol, drug metabolism, analgesic pharmacology

Acetaminophen, broadly known as paracetamol, has been on the market since 1955, yet its mechanism of action remains only partially understood. Recent research suggests that it is not the paracetamol molecule itself that is responsible for this drug's analgesic mechanism, but its metabolites, mainly AM404. AM404 exerts effects on a variety of molecular targets, mainly the vanilloid receptor TRPV1, the cannabinoid receptors CB1 and CB2, transporter proteins such as human serum albumin (HSA), and voltage-gated sodium channels NaV1.7 and NaV1.8.

Molecular research is crucial for studying the mechanisms underlying paracetamol's analgesic action, particularly the influence of AM404 on various molecular targets. By broadening knowledge of AM404's interactions with its designated molecular targets, we can explore novel approaches to pain treatment.

In this work, we present key findings on AM404 and its interactions with several molecular targets, performed with molecular dynamics and molecular docking.

This work is especially important in the context of the opioid addiction crisis, as AM404 can be used as a 'template' for novel analgesic development. Another interesting aspect of this study is the polypharmacology of paracetamol, particularly given the variety of molecular targets of AM404, guiding future research on safer and more targeted analgesic therapies.

Analysis of the Expression of Adhesion Proteins From Mytilus Californianus in E. Coli Bacteria

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Mussel foot proteins, recombinant proteins, Escherichia coli, affinity chromatography

The ability of mussels to adhere to wet, slippery surfaces in a saline environment has attracted the attention of researchers for decades. This phenomenon is largely attributed to adhesive proteins produced by the mussel foot, known as Mussel Foot Proteins. These proteins are being intensively studied due to their remarkable adhesive properties and potential biomedical and engineering applications. They can be used, for example, in the development of surgical adhesives that will work effectively in a humid environment.

The main objective of the study is the optimization of expression and purification of five novel mussel adhesive proteins produced by Mytilus californianus in Escherichia coli cells (Mcfp).

The proteins were purified using affinity chromatography under native and denaturing conditions on nickel or cobalt resin. To assess the purity of the obtained proteins and confirm their identity, SDS-PAGE and Western blot analyses were performed.

All target proteins were successfully expressed; however, the best results were obtained during the purification of Mcfp-3 under denaturing conditions using nickel affinity resin and imidazole elution.

The obtained results confirm the feasibility of expressing mussel-derived adhesive proteins in the bacterial system Escherichia coli. However, optimization of cultivation and purification conditions is required to improve process efficiency.

Analysis of the Influence of Biologically Synthesized Metal Nanoparticles on Plant Growth and Development

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: green tea, biosynthesis, iron nanoparticles, agriculture

The development of sustainable agricultural products is essential to reduce the environmental impact of conventional agrochemicals. In this context, green synthesis of metal nanoparticles (NPs) using plant extracts has emerged as a promising and environmentally friendly approach. Iron-based nanomaterials are of particular interest due to their potential role in improving plant nutrition and supporting early growth.

However, despite increasing interest in plant-mediated nanoparticle synthesis, limited data are available regarding their biological safety and effects on plants under soil conditions. Therefore, the aim of this study was to biosynthesize iron nanoparticles using extract from green tea (*Camellia sinensis*) and to evaluate their influence on early plant development, using radish as a model species.

The results confirmed successful nanoparticles formation and, importantly, demonstrated no phytotoxic effects on seeds germination and plant growth in soil-based experiments. Although no statistically significant differences were observed between tested groups, a consistent growth-promoting tendency was noted at a concentration of 50 mg/L (among tested concentrations of NPs 10, 50 and 100 mg/L).

These findings suggest that green-synthesized iron nanoparticles may represent a safe and promising candidate for agricultural applications. Nevertheless, long-term studies are required to evaluate their effects on plant physiology, soil interactions, and potential environmental accumulation in order to comprehensively assess their sustainability and ecological safety.

ANALYSIS OF THE PROTECTIVE EFFICIENCY OF A SPEEDWAY HELMET SUBJECTED TO DYNAMIC LOAD

Health Engineering, Future Medicine, and Biotechnologies

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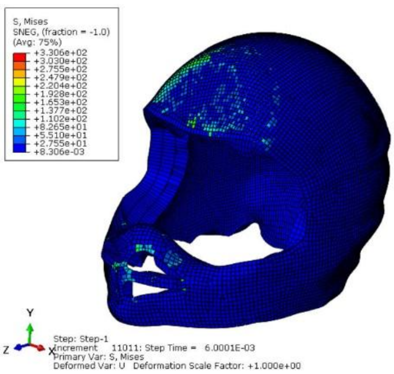
Keywords: speedway helmet, biomechanics of injuries, explicit numerical analysis, medical engineering

Motor sports are characterised by a high risk of injury, particularly head injuries, resulting from high speeds and limited physical protection for competitors. Protective helmets are a fundamental element in the prevention of traumatic brain injuries, but their effectiveness is often assessed in simplified test conditions that do not fully reflect real-life accident scenarios.

The aim of this study was to investigate the impact of dynamic loads on the protective effectiveness of a speedway helmet using advanced medical engineering methods. A detailed numerical model of the helmet was developed based on computed tomography data and integrated with a biomechanically advanced model of the human head. Dynamic simulations of typical fall scenarios at different speeds and impact directions were performed, analysing the distributions of stresses and strains in the helmet and intracranial pressure.

The results indicate that the direction and speed of impact are critical to the risk of brain injury, with frontal impacts generating the highest biomechanical loads on the brain. The work highlights the potential of virtual testing environments, anatomically accurate models and numerical simulations as tools to support the development of safer protective technologies in the medicine of the future.

a)



b)

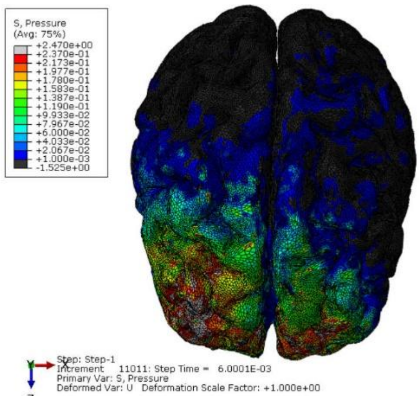


Fig. 1. a) H-M-H stresses [MPa] and b) pressure distribution [MPa] in the brain during frontal impact with a protective barrier at a speed of 70 km/h

APPLICATION OF CDNA VECTORS TO STUDY EXPRESSION AND LOCALIZATION OF FLUORESCENTLY TAGGED TAU AND PARP1 PROTEINS IN MAMMALIAN CELLS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: neurodegenerative diseases, Tau, PARP1, cDNA vectors

Neurodegenerative diseases are a growing problem in aging societies, and understanding the mechanisms underlying their development is one of the key challenges of modern molecular biology. Previous studies have demonstrated the role of numerous proteins in the development of these diseases, including Tau and PARP1.

The aim of presented study was to prepare cDNA vectors encoding human Tau and PARP1 proteins fused with fluorescent proteins: enhanced yellow fluorescent protein (EYFP) and monomeric red fluorescent protein (mRFP), enabling the study of their intracellular distribution under a fluorescence microscope.

Obtaining of desired constructs: pEYFP-C1/Tau, pEYFP-C1/PARP1, pmRFP/Tau, and pmRFP/PARP1 was confirmed by restriction analysis and sequencing, and preliminary expression of the constructs in mammalian N2a and COS-7 cell lines demonstrated intracellular localization of fusion proteins corresponding to Tau and PARP1 under physiological conditions.

It was confirmed, that resulting vectors constitute a useful tool for studying changes in Tau and PARP1 localization under various experimental conditions. Such studies may help understand the role of both proteins in the development of neurodegenerative diseases. Importantly, the ability to simultaneously visualize both proteins allows for the analysis of their interaction and potential interplay.

BIOCHEMICAL ANALYSIS OF POLYSACCHARIDES FROM CALCIUM CARBONATE BIOMINERALS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: glycosaminoglycans, biomineralization, calcium carbonate, otoliths

Calcium carbonate is an inorganic salt that serves as a primary structural component of mollusc shells and otoliths in the inner ear of fish. The organic matrix includes glycosaminoglycans (GAGs), although their role in biomineralization remains unclear. The mechanisms of biomineralization are complex, involving tight regulation of calcium carbonate crystal growth and organization. Examples include calcite and aragonite in mollusc shells, nacre, and corals. Understanding the mechanisms underlying calcium carbonate biomineral formation could lead to novel strategies for designing advanced materials and approaches in tissue regeneration. In this study, we investigate the presence of GAGs in common carp otoliths and examine the effect of the organic matrix on calcium carbonate crystal formation. Biomineralization research integrates knowledge from biochemistry, physics, and materials science, offering an interdisciplinary framework for understanding and harnessing nature's strategy for constructing complex mineral structures. A deeper insight into these processes may contribute to the development of methods for regenerating human otoconia. Our next goal is to elucidate how interactions between GAGs and ototoxic drugs influence biomineral degradation.

BIOCONTROL ABILITY AND ACTION MECHANISM OF *BACILLUS LICHENIFORMIS* AGAINST FUNGAL PHYTOPATHOGENS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: *Bacillus licheniformis*, antifungal activity, VOCs, phytopathogens

Fungal diseases pose a significant threat to global agriculture, often leading to substantial crop losses and reduced food quality. In the era of searching for sustainable solutions in agricultural production, biological control with beneficial bacteria offers a promising way to protect plants without harming the environment.

Despite the potential of various microbial agents, identifying highly effective strains and fully understanding their complex modes of action remains crucial for developing reliable biopesticides. This study focuses on *Bacillus licheniformis* CCM 2145, investigating its multi-faceted approach to suppressing the growth of aggressive fungal phytopathogens, including *Alternaria alternata*, *Rhizopus stolonifer*, and *Penicillium expansum.*

Our research demonstrates that biomass of *B. licheniformis* CCM 2145 effectively suppresses fungal growth through by the production of volatile organic compounds (VOCs), which achieved total growth inhibition of all tested pathogens.

These findings highlight the potential of *Bacillus licheniformis* CCM 2145 as an environmentally friendly biocontrol agent. VOC-driven inhibition contributes to a deeper understanding of bacterial–fungal interactions and supports sustainable plant- protection strategies. Furthermore, combining antifungal bacterial activity with interdisciplinary strategies such as immobilization within electrospun fibers may support the development of non-invasive, eco-friendly delivery systems for beneficial microorganisms in sustainable agriculture.

This research was funded by the National Science Centre, Poland, OPUS25 Grant Number 2023/49/B/NZ9/00959, "*Designing a versatile and environmentally friendly alginate-based fiber platform and evaluating the impact on the soil environment".*

BIODEGRADATION OF COTTON BY *GALLERIA MELLONELLA* LARVAE

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: *Galleria mellonella*, cotton degradation, cotton waste, cellulose

Galleria mellonella is a model organism in microbiology and toxicology studies. Recently, its larvae have attracted attention because of their reported ability to degrade synthetic polymers such as polyethylene and polystyrene [1, 2]. In contrast, little is known about their ability to degrade cotton, composed primarily of cellulose. Global cotton production reached approximately 24.8 million tons in 2024 [3]. Despite this large-scale production, environmentally friendly strategies for managing cotton waste remain limited, as current approaches rely mainly on incineration or landfill disposal. We hypothesized that *G. mellonella* larvae are capable of digesting cellulose and thus may contribute to the degradation of cotton.

In our experiments, we demonstrated that *G. mellonella* larvae are capable of gnawing cotton fibers with their mandibles, resulting in significant material degradation. To enhance this process, fragments of cotton textiles were subjected to enzymatic pre-treatment with cellulases from *Trichoderma reesei* followed by soaking in sucrose solution before being fed to the larvae under controlled conditions. Depending on the experimental conditions, including enzymatic pre-treatment length and sugar concentration, the degradation of cotton reached up to 80% of the initial material mass. These findings demonstrate the potential of *G. mellonella* larvae as a biological system capable of reducing cotton textile waste.

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Biomechanical Abdominal Aortic Aneurysm Analysis

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: abdominal aortic aneurysm, Finite Element Analysis (FEM), Maximum Principal Stress (MPS)

Abdominal aortic aneurysms are a significant clinical problem due to the risk of rupture and high mortality. Modern imaging and numerical modeling methods allow for an increasingly accurate assessment of the stress distribution in the aneurysm wall and prediction of the rupture place. The aim of the study was to analyze the impact of the boundary conditions on the results of biomechanical simulations of abdominal aortic aneurysms. The study was conducted on five patients using geometric models reconstructed from medical imaging (CT scans). Different load models (i.e. different values of blood pressure) and different material models describing the properties of the aneurysm wall were used. The results showed that both the choice of material model and the load conditions significantly affect the values of maximum stresses (99th percentile), with the greatest differences observed depending on the individual geometry of the aneurysm of a patient. The results obtained emphasize the importance of personalization of numerical models in assessing the risk of aneurysm rupture. The work contributes to the development of more reliable, individualized methods to support clinical decisions in the treatment of abdominal aortic aneurysms.

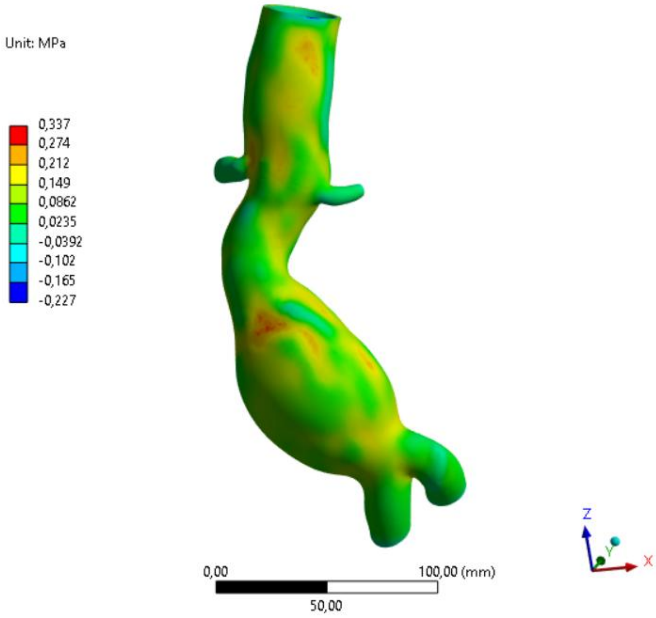

Fig. 1. Maximum principal stress distribution in the abdominal aortic aneurysm wall patient No. 1 (Mooney-Rivlin material model)

Biomimetic Nanofiber Scaffolds for Post-Extraction Socket Preservation Via Electrospinning

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: electrospinning, nanofiber scaffolds, dental tissue engineering, biomechanical matching

This work leverages established electrospinning protocols to engineer nanofiber mats specifically tailored to replicate the structural and mechanical properties of alveolar socket tissues. Optimizing parameters of the process will lead to producing uniform nanofibers (~250–300 nm diameter) with 60–90% porosity matching trabecular bone architecture, designed to conform to standard molar socket dimensions and withstand masticatory loading. The core innovation lies in matching scaffold compliance to native tissue mechanics during the critical 3-month resorption window, when ~50% socket width loss occurs. Nanofibers should deliver topographic guidance for osteoblast proliferation while maintaining dimensional stability under physiological strain.

This biomimetic electrospinning approach advances ridge preservation by creating anatomically and mechanically robust scaffolds that harmonize with socket biomechanics, enabling successful implant site development.

Bone Degeneration in the Osteoarthritic Knee: The Role of Asymmetry

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: tibial plateau; osteoarthritis; computed microtomography; microhardness

Osteoarthritis is a common degenerative joint disease that significantly affects mobility by causing cartilage degeneration and structural changes in the subchondral bone. In the knee, these changes are often driven by mechanical misalignments, such as valgus deformity, which create uneven mechanical load across the joint, especially in the tibial plateau. Understanding the specific structural and mechanical shifts in bone tissue is essential for improving osteoarthritis diagnosis, refining surgical plans, and developing more effective orthopedic implants.

This study investigates the tibial plateau of patients with advanced osteoarthritis and valgus deformity using high-resolution micro-computed tomography (μCT), scanning electron microscopy (SEM), and microhardness testing. The research quantifies critical parameters like bone volume fraction (BV/TV), trabecular thickness (Tb.Th), and Young's modulus to map how the subchondral layer adapts to pathological loading.

Our findings reveal that uneven load distribution triggers significant bone remodeling, characterized by microstructural degradation, extensive microcracks, and altered mineralization patterns, specifically in the medial regions of the tibial plateau.

These results provide a comprehensive map of how osteoarthritis physically transforms bone at the microscopic level. By bridging the gap between biomechanical overload and tissue degradation, this study supports the design of more biocompatible prostheses and enhances our ability to detect early-stage joint degeneration.

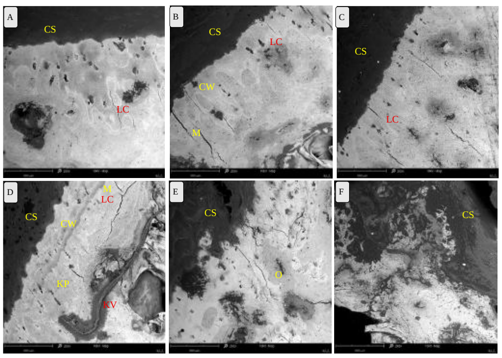

Fig. 1. SEM images of trabecular bone tissue located in the subchondral region of the lateral tibial condyle, magnification ×265 (Phenom ProX)

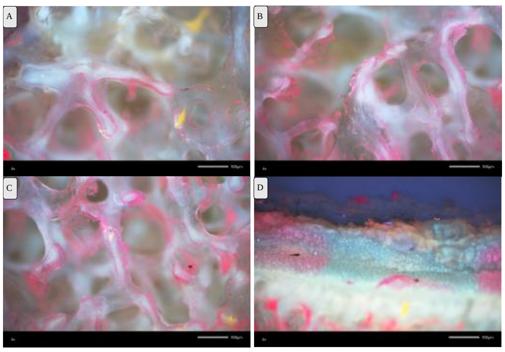

Fig. 2. Fluorescence microscopy images showing trabecular bone and cartilage–bone interface regions, revealing variable mineralization and structural alterations indicative of osteoarthritic changes

Boronic Acid–Containing Compounds as Novel Inhibitors of Tyrosinase: In Vitro and Computational Insights

Health Engineering, Future Medicine and Biotechnologies

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Keywords: Tyrosinase, boronic acid, enzyme inhibition, molecular docking, melanin

Tyrosinase is a copper-containing enzyme involved in melanin biosynthesis and is associated with hyperpigmentation, food browning and melanoma [1, 2].

The discovery of effective tyrosinase inhibitors remains a key goal in medicinal and cosmetic chemistry, as many existing inhibitors are limited by instability, toxicity and low efficacy [2, 3].

In this study, a series of boronic acid–containing compounds was evaluated for tyrosinase inhibition using in vitro enzymatic assays and computational approaches. Five derivatives were tested, showing IC_{50} values ranging from 1.182 mM to 3.554 mM, with AAW-10 exhibiting the strongest activity compared to reference Kojic acid. Molecular docking studies were performed to investigate interactions within the tyrosinase active site, highlighting the role of the boronic acid moiety in binding, and rationalizing their inhibitory activity as the boronic acid moiety plays an important role in interactions with residues in the enzyme active site.

These results suggest that boronic acid-containing compounds are promising scaffolds for the development of new tyrosinase inhibitors, providing a foundation for future structural optimization and rational drug design.

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Characteristics of Liposomes' Chitosan Coating Produced by T-Junction Microfluidic Chip

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: microfluidics, microfluidics chip, liposomes, chitosan

Coating is a critical step in nanoformulation development, as it can improve stability, prolong circulation time, and enable surface functionalization for targeted delivery while reducing recognition by the immune system. Chitosan, a biocompatible and biodegradable polysaccharide, is widely used as a coating material due to its hydrophilic character and mucoadhesive properties. Chitosan coating also enables modulation of surface properties, which is essential for improving drug delivery performance.

The main objective of this study was to investigate the efficiency of POPC and DMPC liposomes coating using a microfluidic T-junction chip with varying chitosan concentrations under constant flow conditions. A systematic characterization was performed using both experimental and computational fluid dynamics (CFD) approaches. The presence of chitosan on the liposome surface was confirmed using Fourier transform infrared spectroscopy (FTIR) and colorimetric analysis. Additionally, the density and viscosity of chitosan solutions were experimentally determined and incorporated into CFD simulations to evaluate the mixing ratio within the microfluidic chip.

The combined experimental and numerical analysis enabled identification of optimal chitosan concentrations that provide the most efficient liposome coating. This approach demonstrates the potential of microfluidic systems for controlled and reproducible preparation of coated liposomal formulations for biomedical and drug delivery applications.

Characterization of Crystal-Associated Proteins in Calcium Oxalate-Rich Plant Tissues

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: proteins, calcium oxalate, plants, crystals

Despite the widespread occurrence of calcium oxalate in plants, the molecular mechanisms underlying its formation, including the processes that guide nucleation, polymorph development, and spatial arrangement remain poorly understood. It is also unclear how these biomineralization events relate to cellular ion balance, or how associated macromolecules contribute, highlighting the need for protein level investigations.

SDS-PAGE was used to separate crystal associated proteins extracted from calcium oxalate rich plant tissues, allowing visualization of distinct protein profiles. LC-MS/MS was then used to perform high resolution peptide separation and fragmentation, enabling proteomic profiling of the crystal associated fractions. Mass spectrometry-based protein identification was carried out by matching detected peptide spectra to plant protein databases using established search algorithms.

In proteomic analysis of calcium oxalate rich fractions are expected to reveal proteins associated with crystal formation and organization. Distinct protein patterns may indicate molecules involved in stabilizing or shaping crystals. Differences between tissues could suggest how local cellular conditions influence crystal development.

This study aims to show that calcium oxalate crystal formation is influenced by specific proteins rather than occurring purely physically. Identified proteins may contribute to crystal development and stability.

Overall, the work will provide insights into the molecular mechanisms of plant biomineralization.

Comparative Analysis of Three Analytical Methods for Evaluating the Proliferation of L929 and KERT Cells in the Presence of Apple Cider Vinegar

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: apple cider vinegar (ACV), cell culture, fibroblasts

Apple cider vinegar (ACV) is a fermentation product widely recognized for its diverse biological properties, including antimicrobial and antioxidant activities. Its increasing use in health-related and topical applications necessitates a thorough understanding of its interaction with mammalian cell lines.

To ensure maximum data reliability, this study employed a comparative analytical framework to evaluate the effects of sub-inhibitory concentrations of ACV on L929 fibroblasts and KERT cells. The primary objective was to cross-validate metabolic-based assays (MTT and resazurin assay) against automated confluence-based imaging to determine the consistency and robustness of these independent methods in assessing cell proliferation.

The comparative analysis revealed that all three independent methodologies – MTT, resazurin assay, and confluence algorithms – yielded highly congruent and reproducible results, collectively confirming that ACV does not impair cell viability or proliferation at concentrations up to 1.25% (v/v).

By validating the high correlation between metabolic and morphological assessments, this research establishes a robust multi-assay protocol for evaluating the biocompatibility of natural fermentation products. These findings provide a reliable methodological foundation for future studies investigating the therapeutic potential of ACV at higher concentration ranges.

Computational Design of Salen-Based Drug Candidates For Cancer And Tuberculosis Using DFT, Molecular Docking, And Molecular Dynamics

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: SL derivatives, DFT and in silico study, Molecular docking and dynamics simulation, Anticancer and antitubercular activity

Salen ligands are coordination compounds with a planar structure and exhibit diverse biological activities. These ligands have been widely studied and applied in the field of medicinal chemistry owing to their flexible chemical structure. Recently, computational chemistry has been employed as a new method for the study of medicinal chemistry, enabling the design and assessment of potential drug candidates. Despite the promising characteristics of salen ligands (SL), their applications have been restricted by their cytotoxicity, solubility, and stability under physiological conditions. Therefore, the design and study of their modified forms with better stability and biological activities have been an important goal for researchers. In the present study, some SL derivatives were computationally designed by modifying their functional groups and evaluated by using density functional theory, molecular docking, molecular dynamics, and ADMET methods to assess their potential for the treatment of cancer and tuberculosis. The results indicated that the SL5, SL6, and SL7 derivatives have better stability, protein binding affinity, and pharmacokinetic properties compared to the original ligand. These results suggest the potential of the computationally designed SL ligand derivatives as promising drug candidates for the treatment of diseases such as cancer and tuberculosis.

Computational Stress Analysis of Personalized Mandibular Implant Under Physiologically Accurate Multi-Muscle Loading

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: biomechanical analysis, patient-specific implant, mandibular defect reconstruction, finite element method

Combining additively manufactured implant with vascularized fibula free flap is one of the most promising reconstructive techniques for severe mandibular defects. This method enables both excellent aesthetic outcomes and good mechanical strength, while also providing sufficient space for placing dental implants. Previous studies have not presented the results of biomechanical analysis under physiologically accurate multi-muscle loading for such a solution.

The main purpose of this study was to assess the biomechanical performance of a patient-specific mandibular implant designed for a patient with a bone tissue neoplasm. Finite element analysis was conducted in the case of four common occlusion conditions in a model consisting of the mandible, patient-specific implant, fibula fragments, and screws.

This study showed that the stress that could lead to damage to the implant has not been exceeded; however, significant stress has been observed in the lowest hole of the right mounting plate and on right screws securing the free fibula fragments in ICP, RMOL and RGF occlusion conditions.

The use of multi-muscle loading allows for a better understanding of the biomechanics of a combined implant for mandibular reconstruction, which translates into improvements in the implant design process and its subsequent clinical use.

Decoding the Glyco-Landscape: Analysis of α-2,6-Sialylation Patterns in Astrocyte and Microglial Cell Lines

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Multiple Sclerosis, glial cells, α2,6-sialylation, glycobiology

Multiple sclerosis (MS) is a neurodegenerative disease characterized by progressive axonal degeneration. Astrocytes and microglia are key regulators of de- and remyelination, and their dysregulated activation contributes to disease progression. Increasing evidence suggests that post-translational modifications, including glycosylation, play important roles in regulating immune signaling and cell-cell interactions. Sialylation, the addition of sialic acid residues to the terminal positions of glycoproteins, modulates immune responses and is altered in several diseases. However, glial sialylation patterns in MS remain poorly understood. Our previous studies in the cuprizone mouse model indicate increased α2,6-linked sialylation in astrocytes and microglia during demyelination, suggesting its potential role in glial dysfunction. In this study, we aim to functionally characterize α2,6-sialylation in murine BV-2 microglial and C8-D1A astrocytic cell lines by analyzing sialylation patterns and key enzymes involved in sialic acid metabolism. Both BV-2 and C8-D1A cells showed prominent α2,6-sialylation. Sialyltransferase ST6GAL1 was observed in the Golgi apparatus, with no differences in the protein level between glial cells. We also observed that most of the α2,6-sialylated proteins are localized mainly in the Golgi apparatus. Integrating glycobiology with neurobiology highlights the role of glycosylation in glial function and may suggest novel mechanisms of inflammation relevant to Multiple Sclerosis.

Determination of the Molecular Mechanisms of Neuroprotective Effects of CBD and CBG on Human HMC3 Microglial Cells

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: microglial cells, CBD, CBG, neuroprotection

Microglia, the immune cells of the central nervous system, can initiate a vicious cycle of chronic neuroinflammation when activated by factors like ATP, driving neuronal damage in diseases such as Alzheimer's and Parkinson's. Cannabidiol (CBD) and cannabigerol (CBG), natural cannabinoids, have emerged as potential therapeutic agents due to their anti-inflammatory and antioxidant properties.

Our study investigated the effects of CBD, CBG, and their combination on ATP-stimulated human microglial cells (HMC3). Using the Incucyte Live-Cell Imaging System, we analyzed cell proliferation, cytotoxicity. The studies analyzed the expression of key markers associated with pro-inflammatory (M1) and anti-inflammatory (M2) phenotypes, including iNOS, IL-1β, TNF-α, and SOD.

We observed a dose- and time-dependent cytoprotective effect, with higher compound concentrations reducing cell death compared to the control. Furthermore, both CBD and CBG significantly modulated the expression of inflammatory markers. Our findings indicate that these cannabinoids can steer activated microglia away from a harmful pro-inflammatory state towards a homeostatic, neuroprotective phenotype, highlighting their therapeutic potential for managing neuroinflammation.

This work was supported by National Science Center grant 2023/49/B/NZ7/02172.

Development of Molecular Probes for Taurine Detection in Commercial Energy Drinks – Implications for Consumer Safety

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: taurine, molecular probes, quantitative analysis, analytical chemistry

Monitoring bioactive compounds in food and beverages is an important aspect of consumer safety and public health protection. Energy drinks, widely consumed worldwide, often contain taurine, a compound with physiological effects on the nervous and cardiovascular systems. Reliable analytical methods are therefore essential to ensure accurate labeling and regulatory compliance.

Although advanced chromatographic techniques are available for taurine determination, they are not always practical for routine quality control due to cost and operational complexity. Additionally, taurine lacks natural chromophoric and fluorophoric groups, which makes its direct detection difficult. This creates a need for simple, sensitive, and cost-effective analytical approaches based on molecular probe chemistry.

The developed spectrofluorimetric method showed approximately 2.4-fold lower detection and quantification limits than the spectrophotometric method, while both techniques demonstrated high linearity and satisfactory precision.

These findings demonstrate that molecular probe-based systems can provide accessible and reliable tools for taurine determination in commercial beverages. By offering sensitive and practical alternatives to more complex techniques, the proposed methods support routine quality control and regulatory monitoring. This work contributes to the advancement of analytical strategies that integrate chemistry, biotechnology, and public health protection.

Directed Horizontal Visibility Graph Analysis of Irreversibility of Heart Rate Variability and Pulsatility Index During Slow Breathing

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: directed horizontal visibility graphs, irreversibility, heart rate variability, cerebral hemodynamics

Cardio- and cerebrovascular dynamics are inherently nonlinear and non-stationary, thus requiring advanced methods to capture their complex temporal organization beyond conventional statistical approaches. The Directed Horizontal Visibility Graph (dHVG) is a method that transforms time series into a network while preserving its topology.

Respiration strongly modulates autonomic nervous system (ANS); however its influence on cerebral hemodynamics remains incompletely understood. In this study, dHVG metrics and the Kullback–Leibler Divergence (KLD) irreversibility index were applied to R–R interval (ANS metric derived from ECG) and pulstility index(PI) time series (cerebral hemodynamic index estimated from cerebral blood flow velocity pulses) of 26 volunteers during slow and spontaneous breathing.

Slow breathing significantly reduced graph energy for both PI (453 ±64 vs. 514 ±67 [a.u]; p < 0.001) and R–R intervals (454 ±64 vs. 513 ±72 [a.u.]; p < 0.001) and increased graph density ($5 \times 10^{-3} \pm 7 \times 10^{-4}$ vs. $4 \times 10^{-3} \pm 6 \times 10^{-4}$ [a.u.]; p < 0.001 for both) compared to spontaneous breathing. KLD analysis revealed greater irreversibility and asymmetry in R–R dynamics during slow breathing (p < 0.01) with no significant changes in PI.

Respiratory-induced variations in cardiac and cerebral signals, captured by the autonomic and cerebral component reshape the topology of HVGs and affect the degree of time-series irreversibility. Slow breathing may augment cardiac autonomic regulation without altering cerebral hemodynamic pulsatility.

EFFECT OF 3D-PRINTED INSOLE COMPLIANCE ON LOWER-LIMB MUSCLE ACTIVITY: A PILOT SEMG STUDY

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: 3D printing (FDM), personalized insoles, surface electromyography (sEMG), plantar pressure

Foot insoles are widely used to improve foot support, comfort, and stability in daily activities and sports. Traditionally, insole selection has been empirical, with limited quantitative biomechanical validation of its effects. This study presents a mechanically informed design approach combined with experimental verification using surface electromyography (sEMG).

Personalized insole geometry was developed from individual footprints, static plantar-pressure maps, and rearfoot alignment. Cylindrical specimens made of PrintMe Flex 20D (TPEE) with various gyroid infill ratios were tested under uniaxial compression to determine the relationship between apparent compressive modulus and infill ratio. This relationship was used to assign region-specific infill while maintaining a consistent overall geometry. Two printed insole variants – “customized” and “stiffer” (targeting a 1.5× regional modulus) – were compared with a stock insole and a no-insole condition.

Main finding: In this single-subject pilot, sEMG recordings from tibialis anterior (TA) and lateral gastrocnemius (GAS) during walking, squats, and single-leg stance were task- and muscle-dependent, with no monotonic relationship between insole compliance (“customized vs. stiffer”) and muscle activation. The proposed methodology enables repeatable, mechanically justified tuning of region-specific insole support and motivates larger studies combining sEMG, plantar pressure, and kinematics.

Effect of EDTA on Stability and Structural Transformations of Gomphrenins and Their Acylated Derivatives

Health Engineering, Future Medicine and Biotechnology

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Keywords: betalains, betacyanins, gomphrenins, stability

Betalains are natural pigments derived from plants of the Caryophyllaceae family which are valued for their high extinction coefficients and health-promoting properties. Their wider application is limited by poor stability when exposed to d-block metal ions in solution.

This study investigated the effect of EDTA on the stability and structural transformations of gomphrenins and their acylated derivatives upon exposure to Cu^{2+}, Ni^{2+}, Zn^{2+}, Fe^{2+} and Fe^{3+} ions. Experiments were performed at pH 3-8 using acetate-phosphate and citrate-phosphate buffers. The initial absorbance of the tested solutions was 1 and the final metal ion concentration was 1 mM. Spectral changes were monitored before and after EDTA addition.

The impact of metal ions on pigment stability varied strongly with ion type and pH. Extensive pigment degradation was observed under Cu^{2+} activity. The subsequent addition of EDTA did not reverse this process. In contrast, for Ni^{2+} the chelator induced partial regeneration of the pigments, reaching approximately 20 % at pH 6 – an effect consistent with earlier reports for non-acylated betalains. For the remaining ions (Zn^{2+}, Fe^{2+}, Fe^{3+}), EDTA showed pH-dependent effects ranging from no detectable changes to slight stabilization.

These results demonstrate that the ability of EDTA to counteract metal-induced degradation of gomphrenins is highly selective and depends critically on both the metal ion presence and pH. The observed differences in regenerability may guide strategies for stabilizing betalain-based formulations using chelating agents.

Effects of Plant Extracts on Selected Fungal Diseases of Crop Plants

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: fungicides, plant extracts, positive allelopathy, Fusarium culmorum, Alternaria alternata, Botrytis cinerea, Fusarium oxysporum

Due to the intensive use of agrochemicals and its subsequent impact on food quality, there is a critical need for innovative plant protection solutions. A promising approach involves leveraging positive allelopathy to identify bioactive compounds with fungicidal properties. This study evaluates the antifungal activity of various plant extracts against pathogenic strains of Fusarium culmorum, Alternaria alternata, Botrytis cinerea, and Fusarium oxysporum. The screening revealed that ethanolic extracts of chives and parsley significantly inhibited F. culmorum, while F. oxysporum was most effectively suppressed by ethanolic extracts of goldenrod and turmeric, as well as aqueous mint extracts. Comprehensive GC-MS and LC-MS/MS analyses identified key antifungal constituents, including cyclic dipeptides such as Cyclo-(Leu-Ile), organic acids (malonic, citric, malic, and DL-lactic acids), and bioactive substances like erucamide, choline, and camphor. Additionally, extraction-induced reactions yielded hydroxyacetone and ethyl esters, which further contribute to antimicrobial efficacy. These findings demonstrate the potential of allelopathic extracts as viable, bio-based alternatives to synthetic fungicides. By pinpointing specific botanical sources of antifungal activity, this research supports the development of eco-friendly strategies to enhance food safety and reduce environmental chemical loading.

Estrogen Alternatives as Modulators of Nanosecond Pulsed Electric Field-Based Electrochemotherapy

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: nanosecond pulsed electric fields, electrochemotherapy, estrogen alternatives, calcium electroporation

Electrochemotherapy (ECT) is an emerging anticancer modality that combines pulsed electric fields (PEFs) with cytotoxic agents to enhance intracellular drug delivery and cytotoxicity. Nanosecond pulsed electric fields (nsPEFs) represent a new generation of electroporation (EP) techniques capable of affecting not only the plasma membrane but also intracellular structures. A related approach, calcium electroporation (CaEP), replaces conventional chemotherapeutic drugs with calcium ions (Ca^{2+}), inducing cancer cell death by disrupting intracellular calcium homeostasis.

Despite promising therapeutic outcomes, the molecular determinants influencing cellular sensitivity to nsPEF-based ECT remain poorly understood. Growing evidence suggests that estrogen signaling may regulate Ca^{2+} homeostasis through modulation of voltage-gated calcium channels (VGCCs), potentially affecting treatment efficacy.

This project aims to investigate whether selected estrogen alternatives (EAs), including resveratrol and equilin can potentiate nsPEF-based ECT. Using breast cancer cell lines with different estrogen receptor α (ERα) expression levels, we will analyze treatment--induced cytotoxicity, intracellular Ca^{2+} dynamics, and the involvement of VGCCs. Experiments will be performed in both conventional 2D cultures and 3D tumor spheroids.

Understanding the interaction between estrogen-related signaling, calcium influx, and nsPEF-mediated ECT may support the development of more effective electroporation-based cancer therapies.

The research was funded by the Research Council of Lithuania, Grant No. S-PD-25-31.

Exploiting Structural Divergence in SGLT1-MAP17 Complex: Molecular Dynamics Insights into Isoform-Selective Inhibitor Design

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: hSGLT1-MAP17, Molecular Dynamics, SGLT2 Inhibitors, Steric Selectivity

The human Sodium/Glucose Cotransporter 1 (hSGLT1) is a vital therapeutic target for intestinal glucose regulation and cardiovascular disease [1]. However, designing inhibitors that avoid cross-reactivity with the renal SGLT2 isoform remains a major challenge [2]. This study utilizes 300 ns Molecular Dynamics (MD) simulations to investigate the structural basis of hSGLT1 selectivity within the biologically relevant SGLT1-MAP17 outward-facing complex to elucidate the structural determinants of selectivity for potent inhibitors.

Our findings demonstrate that the hSGLT1-MAP17 heterodimer exhibits exceptional structural stability (Backbone RMSD ∽1.7 Å), providing a high-fidelity template for drug discovery. MD trajectories highlight that SGLT1-selective inhibitors exploit a "volume-based" exclusion mechanism. Specifically, the presence of Asn78 and Thr460 in hSGLT1 creates a roomier binding pocket compared to the bulky His80 and Phe453 residues in SGLT2. While SGLT1-specific scaffolds like KGA_2727 maintain stable hydrogen-bonding networks with Gln457, SGLT2-selective inhibitors exhibit significant steric clashes and increased translational mobility within the SGLT1 core. This work confirms that targeting the unique spatial environment created by Asn78 and the MAP17-stabilized vestibule is essential for the rational design of potent, gut-restricted SGLT1 inhibitors.

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Expression Analysis of Potentially Reducing Proteins from Mytilus Californianus in Escherichia Coli

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: *Mytilus californianus*, mussel foot proteins, adhesion, expression

Maintaining redox balance in a highly oxidizing environment such as seawater is particularly challenging. To overcome this, *Mytilus californianus* produces a byssus containing adhesive and reducing proteins. Redox-active proteins are rich in DOPA and cysteine residues, which are essential for maintaining a reducing microenvironment required for adhesion and cohesion during plaque formation. Because natural isolation and purification of these proteins are inefficient and yield limited amounts of material, recombinant expression is used as an alternative production method.

The aim of this study was to produce and purify recombinant mussel foot proteins Mcfp-6v2, Mcfp-9v2, and Mcfp-14 from the byssus of *Mytilus californianus* using *Escherichia coli* as an expression system to better understand their biological functions, structure, and redox activity.

Expression vectors carrying the target genes were transformed into *E. coli* as the expression host. Recombinant proteins were purified by affinity chromatography, and their purity was confirmed by SDS-PAGE and Western blot analysis.

The results demonstrated successful recombinant protein production in *E. coli*. Expressed proteins were detected by SDS-PAGE and Western blot, with the highest expression and purification efficiency observed for Mcfp-9v2.

Recombinant production of mussel foot proteins enables further investigation of their redox mechanisms and adhesive properties and supports the development of bioinspired adhesives for use in highly oxidizing and aqueous environments.

Freehand Ultrasound 3D Reconstruction of a Sacral Bone Phantom: Accuracy Evaluation Using Optical Tracking and Laser Scanning

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: freehand ultrasound, 3D reconstruction, medical imaging, optical tracking

Three-dimensional reconstruction from freehand ultrasound imaging has become an important tool in biomedical engineering. Such methods offer a cost-effective and portable alternative to traditional imaging techniques such as computed tomography or optical scanning.

The aim of this study was to evaluate the accuracy of three-dimensional reconstruction of a sacral bone phantom using freehand ultrasound imaging. Ultrasound data were acquired using a wireless Clarius L15HD3 probe operating in B-mode in a water tank filled with degassed water to minimize imaging artifacts and ensure acoustic impedance matching. The probe position and orientation were tracked using an NDI Polaris Vicra optical tracking system. The ultrasound video stream and tracking data were synchronized using the PlusToolkit/PlusServer framework and processed in 3D Slicer to reconstruct a volumetric model.

The reconstructed ultrasound model was compared with a reference model obtained using a high-resolution diode laser scanner. Accuracy assessment was performed by evaluating volume differences and surface deviation maps after model registration.

The results demonstrate that the PlusToolkit and 3D Slicer workflow enables consistent three-dimensional reconstruction and allows identification of the main sources of reconstruction error, supporting the potential of freehand ultrasound for low-cost 3D anatomical modeling.

FUNCTIONAL PERFORMANCE OF ADDITIVELY MANUFACTURED TI-6AL-7NB ALLOY MODIFIED BY PERIODIC LASER SURFACE STRUCTURING

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Ti-6Al-7Nb, PBF-LB/M, laser surface texturing, biocompatibility

Additive manufacturing (AM) of titanium alloys offers unique opportunities to produce patient-specific orthopaedic implants with complex geometries and tailored internal architecture. Despite these advantages, achieving surfaces that combine optimal mechanical performance, and favourable biological response remains challenging.

In this study, Ti-6Al-7Nb alloys were fabricated using Powder Bed Fusion. Femtosecond laser processing was applied to create controlled chevron-shaped patterns on the surfaces. Selected samples were further treated with chemical etching. Surface morphology and topography were characterized, while functional performance was assessed through tribological testing and in vitro studies with U2-OS osteoblast-like cells.

Results showed that while tribological properties and cytotoxicity were similar across all surfaces, combining low-power laser structuring with chemical etching increased cell colonization.

These findings highlight that AM provides surfaces compatible with mechanical demands and cell attachment, while targeted surface modifications can further promote cellular colonization. This demonstrates that additive manufacturing, complemented by simple post-processing, provides a practical pathway to optimize implant performance.

Generation and Characterization of Cal-1 DTX3L –/– Cell Line as a Model for Toll-like Receptor Function

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: plasmacytoid dendritic cells (pDCs); DTX3L; innate immunity; interferon signaling

Plasmacytoid dendritic cells (pDCs) serve as a critical bridge between innate and adaptive immunity, playing a pivotal role in the host defense against invading pathogens [1]. Upon viral infection, pDCs rapidly respond through pattern recognition receptors (PRRs), including Toll-like receptors (TLR7 and TLR9), which trigger signaling cascades leading to interferon and pro-inflammatory cytokine production [2]. A key regulatory mechanism in these pathways is ubiquitination – a post-translational modification that controls protein stability, localization, and activity. DTX3L, a RING-domain E3 ubiquitin ligase operating in complex with PARP9, has been implicated in promoting interferon-stimulated gene expression and antiviral defense; however, its precise role in PRR-induced signaling during viral infection remains poorly defined [3, 4]. Using the Cal-1 pDC cell line, we confirmed endogenous expression of TLR7 and TLR9, generated a stable DTX3L knockout (Cal-1 DTX3L –/–), and demonstrated that loss of DTX3L significantly alters IFN-β secretion in response to PRR stimulation. These findings establish DTX3L as a functional regulator of innate antiviral signaling in pDCs and reveal a novel layer of ubiquitin-mediated control over interferon-β responses. By clarifying DTX3L's molecular role, this work contributes to a deeper understanding of antiviral immunity and may inform future strategies to modulate interferon pathways in the context of viral infection and immune dysregulation.

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GLASS FORMING CROWN ETHERS: A STEP TOWARDS EFFECTIVE DRUG CARRIERS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Crown ethers, glass transition, molecular dynamic, association process

Crown ethers are heterocyclic organic compounds with a regular structure. Owing to their molecular architecture, they exhibit amphiphilic properties, which enable them to interact with both polar and nonpolar substances. For this reason, they demonstrate potential applications in medicine, industry, and environmental protection. Previous studies indicate their significant potential as drug carriers, which could help address one of the major challenges of modern pharmacology, namely the poor solubility of many active pharmaceutical ingredients. In this field, of particular value are compounds with glass-forming properties, as in this state molecules possess higher free energy, which facilitates their dissolution. Here, we demonstrate that selected derivatives of 15-crown-5 ether readily undergo vitrification and exhibit relatively high glass transition temperatures. We attribute this behavior to their high molar mass and pronounced conformational diversity, which hinder crystallization and favor glass formation. Furthermore, we investigate their molecular dynamics both above and below the glass transition temperature, revealing a marked sensitivity to thermal variations. These findings advance the understanding of the molecular dynamics of crown ether derivatives in supercooled and glassy states. Importantly, they suggest that glass-forming ability may be a more widespread characteristic within this class of compounds than previously assumed.

GLYCOSAMINOGLYCAN INTERACTIONS WITH OTOLITH ORGANIC MATRIX PROTEINS AND THEIR IMPACT ON BIOMINERAL FORMATION

Health Engineering, Future Medicine and Biotechnologies

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Keywords: biomineralization, calcium carbonate, vestibular system, molecular biophysics

Biomineralization is a fundamental biological process responsible for forming mineralized structures such as bones, teeth, and inner-ear sensory elements. In fish, otolith formation is regulated by an organic matrix composed of negatively charged biopolymers, primarily proteins and polysaccharides, yet the molecular interactions governing crystal growth remain poorly understood.

The otolith matrix contains intrinsically disordered proteins, including Starmaker and Starmaker-like, as well as glycosaminoglycans such as hyaluronic acid, chondroitin sulfate, and heparin. We hypothesized that these biomolecules act synergistically during biomineralization. Recombinant proteins were produced and their interactions with glycosaminoglycans were investigated using *in vitro* crystallization assays, multiple microscopy techniques, and remineralization experiments on demineralized otolith sections. We additionally examined whether Starmaker-like undergoes Liquid–Liquid Phase Separation in the presence of calcium ions when hyaluronic acid acts as a biologically relevant crowding agent instead of polyethylene glycol.

Scanning electron microscopy showed that hyaluronic acid combined with either Starmaker or Starmaker-like significantly altered calcium carbonate crystal morphology, producing larger and more organized mineral structures not observed for individual components, remineralization assays further confirmed the essential role of organic matrix components in mineral formation.

These findings reveal previously uncharacterized protein–glycosaminoglycan cooperativity in otolith biomineralization and may inform strategies for human otoconia regeneration and the design of biomimetic mineralizing materials for health engineering and biotechnology.

This research was funded by the National Science Centre Poland (NCN), grant UMO-2023/51/D/NZ4/01706.

Green Valorization of Spent Coffee Grounds Via Enzyme-Assisted Extraction For Biostimulant And Soil Amendment Application

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Spent coffee grounds, Enzyme-assisted extraction; Biostimulant, Soil amendment, Circular economy

Spent coffee grounds (SCG) represent one of the largest global streams of agro-industrial waste, with an annual production of more than 60 million tons. SCG contain valuable bioactive compounds such as polysaccharides, proteins, lipids, and polyphenols. This rich composition is usually lost in landfills as that remain as the major fate of most coffee grounds generated.

This research aims to valorise SCG through enzyme-assisted extraction (EAE), a green and efficient method of recovery of bioactive compounds from biomass and assesses the functional potential of both liquid extracts and solid residues.

Initially, the raw biomass undergoes comprehensive physicochemical and compositional characterization, followed by enzyme-assisted extraction, where parameters such as enzyme type, enzyme-to-substrate ratio, pH, and temperature, are optimized to maximize yield. Next, obtained extracts are characterized in terms of chemical composition and tested for their biostimulant potential on plant growth, addressing a rising interest in sustainable bio-based agricultural products. The extraction residue will be assessed as a soil amendment for full resource utilisation. The research is therefore consistent with the assumptions of the circular economy. Valorisation of this biomass into biostimulant of plant growth and soil amendment could reduce SCG disposal as an organic waste and promote green and sustainable agriculture.

Hen Egg White Lysozyme Aggregate Characterisation Over Time

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: lysozyme, amyloidosis, aggregation, structural changes

Amyloids are ordered fibrillar aggregates formed from the shift to β-sheet from α-helical. This process has three distinct phases: nucleation, elongation, and stationary. However, pre-fibril entities are considered cytotoxic for all proteins associated with amyloid diseases, and new research suggests cytotoxicity extends to amyloid fibrils under certain environmental conditions.

Lysozyme exhibits complex and interesting aggregation mechanisms. Due to the strong structural similarities between human and hen egg white enzyme, hen egg white can be used as a model protein. Despite wide research on lysozyme fibrilisation, the structural changes throughout the aggregation process have yet to be characterised. Lysozyme amyloid formation can be indicated by elevating temperature or pH. Parallel β-sheets appear at elevated temperatures, whilst antiparallel β-sheets develop at room temperature. β-sheets structures are linked to neurodegenerative diseases such as lysozyme amyloidosis, affecting kidney function.

In our study, we incubated lysozyme for a week, during which we monitored size (DLS), II structure (FTIR spectra), stability (UV-vis), aggregation (viscosity and density), and effectiveness of adsorption (SPR, QCM-D) to indicate when fibrilisation might start and when fibrils were obtained. According to our results, the first noticeable changes appear during one week.

This work was supported by the project NCN OPUS 2021/41/B/ST5/02233.

Hybrid Morphology-Rhythm Analysis for Beat-by-Beat Arrhythmia Detection in Phantom-Based Single-Channel ECG Measurements

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: ECG signal analysis, arrhythmia detection, self-supervised learning, wearable biosensors

The aim of this study is to validate the detection of cardiac arrhythmias in a single-channel ECG biopotential acquisition system based on the AD8232 analog front-end. The developed measurement system enables differential ECG acquisition using disposable electrodes and a microcontroller-based data acquisition module. Controlled rhythm disturbances are generated using an ECG phantom capable of reproducing ectopic beats under repeatable experimental conditions, allowing systematic evaluation of the device performance.

The recorded signals are resampled to 250 Hz and normalized using robust statistics based on the median and median absolute deviation. R-peaks are detected using a modified Pan-Tompkins algorithm, and signal quality with a Signal Quality Index. The analysis is performed on a beat-by-beat basis, where each heartbeat is represented by a signal segment from which morphological and rhythm-related features are derived. These features are fused and analyzed using unsupervised clustering to identify the dominant normal rhythm and detect anomalous beats.

Previous evaluation on the MIT-BIH arrhythmia database demonstrated the effectiveness of the proposed hybrid morphology-rhythm analysis approach, achieving a sensitivity of 0,914 in the detection of ventricular ectopic beats.

The presented study focuses on evaluating the robustness of the developed measurement system and analysis pipeline under controlled phantom-based experimental conditions.

Impact of Bipolar Nanosecond Electric Pulses (nsPEFs) on Reactive Oxygen Species and Cell Survival in Electrochemotherapy (ECT) with Bleomycin

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: electrochemotherapy, bipolar cancelation, reactive oxygen species, bleomycin

Nanosecond pulsed electric fields (nsPEFs) are an emerging technique in electroporation-based therapies that enable the delivery of chemotherapeutic drugs such as cisplatin and bleomycin during electrochemotherapy (ECT). Compared with conventional protocols, shorter pulse durations can reduce painful muscle contractions, limit oxidative damage, and improve treatment homogeneity.

In recent years, the phenomenon of bipolar cancellation (BPC) has been described, where a pulse with negative polarity can reduce or eliminate the effects of a preceding positive pulse. However, the molecular mechanisms behind that are still not well understood, highlighting the need for further investigation.

The results showed that exposure to bipolar nsPEFs decreased membrane permeabilization and increased cell survival, with stronger effects observed under symmetrical bipolar protocols. Asymmetrical pulses induced higher levels of ROS, influencing the efficacy of bleomycin (BLM) treatment in ovarian carcinoma cell lines MDAH-2774 and SKOV-3. The obtained data revealed the importance of pulse symmetry in the observation of the BPC effect.

These results improve our understanding of how cells respond to electrical pulses and may help optimize electrochemotherapy protocols for more effective and controlled treatments.

The research was funded by the Research Council of Lithuania, Grant Nr. S-PD-24-124 (PI Prof. J. Kulbacka, and dr Veronika Malyško-Prašinskė post-doc position).

In Silico Methods in The Cosmetic Industry: From Safety Assessment to Formulation Design

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: in silico studies; cosmetic industry; predictive toxicology; formulation design

The cosmetic industry increasingly relies on in silico approaches to accelerate product development, improve safety evaluation, and reduce the need for animal testing. Computational methods, including molecular modeling, quantitative structure–activity relationship models, machine learning, and predictive toxicology, are becoming important tools in the design and assessment of cosmetic ingredients and formulations. This work discusses how in silico research is currently applied in the cosmetic sector and why these methods are gaining strategic importance under growing regulatory, ethical, and economic pressures. Particular attention is given to their role in predicting skin permeability, irritation potential, ingredient interactions, and formulation stability before laboratory testing. The main conclusion is that in silico methods are no longer only supportive tools, but are becoming an integral part of decision-making in cosmetic research and development. In a broader context, these approaches contribute to faster innovation, more sustainable product design, and improved consumer safety. Their development also strengthens the shift toward more data-driven, ethical, and cost-effective industrial practice.

K. Pneumoniae Enolase Interactions with Metal Ions

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: *Klebsiella pneumoniae*, Enolase like protein, microscopy, CD spectroscopy

Enolases are highly conserved enzymes that are associated with the glycolytic pathway. In addition to the main function, enolases perform many other functions that are specific to the cell type and stage of development. In the case of *Klebsiella pneumoniae* enolase, it can also exist as a cell surface protein. In this form, enolase can interact with plasminogen and activate it. Activated plasminogen degrades the extracellular matrix, promoting bacterial infection.

The most common condition caused by *K. pneumoniae* bacteria is pneumonia. Even with the antimicrobial treatment, it has death rate of around 50%. Metals have strong and documented antimicrobial properties. Preventing or limiting spread of bacteria by targeting an enzyme used in proliferation with metal ions may help to decrease death rate.

With the exception of zinc, most metal ions did not change the enolase structure. Zinc caused enolase to coagulate. This process was observed using fluorescent microscopy and further studied using CD spectroscopy. *In silico* analysis was carried out to determine the zinc binding region of enolase.

The discovery that zinc ions induce coagulation of enolase presents a promising avenue for metal ion-based treatments that could help with traditional antibiotics treatment and with MDR strains of *K. pneumoniae.*

LIGNIN-DERIVED BIO-MOFS – SYNTHESIS CONDITIONS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: MOF, ferulic acid, lignin, adsorbent

Metal-organic frameworks are polymer adsorbents consisting of organic linkers and metallic nodes. MOFs differ from other adsorbents in their exceptionally high specific surface area and their crystalline structure, which results in standardized pore sizes, making them particularly useful in gas separation and storage. The use of MOFs in the pharmaceutical industry as drug carriers is rare due to the toxic organic linkers used in synthesis. This study focuses on the synthesis methods of MOFs composed of various copper and zinc salts with ferulic acid, a biocompatible lignin derivative known for its anticancer properties. Various synthesis conditions and substrates were adjusted to improve the yield and properties of the resulting materials. This resulted in the development of a new method for synthesizing bio-Cu-MOFs and identifying the optimal synthesis conditions of bio-Zn-MOFs. The products were characterized using FTIR, XRD, TGA, and SEM. The research results indicate the possibility of using synthesized bio-MOFs as carriers for drugs, reducing the negative impact of the carrier on patient health.

Magnesium-based Resorbable Biomaterial

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Keywords: biomaterial, magnesium alloy, properties, implemental doctorate

Magnesium-based biomaterials are gaining attention as candidates for next-generation orthopedic implants due to their low density, mechanical similarity to bone and natural biodegradability. A key barrier to their clinical use is the rapid and insufficiently controlled degradation of magnesium alloys.

This study presents a surface engineering strategy designed to slow the degradation of the WE43 alloy. Ceramic coatings were deposited to adjust the calcium content within the surface layer. These calcium-phosphate coatings aim to improve corrosion resistance while enhancing biological interactions.

The coated WE43 alloy retains mechanical strength exceeding that of natural bone, and its composition consistent with the expected phase structure. The ceramic layers show good adhesion and surface wettability. Biological tests indicate favorable indirect cytotoxicity results, although long-term corrosion studies remain difficult because the alloy still degrades rapidly in physiological media.

Overall, the findings demonstrate the potential and limitations of calcium-phosphate-coated magnesium alloys for resorbable orthopedic applications. The study advances understanding of how surface chemistry and coating composition influence degradation behavior, and highlights the need for further optimisation to achieve clinically relevant stability. The research was conducted within the 6th edition of the Implementation Doctorate program funded by the Ministry of Education and Science.

Mechanical Characterization of Highly Deformable Polymers for Tendon-Inspired Compliant Elements Used in Prosthetic Limbs

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: thermoplastics; injection molding; LFS 3D printing; mechanical properties

The design of prosthetic limbs requires biomaterials whose mechanical behaviour resembles that of biological tissues, particularly tendons that enable compliant motion and energy storage during human gait. Modern prosthetic feet are typically constructed as modular systems combining rigid elements that replicate the structural role of bones with compliant components enabling controlled elastic deformation during walking. However, prosthetic devices are expected to operate reliably for several years while being exposed to environmental and mechanical factors that may affect material performance. Temperature fluctuations, ultraviolet radiation, humidity and repetitive cyclic loading during daily use may lead to degradation and changes in the mechanical properties of polymeric components.

In this study, selected polymers were manufactured using injection molding and low-force stereolithography (LFS) 3D printing. Injection-molded specimens were produced from thermoplastic polyurethane (TPU), PBS, LDPE and PBT using a BOY 35 E injection moulding machine (Dr. Boy GmbH, Germany), while additively manufactured samples were fabricated from Flexible 80A, Ultracur3D FL60 and Durable resins using a Formlabs Form 3 system (Formlabs Inc., USA). Mechanical behaviour was evaluated using an MTS 858 Mini Bionix testing machine equipped with hydraulic grips. Uniaxial tensile tests were conducted according to ISO 527-1 and ISO 527-2 at a crosshead speed of 50 mm/min until failure. Among the tested materials, PBT exhibited the highest Young's modulus, indicating significantly higher stiffness than PBS, LDPE and elastomeric materials. Elastomeric photopolymer resins enable fabrication of complex compliant structures; however, further studies are required to evaluate their long-term mechanical performance under cyclic loading.

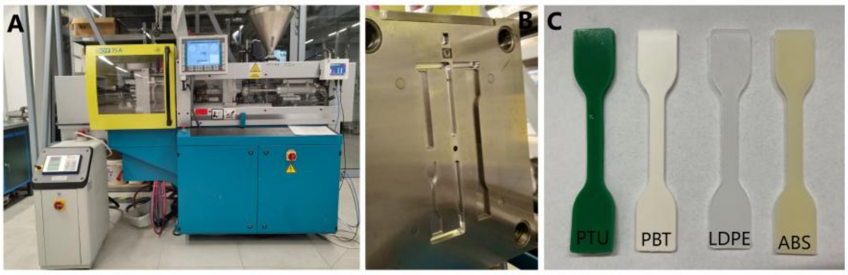

Fig. 1. A) BOY 35 E injection molding machine (Dr. Boy GmbH, Germany); B) metal injection mold used for specimen fabrication; C) representative thermoplastic specimens prepared for mechanical testing

This research was funded under the FENG.01.01 – SMART Path programme, grant agreement No. FENG.01.01-IP.01-A0F6/24-00.

Nanoparticle-Enhanced Photodynamic Activity of Methylene Blue: A Comparative Study of Silver and Gold Systems

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: photodynamic therapy, methylene blue, plasmonic nanoparticles, singlet oxygen generation

Photodynamic therapy (PDT) relies on the efficient generation of reactive oxygen species (ROS) upon light activation of a photosensitizer. Methylene blue (MB) is a well-known photosensitizer; however, its photostability and ROS generation efficiency strongly depend on the surrounding matrix and the presence of nanomaterials. In this study, we investigated the photobleaching behavior and singlet oxygen production of MB systems modified with silver (AgNP) and gold nanoparticles (AuNP).

Photobleaching kinetics were monitored under controlled irradiation conditions to evaluate the stability of MB in nanoparticle-containing systems. Additionally, singlet oxygen generation was quantified using Singlet Oxygen Sensor Green (SOSG), enabling comparative analysis of ROS production efficiency. The results demonstrated distinct differences between AgNP- and AuNP-modified systems, indicating that nanoparticle type significantly influences both photodegradation rate and ROS generation dynamics.

Our findings highlight the potential of nanoparticle-assisted modulation of photosensitizer performance and provide insight into optimizing material design for enhanced photodynamic applications. This study contributes to the rational development of nanostructured PDT systems with improved therapeutic efficiency.

Natural Complex Substances from Asteraceae Family as Potential Antimicrobial Agents

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Pluchea grevei essential oil, Natural complex substances (NCSs), Antimicrobial activity, Dermocosmetic ingredients

Natural ingredients with multiple biological functions are increasingly sought in cosmetic and dermocosmetic formulations. Natural Complex Substances (NCSs), such as plant extracts and essential oils (EOs), are attractive because they combine sensory properties with biological activities including antioxidant and antimicrobial effects relevant to skin care.The Asteraceae family is widely recognized as a rich source of bioactive secondary metabolites. Many Asteraceae-derived NCSs exhibit antioxidant, antimicrobial and anti-inflammatory activities, making them promising candidates for dermocosmetic applications. In this study, antimicrobial activity of several commercial Asteraceae NCSs was evaluated using minimal inhibitory concentration (MIC) assays against microorganisms associated with skin conditions and cosmetic contamination.

Among the tested materials, *Tagetes minuta* EO, *Matricaria recutita* CO_2 extract and *Cynara cardunculus* absolute showed activity, while *Pluchea grevei* EO exhibited the broadest antimicrobial spectrum.

Further investigation showed that *P. grevei* EO demonstrated moderate antioxidant activity (IC_{50} ≈ 32 mg/mL in DPPH, ≈10 mg/mL in ABTS and ≈ 1885 μmol TE/g in FRAP assays) and selective antimicrobial effects against *Staphylococcus epidermidis* and *Acinetobacter baumannii*. Cytotoxicity toward skin cells and ecotoxicity toward marine organisms were also evaluated. A prototype natural cream confirmed formulation compatibility, highlighting *P. grevei* EO as a promising multifunctional dermocosmetic ingredient.

Nematicidal Activity of Essential Oils Against Bursaphelenchus xylophilus

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: *Bursaphelenchus xylophilus*, essential oils, nematicidal activity, pinewood nematode

Pine wilt disease is a major threat to conifer forests worldwide. It is caused by the pinewood nematode *Bursaphelenchus xylophilus*, which infects the vascular tissues of pine trees and disrupts water transport, leading to the death of infected trees. Because this disease has severe ecological and economic consequences, the search for environmentally safe control strategies is important.

Current management approaches rely on chemical control methods that may have environmental effects. Essential oils (EOs), mixtures of naturally occurring compounds produced by plants, have attracted attention as potential biopesticides owing to their biodegradability, diverse bioactive constituents, and reduced likelihood of inducing resistance in target organisms.

This study evaluated the nematicidal activity of commercially available EOs against *B. xylophilus* using direct-contact bioassays in 96-well microtiter plates across a concentration range of 1–0.125 µl/ml. Among the EOs tested, coriander leaf, geranium, and lemon verbena basil CT citral EOs showed the highest activity, causing corrected mortality rates of 100%, 97.62%, and 93.11%, respectively, at the lowest concentration (0.125 µl/ml).

These findings highlight the potential of plant-derived EOs as natural nematicidal agents. The results contribute to the development of sustainable strategies for managing pine wilt disease and reducing the ecological impact of conventional chemical pesticides.

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NEW 4,6-DIMETHYL-2-SULFANYLPYRIDINE-3-CARBOXAMIDE DERIVATIVES WITH CYTOTOXIC ENHANCED BY ELECTROPORATION IN ONCOLOGICAL THERAPIES

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: electroporation (EP), electrochemotherapy (ECT), cancer therapy

Electroporation (EP) is a technique involving a transient increase in cell membrane permeability through the application of pulsed electric fields (PEFs). In medicine, EP forms the basis of electrochemotherapy (ECT), which facilitates the transport of molecules into cells. Conventionally, compounds such as bleomycin and cisplatin are used in ECT to treat cancer cells when other methods fail. Currently, there is a lack of new, safer anticancer drugs that will minimize the adverse effects of current treatment methods and improve the quality of patients' lives. The project aims to introduce 4,6-dimethylpyridine-3-carboxamide derivatives in the context of ECT. The implementation of these new drugs could significantly enhance treatment efficacy by improving their intracellular concentration, increasing their active dose and boosting the therapeutic effect. EP markedly increased Yo-Pro-1 uptake, confirming enhanced membrane permeability. Under these conditions, a decrease in viability was observed in treated cells compared to treatment with the compounds alone or EP alone. Our preliminary results suggest that the investigated 4,6-dimethyl-2-sulfanylpyridine-3-carboxamide derivatives may exhibit anticancer activity, which can be further enhanced or modulated by electroporation. However, additional experiments are required to confirm these findings and to fully elucidate the underlying mechanisms of action.

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Numerical Analysis of Surgical Treatment of Prognathism Using the Finite Element Method

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: prognathism, osteotomy, facial plates, numerical analysis

Orthognathic surgery has significantly advanced in recent years; however, concerns regarding postoperative safety, treatment outcomes, and recovery remain important clinical challenges. These procedures involve displacement of facial bones, and post-operative stabilization largely depends on the fixation plates used.

The aim of the study was to compare how different geometries of facial plates used after surgical treatment of prognathism influence load transfer. Five types of facial plates differing in geometry, size, and number of holes were analyzed. The influence of plate geometry on stress, deformation, and displacement distribution was evaluated using numerical analysis under three loading conditions: intercuspal clenching, right unilateral molar clenching, and left unilateral molar clenching.

The results demonstrated that plate geometry significantly affects biomechanical behavior. Different designs showed varied capacities to transmit and distribute loads, resulting in differences in stress, deformation, and displacement. The most favorable outcomes were observed for the configuration consisting of double vertical plates, whereas the least favorable results were obtained for a single vertical plate. Differences between mandibular sides were observed despite identical loading conditions, reflecting individual anatomical characteristics.

The study highlights the importance of careful selection of plate geometry for safe and effective mandibular stabilization and may support optimization of patient-specific fixation systems.

Optimisation of the Expression System and Purification Conditions for TCF4 Regulatory Elements

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Transcription factor 4 (TCF4), inherently disordered regions (IDRs), affinity chromatography, gel filtration

TCF4 is a bHLH class I transcription factor belonging to the E protein family and plays a critical role in the development and proper functioning of the central nervous system. Regardless of great progress in understanding its function and contribution to the development of organisms, the complete structural characteristics of this protein remain unknown. The aim of this work was to optimize both the expression system and the purification conditions for a potentially intrinsically disordered fragment of TCF4. The purification strategy involved affinity chromatography, gel filtration, and ion-exchange chromatography. Ultimately, the expression parameters and key purification steps were successfully optimized, creating a solid foundation for the development of an effective protocol for obtaining the target protein.

Phosphatidic Acid Behavior in Biomimetic Fungal Membranes

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: molecular dynamics, phosphatidic acid, biomimetic fungal membrane models

Phosphatidic acid (PA) constitutes approximately 1–2% of total cellular lipids, nevertheless, it performs a broad spectrum of essential biological functions, serving as a key precursor in the biosynthesis of other glycerophospholipids. Its intrinsic propensity to induce negative membrane curvature underlies membrane fusion and fission events. In fungal cells, these dynamic membrane rearrangements regulate metabolism and turgor through modulation of vacuolar membrane architecture.

In this study, the influence of various lipid species on PA properties in biomimetic fungal membrane models was investigated using molecular dynamics simulations. Three bilayer systems composed of phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidylserine (PS), phosphatidylinositol (PI), and PA, were analysed. In the PC/PE/PA/PS and PC/PE/PA/PI systems, PA exhibited a significant increase in membrane thickness, accompanied by a reduction in area per lipid, in contrary to PC/PE/PA. This was followed by membrane curvature analysis.

To assess the mechanical implications of these membrane properties alterations, complementary experimental measurements of membrane bending rigidity (κ) were performed. Notably, despite pronounced composition changes, no significant differences in κ were detected.

Collectively, these findings indicate that PA behavior modulates local membrane composition and may thereby influence the regulation of membrane fusion and fission events in fungal cells.

Preparation of Recombinant Vectors Enabling Stable and Efficient Overexpression of a Receptor From the GPCR Receptor Family in a Mammalian Cell Line

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: GPCR, CCR9, cancer progression, NEBuilder HiFi Assembly

G protein-coupled receptors (GPCRs) play a crucial role in the regulation of immune responses, including the migration, activation and differentiation of immune cells. One important member of this family is the CCR9 receptor, which directs lymphocytes to secondary lymphoid organs and the intestinal mucosa. CCR9 dysregulation is associated with inflammatory bowel diseases. Moreover, CCR9 overexpression is associated with highly metastatic stages of pancreatic cancer and solid tumors. Despite the growing recognition of CCR9 as a potential therapeutic target, current treatment strategies remain limited, highlighting the need of further molecular studies and development of new modulators of receptor activity. The aim of this study was to construct recombinant vectors enabling stable and efficient overexpression of the human CCR9 receptor in two selected mammalian cell lines. The cDNA fragments encoding CCR9 and the fluorescent protein EYFP, were amplified by PCR and used to generate expression constructs based on specific plasmids. A key step of the cloning strategy was the use of unique NEBuilder HiFi DNA Assembly strategy, which enables efficient seamless joining of DNA fragments containing homologous overlaps in a single reaction. Obtaining stable cell lines overexpressing CCR9 may enable the discovery of new innovative molecules modulating the activity of this receptor.

Recombinant Heterologus Expression of the FKBD Domain from Drosophila FKBP39

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: FKPB39, BL21(DE3), protein purification, *Drosophila melanogaster*

FKBP39 belongs to the family of FK506-binding proteins (FKBPs), which are part of a large group of proteins known as immunophilins that bind immunosuppressive drugs. A characteristic feature of these proteins is their peptidyl-prolyl isomerase activity associated with a highly conserved FKBD domain specific to this family. Enzymatic activity enables the catalysis of cis-trans isomerization of a peptide bond preceding a proline residue in a polypeptide chain. It may play an important role in the protein folding and the regulation of many cellular processes.

The main aim of this study was the development of an expression system and purification of the C-terminal domain of FKBP39. To achieve this, various host strains, culture conditions and FKBD construct variants were tested. The best-expressing variant was purified under native conditions using affinity chromatography followed by size-exclusion chromatography.

These procedures resulted in a homogeneous preparation of the FKBD domain, which was subsequently used to determine its molecular properties. The developed purification protocol provides a basis for further structural and functional studies of the FKBD domain and further studies FKBP39.

Regorafenib-induced Extracellular Vesicles (EVs) miRNA Signatures in Osteosarcoma Are Determined by Cellular Context – Analysis Of Profiles In The Established MG63 and Primed APR-1 Lines

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: bone cancer, small non-coding RNA, expression profile, extracellular vesicles

Osteosarcoma is an aggressive primary bone malignancy that remains a major clinical challenge. Although its molecular basis has not been fully elucidated, accumulating evidence indicates that disease progression and therapy response are strongly influenced by communication within the tumor microenvironment. This crosstalk is mediated, among others, by extracellular vesicles (EVs), particularly exosomes (EXOs), which deliver functional microRNAs (miRNAs) and constitute a molecular language of paracrine communication.

The aim of this study was to determine the effect of regorafenib on the EXOs' miRNA expression profile in EVs released by human osteosarcoma cells. Experiments were performed using two complementary in vitro models: the established MG-63 cell line and a drug-resistant primary osteosarcoma cell line (APR1). Cells were exposed to regorafenib at the IC_{50} concentration, and exosomes and characterized using Qiagen miRCURY LNA miRNA Focus PCR Panels.

The obtained results indicate that regorafenib not only acts directly on osteosarcoma cells inhibiting their growth but also remodels EV-mediated paracrine communication modifying the exosomal miRNA cargo. The divergent patterns observed between models suggest that therapy-induced exosomal signatures are shaped by cellular context, including baseline drug/chemoresistance. The findings underscore the importance of exosome-associated miRNAs as indicators of adaptive responses to targeted therapy.

Role Of Arel1 Ligase In Immune Response Regulation

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: AREL1, E3 ligase, ubiquitination, immune response

Apoptosis-resistant E3 ubiquitin protein ligase 1 (AREL1) belongs to the family of E3 ubiquitin ligases responsible for the selective attachment of ubiquitin to target proteins during the ubiquitination process. This is a crucial mechanism that controls protein stability and activity within the cell. Despite its potential involvement in immune regulation, the role of AREL1 in signaling pathways initiated by pattern recognition receptors (PRRs) remains poorly characterized. This study was conducted using human THP-1 and Cal-1 cell lines. To generate AREL1 knockout models, a gesicles-mediated CRISPR-Cas9 delivery system was employed in both cell lines, and successful genetic modification was confirmed by Western blot analysis. Following PRR ligand stimulation, secretion levels such as CCL5, TNF-α, and IL-8 were quantified using enzyme-linked immunosorbent assay ELISA. Our results demonstrate that AREL1 deficiency alters the secretion of key pro-inflammatory cytokines, indicating its regulatory function in innate immune signaling. The results obtained so far indicate that AREL1 may function as an important regulatory factor in innate immune signaling pathways. A more comprehensive understanding of the molecular mechanisms mediated by this ligase may facilitate the identification of novel therapeutic targets in inflammatory and cancer-related diseases.

Safety Engineering – a New Insight into SIRS, Sepsis, COVID-19 And CBRN. Prevention and Therapy

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: SIRS, Sepsis, Mast cells, Histamine

Severe viral infections can lead to systemic inflammatory responses, including systemic inflammatory response syndrome (SIRS) and sepsis. However, the mechanisms responsible for the rapid deterioration of patients' conditions remain incompletely understood. A deeper understanding of the physiological and immunological processes involved may contribute to the development of more effective therapeutic strategies. Previous research on severe COVID-19 has focused primarily on the so-called "cytokine storm" and damage to lung tissue. Recent observations suggest a possible role of mast cells and inflammatory mediators such as histamine and its receptors (H1–H4) in initiating and amplifying this response. Attention has also been drawn to physical factors associated with mechanical ventilation. Air delivered by a ventilator may be colder and drier than the physiological conditions of the respiratory tract. When such air is warmed by the body only after reaching the lungs and delivered under elevated pressure, it may – according to Charles's law – increase local mechanical stress on lung tissues. These CBRN factors may promote mast cell activation and histamine release, combined biological, chemical and physical triggers could initiate an inflammatory cascade leading to SIRS and sepsis, highlighting the potential importance of mast cell stabilization, antihistamine therapies, and optimized ventilator air temperature and humidity.

Poster based on authors discovery and publications: "*Discovery of the Mechanism of COVID-19, SIRS and SEPSIS, Defense and Treatment. Mast cells and Histamine Storm an Overlooked Aspects in COVID-19 and in Ventilated Patients Potential Role of Antihistamine" MA Magdalena Filcek1, MD Mayank Vats2, MD Anna Skrzyniarz-Plutecka3 published in Medical and Research Publication Journal of MAR Pulmonology (Volume 3 Issue 5) 2021, "Nowy Wglad w Profilaktyke i Terapie COVID-19, SIRS i SEPSY Rowniez Jako Wsparcie Ochronne Przed PTSD i CBRN" Wydawnictwo Akademia Wojsk Lądowych we Wrocławiu ISBN 978-83-66299-54-2 Magdalena Filcek, and the poster published in 2023 „A New insight into SIRS, SEPSIS, COVID-19 and CBRN – Prevention and therapy"* (DOI: https://doi.org/10.54985/peeref.2304p7212147).

SENSORY SYSTEM FOR ARM PROSTHESIS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: bionic prosthesis, tactile sensor, soft tactile sensor, MEMS

Tactile sensing plays an important role in the development of advanced prosthetic devices, enabling safer and more precise interaction with objects. Modern bionic prostheses increasingly rely on artificial sensory systems to restore some aspects of human touch perception.

Most commercially available sensors are designed for use in industrial environments and are not well suited for direct human interaction. This study investigates the design and implementation of a tactile sensing system for a bionic arm prosthesis based on pressure measurements in an elastic medium using MEMS barometric sensors.

The developed system, built using BMP581 pressure and temperature sensors integrated with a Raspberry Pi Zero 2 W platform, detects touch, estimates force magnitude, and differentiates contact locations on the sensor surface. Experimental evaluation indicates that pressure-based MEMS sensing can support tactile sensing in prosthetic devices.

The proposed approach demonstrates the feasibility of using barometric sensors embedded in soft structures for prosthetic tactile sensing. These findings indicate opportunities for further development toward higher sensitivity, spatial resolution, and reliability. The use of easily available materials may simplify future research and reduce the potential cost of production.

Spontaneous Canine Osteosarcoma as a Model for NGF-Targeted Antibody Therapies: A Literature-Based Perspective

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: bone cancer, NGF signalling, monoclonal antibodies, comparative oncology

Osteosarcoma (OSA) is an aggressive primary bone malignancy in dogs and humans, characterised not only by uncontrolled proliferation but also by complex tumour–bone–nerve interactions. Nerve growth factor (NGF) functions as a critical signalling mediator linking nociception, neurogenesis, and bone remodelling. Understanding this integrated network is essential for next-generation targeted therapies.

Spontaneous canine OSA closely mirrors human disease at molecular and microenvironmental levels.While anti-NGF monoclonal antibodies are clinically applied for pain management in canines, their system-level biological impact within malignant bone microenvironments remains insufficiently characterized.

Through an integrative review of available molecular, preclinical, and clinical data, we conceptualize spontaneous canine OSA as an in vivo platform for interrogating NGF--dependent tumour-bone-nerve crosstalk and its modulation via antibody-based pathway targeting.

In a One Health and comparative oncology context, spontaneous canine osteosarcoma provides a naturally occurring model reflecting the complexity of human disease. Viewing NGF-targeted monoclonal antibodies as biological modulators rather than solely analgesics links comparative oncology with health engineering and future biotechnology. This systems-oriented perspective may advance understanding of tumour-bone-nerve and neuro-immune interactions and support targeted interventions benefiting both canine and human patients.

Stress-Related Neuropeptide Human Galanin: Interaction with Cu(II) Ions – Preliminary Studies

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: galanin, depression, Cu (II) ions, neurochemistry

Understanding how the brain responds to stress is essential for explaining the molecular mechanisms underlying anxiety and depression. Stress is a natural physiological response that enables adaptation to challenging conditions, but prolonged exposure can disrupt neurochemical balance and contribute to stress-related disorders.

Neuropeptides, *e.g.* galanin, are important modulators of neuronal signaling and play key roles in the regulation of stress responses. Chronic stress has been associated with dysregulation galanin levels as well as disturbances in metal ion homeostasis in the brain, *e.g.* involving copper and zinc. Despite the importance of both neuropeptides and metal ions in neuronal processes, their potential interactions remain poorly understood.

Using potentiometric titration at peptide-to-metal molar ratios of 1:1, 1:2, and 1:3, the interaction between human galanin and Cu(II) ions was characterized, and possible Cu(II) binding modes were proposed based on experimental data and peptide sequence analysis.

These results provide the first insights into the metal-binding properties of human galanin and suggest that copper ions may influence the behavior of this stress-related neuropeptide. Such interactions could represent an additional molecular factor contributing to neurochemical changes observed under chronic stress. Further investigation may help clarify the role of metal–neuropeptide interactions in stress-related neurological disorders.

SYNTHESIS AND ANTIBACTERIAL ACTIVITY OF FABIMYCIN – A NOVEL ANTIBIOTIC CANDIDATE AGAINST GRAM-NEGATIVE BACTERIA

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Fabimycin, antibiotic resistance, Gram-negative bacteria, FabI inhibitor

Antibiotic resistance represents a growing global health threat and significantly limits the effectiveness of currently available antibacterial therapies. Gram-negative bacteria are particularly problematic due to the presence of an outer membrane that restricts the penetration of many antibiotics and contributes to multidrug resistance. Consequently, the development of new antibacterial agents targeting these pathogens has become an urgent priority in modern medicinal chemistry. Fabimycin is a recently developed antibiotic candidate designed to selectively target Gram-negative bacteria by inhibiting the FabI enzyme involved in fatty-acid biosynthesis. The aim of this study was to synthesize Fabimycin and evaluate its antibacterial activity against selected Gram-negative bacterial strains. The compound was obtained through a multistep synthetic procedure and subsequently characterized using standard analytical techniques Subsequently, its antibacterial activity will be evaluated using established microbiological assays. The results are expected to provide insight into the antibacterial potential of Fabimycin against Gram-negative pathogens. This study may contribute to the development of new therapeutic strategies targeting antibiotic-resistant bacteria and highlight the potential of FabI inhibitors as promising candidates for next-generation antibacterial drugs.

SYNTHESIS AND BIOLOGICAL EVALUATION OF BORONIC THIOSEMICARBAZONES AS TYROSINASE INHIBITORS

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: tyrosinase inhibitors, thiosemicarbazones, boronic acids, molecular docking

Tyrosinase is a copper-containing oxidoreductase that catalyzes key reactions in the biosynthesis of melanin. Although melanin protects the skin from ultraviolet radiation, excessive melanin production is associated with disorders such as hyperpigmentation and melanoma [1, 2]. Because of this biological role, the discovery of safe and efficient tyrosinase inhibitors remains an important objective in medicinal chemistry and biotechnology.

Thiosemicarbazone derivatives have attracted attention due to their ability to coordinate metal ions in enzyme active sites and exhibit diverse biological activities [3]. However, boronic derivatives of thiosemicarbazones have been less explored as potential tyrosinase inhibitors.

In this work, a series of boronic thiosemicarbazone derivatives was synthesized and evaluated for their inhibitory activity against tyrosinase. Enzymatic assays revealed inhibition in the micromolar range, with the most active derivative showing an IC_{50} value of 1.4 µM. Molecular docking studies suggested that the boronic acid group interacts with the dicopper center of the enzyme, stabilizing the inhibitor-enzyme complex.

These findings highlight boronate thiosemicarbazones as promising scaffolds for the development of new tyrosinase inhibitors with potential applications in dermatology and biotechnology.

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Synthesis, Characterization and Biological Evaluation of Novel Ester Derivatives of Phenolic Acids

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: fragrance compounds, ester synthesis, odor threshold, antifungal activity

Over recent years, the fragrance industry has experienced significant global growth. Due to regulatory restrictions, potential toxicity, and the withdrawal of certain substances from the market, there is a continuous demand for new aroma compounds that can be incorporated into novel fragrance formulations.

This study describes the synthesis and characterization of a series of ester derivatives of phenolic acids and the evaluation of their odor properties and antifungal activity. Seventeen ester derivatives with *o*-, *m*-, or *p*-methyl substituents were synthesized via acid chloride formation followed by esterification. Selected compounds were evaluated for their odor profiles and odor detection thresholds, while antifungal activity was tested against *Malassezia furfur* and *Candida albicans* by determining the minimum inhibitory concentration (MIC).

The synthesized esters exhibited distinct odor profiles with detection thresholds ranging from 20 to 217 ppm, with 2-methyl-2-(4-methylphenoxy)propanoate isobutyl ester showing the lowest threshold (20 ppm), indicating the highest odor potency.

These results demonstrate that the obtained phenolic acid esters combine fragrance properties with measurable antifungal activity (MIC 1600–3200 μg/mL). The dual functionality of these compounds highlights their potential as multifunctional ingredients in fragrance, cosmetic, and antimicrobial formulations.

Targeting Nuclear Export in Canine Osteosarcoma: Molecular Determinants of Verdinexor Sensitivity

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: bone cancer, gene expression profiling, comparative oncology, nuclear transport regulation

Canine osteosarcoma (OSA) is a highly aggressive malignancy with limited therapeutic options and strong translational relevance to human bone cancer. Increasing attention has been given to targeting nuclear export, a process regulated by exportin 1 (XPO1/CRM1), which controls the subcellular localization of key tumor suppressors and oncogenic factors.

The aim of this study was to assess the sensitivity of canine osteosarcoma (OSA) cells to verdinexor (KPT-335), a selective inhibitor of nuclear export, and to investigate the baseline expression–drug sensitivity relationship between endogenous *XPO1* / nuclear transport–related genes and verdinexor response. Three canine OSA cell lines (OSCA-8, OSCA-29, and D17) and normal canine fibroblasts (hTERT; reference) were analyzed. RT-PCR indicated that basal mRNA levels of *XPO1*, *NFKB1*, *RB1*, and *TP53* were lower in D17 cells than in the other lines. In contrast, Western blot analysis showed the highest XPO1 protein abundance in D17 cells and the lowest in OSCA-8 cells. Consistent with this, IC50 profiling identified D17 as the most verdinexor-sensitive cell line.

These findings suggest that verdinexor sensitivity of OSA cells may depend primarily on XPO1 protein abundance rather than transcript levels, underscoring the role of post-transcriptional regulation and the complexity of nuclear export control in osteosarcoma.

THE EFFECT OF LUMINANCE ON THE DETECTION OF DIFFERENCES IN VISUAL STIMULI

Health Engineering, Future Medicine and Biotechnologies

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Keywords: eye-tracking, luminance, visual fixations, contrast sensitivity

Eye tracking is a technology that enables the recording of eye movements and the analysis of how visual stimuli are processed. It is widely used in fields such as psychology [1–3], marketing [4], vision research [5] and many others [6], allowing researchers to determine which elements of an image attract attention and how visual exploration occurs.

The aim of this study was to investigate whether participants could identify a board with lower luminance among four presented boards and whether the distance between the boards influenced recognition accuracy. The experiment involved 23 participants. A total of 20 boards differing in color and luminance level (1–7%) were presented, and eye movements were recorded using the Tobii Pro Lab system. The analysis included the number and duration of visual fixations, response accuracy and the relationship with the MARS contrast sensitivity test.

The main finding was a significant effect of the distance between the boards on response accuracy – boards positioned closer together were recognized more correctly.

Larger distances resulted in a higher number of fixations, suggesting increased cognitive load during stimulus comparison. Although no significant correlation with MARS results was found, a tendency indicated a possible relationship between contrast sensitivity and luminance discrimination.

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The Influence of Pre-Sowing Seed Stimulation Using Low-Temperature Plasma on Plant Growth Parameters

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: agriculture, pre-sowing seed stimulation, cold plasma, plant growth

Modern agriculture faces numerous challenges, including excessive use of synthetic fertilizers, environmental pollution and degradation, climate change, and the growing global population. Therefore, it should rely on innovative and environmentally friendly solutions while ensuring sufficient food quantity and quality. Physical methods of pre-sowing seed stimulation appear to be promising techniques for improving crop yields without negatively affecting the environment.

Cold plasma treatment is a relatively new method gaining attention in many sectors, including agriculture. It is fast, cost-effective, and does not generate pollutants while increasing crop productivity, which makes it suitable for ecological agriculture. Therefore, it was decided to expose radish (*Raphanus sativus*) seeds to cold, low-pressure atmospheric plasma for 0.5, 1, 3, and 5 minutes.

The results confirmed the stimulating effect of plasma on plant biometric parameters – seed germination percentage, plant length, and plant fresh weight. The best results were obtained for a 5-minute exposure time.

The obtained findings suggest that plasma treatment of seeds may be an environmentally friendly technique that stimulates plant growth and could potentially contribute to increasing crop productivity while simultaneously reducing agriculture's negative environmental impact. However, further research is required to fully explore the potential of this method.

The Influence of Viscosity on Myelin Figures Formation

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: lyotropic mesophases, liquid crystals, lipids, polarized light microscopy

Myelin figures (MFs) are systems containing amphiphilic molecules and a solvent, usually water [1–3]. They are physicochemical lipid models of the myelin sheath that can be found in central nervous system and peripheral nervous system [4–6]. By creating its replica in laboratory conditions, we can study its behavior in an easier way than in the cells systems. Determining the effect of viscosity on the myelin figure formation can help with understanding physics and the impact of the environment on formation of MFs. The results demonstrate that the length and stability of myelin figures strongly depend on viscosity of the environment. Our observations establish fundamental understanding of how environmental changes affect MFs, enabling development of complex samples. This has the potential to accelerate other research focusing on the study of MFs. These findings also provide us with a wealth of data, which can be used to build artificial myelin simulations. That in turn may be useful in studying the real-life structures present in our body.

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Ultraviolet Radiation Suppresses Proliferation and Motility of Cutaneous Melanoma Cells via Inactivation of the PI3K/AKT Survival Pathway

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Melanoma, Ultraviolet Radiation, PI3K/AKT Pathway, Apoptosis

Melanoma, one of the highly aggressive skin cancer originating from melanocytes, is strongly linked with ultraviolet (UV) radiation exposure in its etiology. However, the direct therapeutic potential of controlled UV radiation on established melanoma cells remains poorly understood. This study investigates the cytotoxic and anti-migratory effects of UV radiation (specifically UVB at 311 nm) on human cutaneous melanoma cell lines (A375 and SK-MEL-28) to explore the underlying molecular mechanisms, focusing on the PI3K/AKT survival pathway. Cells were exposed to increasing doses of UV radiation (0, 10, 20, 30, and 40 × 100 μJ/cm^2, equivalent to 0–4000 μJ/cm^2). Cell viability and proliferation were assessed via MTT assay at 24 and 48 hours postirradiation. Apoptotic and signaling proteins (BAD, BCL-XL, phospho-PI3K, phosphoAKT) were analyzed by Western blot. A wound healing assay was used to evaluate cell migration. UV radiation significantly reduced melanoma cell viability in a dose- and time-dependent manner. Molecular analysis revealed marked downregulation of phosphorylated PI3K and AKT, along with decreased expression of the anti-apoptotic protein BCL-XL. Interestingly, levels of the pro-apoptotic protein BAD were also reduced, suggesting a complex regulatory apoptotic response. UV exposure potently inhibited melanoma cell migration in a dose-dependent fashion. These findings demonstrate that UV radiation exerts potent anti-tumor effects on melanoma cells by inhibiting proliferation and motility, likely through inactivation of the PI3K/AKT survival signaling axis.

VOLUME-DEPENDENT IMPACT OF INJECTION ON METABOLOMIC CHANGES BASED ON THE MODEL ORGANISM – GALLERIA MELLONELLA LARVAE

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: 1H NMR, metabolomics, Galleria mellonella, primary metabolism

There is no possibility of directly studying toxic compounds in humans and only limited possibilities in mammalian models; therefore, many researchers use non-mammalian organisms such as *Galleria mellonella*. In recent years, numerous studies have shown that invertebrates possess many homologous genes compared with the human genome and, importantly, their use does not require approval from an Ethical Committee. For these reasons they have become widely used model organisms.

G. mellonella larvae are commonly applied in studies on virulence, host resistance, and in evaluating the in vivo efficacy of antibiotics, fungicides, and other biologically active compounds, as well as in toxicity testing. Their life cycle lasts about six weeks, which allows researchers to obtain results relatively quickly. Moreover, the absence of strict environmental requirements makes experiments inexpensive and easy to perform. The use of the greater wax moth as a model organism also contributes to reducing the number of experiments conducted on mammals [1, 2].

The aim of this study is to investigate differences in primary metabolism in *Galleria mellonella* larvae exposed to the same doses of compounds administered in different volumes of liquid. Injection volume may significantly influence physiological responses in the larvae. Larger volumes may impose additional physiological burden, causing mechanical stress, disturbances in fluid homeostasis, or increased mortality independent of compound activity. Optimizing the administered volume is therefore essential for obtaining reliable and comparable results [3].

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VR-Based Motion Analysis with Biomechanical Feature Selection for Assessing Exercise Execution Quality

Health Engineering, Future Medicine, and Biotechnologies

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Keywords: Virtual Reality (VR), HTC VIVE Trackers, Human Movement Quality Assessment, Biomechanical Features

The study aimed to identify key biomechanical features differentiating correct and incorrect execution of the lateral lunge and to determine the minimal sensor set required for reliable, interpretable VR-based motion analysis.

Movement data from 32 healthy adults (211 repetitions) were recorded using the HTC Vive system (7 trackers + headset). Repetitions were clinically classified by a physiotherapist via video observation. To prioritize diagnostic transparency, features including joint kinematics and inter-sensor Euclidean distances were evaluated using Linear Discriminant Analysis (LDA) and Shapley Additive exPlanations (SHAP) for feature selection and classification.

Angular features achieved higher classification performance ($F1 = 0.89$), identifying hip flexion of the stance limb and knee rotation acceleration of the stepping limb as the most discriminative markers. Conversely, distance-based features ($F1 = 0.78$) proved more stable and resistant to the calibration inaccuracies and baseline shifts commonly encountered in non-laboratory settings.

The applied interpretable methods demonstrate that reliable movement quality assessment can be achieved with a simplified sensor configuration (headset, shanks, and feet). These findings support the development of low-cost, transparent VR systems for remote rehabilitation, providing clinicians with understandable biomechanical evidence for targeted patient feedback [1].

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Frontiers of Science: Extreme Technologies and Fundamental Research

ORAL PRESENTATION

DIVERSE APPLICATIONS OF DRIVE SYSTEMS IN SWARM ROBOTICS SYSTEMS

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: SWARM Robotics, Drive systems, Hybrid Swarm Robotics, Multi-Domain Exploration

The simplest system for a swarm of robots is a multi-rotor drive, as it allows them to move freely in any direction in space. However, it is worth considering other types of drives that would open new possibilities for exploring diverse environments and surfaces, such as land or water.

Drones are simple and highly mobile thanks to their propulsion system, but this also makes them very energy-intensive, with low lift capacity, and ineffective in certain conditions. Advancing this research will allow for the creation of a coordinated swarm of hybrid robots, in which drones cooperate with ground robots.

Main findings and conclusions**:** The integration of different drives in a swarm of robots enables the exploration of new types of terrain that are not accessible to standard multirotor systems.

The implementation of diverse drives in robot swarms opens new possibilities for rescue missions in rubble fields and for space and ocean exploration. Ultimately, this will enable humans to be withdrawn from dangerous areas thanks to autonomous systems capable of continuous operation in difficult terrain.

Future research would involve creating simulations of robots with diverse drive systems, addressing challenges such as varying speeds and communication difficulties. Additionally, existing studies on the energy consumption of different drives would be analyzed.

ELECTROHYDRODYNAMIC PROPULSION OF A LIGHTWEIGHT WATERCRAFT – EXPERIMENTAL VERIFICATION AND STABILITY ASSESSMENT

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: ionic wind, corona discharge, ion engine, watercraft propulsion

Electrohydrodynamic (EHD) propulsion, also known as ionic wind propulsion, utilizes corona discharge to accelerate ions, which transfer momentum to neutral air molecules generating thrust. Such systems operate without moving parts and have been investigated in aerial and atmospheric thruster applications [1, 2]. Recent studies also demonstrate their feasibility near water surfaces [3].

This work presents an experimental verification of a lightweight boat propelled solely by an EHD thruster based on a corona discharge configuration The system consisted of a stabilized 6 V DC laboratory power supply, a high-voltage step-up converter, and an asymmetric emitter-collector electrode configuration integrated into a low-mass hull. Thrust was evaluated indirectly by measuring travel time over fixed a distance using repeated stopwatch measurements, while voltage and current on the low-voltage side were monitored with a digital multimeter to estimate input power. The measurable linear velocity of 297 cm/min at an input power of approximately 6 W was achieved, confirming the generation of usable reaction thrust consistent with prior EHD studies [1, 3].

The results demonstrate the feasibility of EHD propulsion for small watercraft. Environmental stability remains a key challenge. These findings support further research on efficiency optimization and stability control for compact, low-noise aquatic propulsion systems.

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Emergent Resilience: Investigating Functional Recovery in Swarm Robotic Systems Under Extreme Agent Loss

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: swarm robotics, functional recovery, extreme agent loss, multi-agent systems

Swarm robotics systems (SRS) get their strength from decentralization and self-organization, allowing a group of simple robots to perform complex tasks. By distributing control, these systems are designed to be more robust than traditional single-unit robots. Consequently, most current research in this field is focused on gradual degradation rather than on sudden agent loss, and even less on extreme agent loss. In nature when swarms are damaged it is often very extreme; example of bees, when the winter comes and temperature drops they die by thousands.

This study addresses this gap by investigating how various coordination algorithms respond to the instantaneous loss of over 75% of the population. Through large-scale computer simulations, we analyzed the foraging efficiency of several distinct algorithms.

Our findings reveal that agent-to-agent communication suffers near-total operational collapse. In contrast, stigmergic models utilizing the environment as a shared memory buffer exhibit emergent resilience, maintaining higher recovery rates despite the thinned population.

These findings demonstrate that SRS are highly dependent on the coordination mechanism rather than just population size. We conclude that in high-risk scenarios, stigmergy provides a superior framework for functional recovery, offering a robust strategy for the design of resilient autonomous swarms.

EXPERIMENTAL INVESTIGATION OF FRICTIONAL HEAT GENERATION IN A MULTI-VANE MACHINE

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: multi-vane machine; frictional heat generation; mechanical losses; energy balance

Multi-vane machines are increasingly used in energy conversion systems due to their compact design, relatively simple construction, and favourable operating characteristics. These machines are applied in various engineering systems where reliable and efficient energy transfer is required. However, their efficiency, performance and durability are strongly influenced by mechanical losses occurring during operation.

Among these losses, friction between moving components plays a significant role. Although frictional effects are commonly recognised as a source of efficiency reduction and wear, the phenomenon of frictional heat generation occurring in the contact zones of working elements remains insufficiently investigated. In the available literature on multi-vane machines, frictional heat is usually treated only implicitly as part of overall mechanical losses rather than being analysed as a distinct thermodynamic process.

To address this research gap, the present study investigates frictional heat generation in a multi-vane machine operating under steady-state conditions using a dedicated experimental test bench enabling measurements of torque, rotational speed, pressure, temperature, and surface heat flux density.

The developed experimental approach and the ongoing formulation of a mathematical energy balance model provide a framework for separating thermal effects associated with friction from other irreversible mechanisms. This work constitutes a preliminary stage of a broader research effort aimed at improving the understanding of frictional heat generation in multi-vane machines and supporting further studies on their efficiency and operational reliability.

EXPERIMENTAL METHOD FOR STUDYING ELECTRON BEAMS IN GASEOUS ENVIRONMENTS USING A CMOS IMAGE SENSOR

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Field emission, Electron beam detection in gases, CMOS image sensor, Microsystems

Conventional electron microscopy requires high-energy beams, vacuum conditions, and sample modifications, limiting effective imaging of non-conductive or biological samples. To overcome these limitations, we present a novel method for detecting electrons in gaseous environments, enabling non-invasive analysis under near-natural conditions. At Wroclaw University of Science and Technology, we are developing miniature MEMS-based electron optics systems, including a MEMS electron microscope [1], and have demonstrated electron detection in gas [2]. Our approach uses a CMOS image sensor to capture electrons after propagation through a gas medium. This allows measurement of beam divergence, spatial distribution, and emission profiles, as well as real-time tracking of changes in the electron beam. The system provides direct, real-time visualization of electron interactions with the surrounding gas on a computer screen, offering an intuitive and quantitative tool for studying electron-matter interactions. This capability opens new avenues for investigating biological and other sensitive samples without vacuum or structural modifications. Biological applications, our method lays the groundwork for gas-based electron detectors, providing insights into electron propagation dynamics and beam optimization. This work demonstrates the potential of combining MEMS electron optics with CMOS sensing to advance electron detection in realistic gaseous environments.

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From Host-Guest Systems to Self-Lasing Liquid Crystal Materials: Exploring Random Lasing in Tunable Photonic Platforms

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: liquid crystals, random lasing, laser dye

Liquid crystals(LCs) are soft, self-organizing materials that combine the fluidity of liquids with long-range orientational order, leading to their unique optical properties. Molecular ordering of LCs can be controlled by temperature, electric fields, or light, making them promising for flexible photonic devices and light sources [1]. The interesting type of stimulated emission process occurring in LCs is random lasing (RL), which produces laser light without conventional mirror-based resonators. Instead, the phenomenon relies on multiple scattering in a disordered material.

The first part of the demonstrated studies concerns RL in host-guest systems, where LC acts as the host and organic laser dyes are the guests. Results for three groups of newly synthesized organic dyes are discussed: *BODIPY, bis-thiophenes,* and *chalcogenophene triads.*

The second goal of experiments is to achieve lasing exclusively in LC materials. To date, no studies on self-lasing LC systems have been reported; this field remains completely unexplored. In these systems, the chromophore is incorporated into the mesogenic structure, allowing the material to simultaneously generate optical gain and provide a tunable, self-organized photonic environment within a single structure.

These studies expand current knowledge of LC systems and reveal a new research direction in self-lasing LC materials, potentially introducing an innovative concept for lasing displays and other photonic devices [2].

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Influence of Surface Enhanced Flake Graphite as Cathode Material on Electrode Performance in MFCs

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: MFC, graphite, cathode

Microbial fuel cells (MFCs) are devices that use microorganisms to simultaneously degrade organic matter, like wastewater or food waste, and produce power. Implementation of this technology could bring substantial benefits due to direct waste-to-energy conversion.

Performance of MFCs is heavily dependent on cathode material, because it facilitates the oxygen reduction reaction (ORR). Demand for cost-effective, efficient and durable cathode materials is rapidly increasing due to the difficulties like oxygen mass transfer limitations, degradation of the cathode and biofouling, which are preventing from upscaling the use of this technology.

A variety of carbon materials are used in air-cathode MFCs because of their low cost and sufficient surface area. Different materials widely used as cathode materials are not suitable for practical applications mainly due to poor stability in wastewater conditions or high cost.

Five different graphite materials and one graphene oxide material were used as air-cathodes in MFCs in this study to determine their utility as cathode materials. Activated carbon CWZ-22 was used as a reference material. Activated carbon CWZ-22 reached 15.05 W/m^3, while the best performing graphite material reached 7.54 W/m^3. The results indicate that surface enhanced flake graphite can be utilized as cathode material. However, their performance didn't outperform CWZ-22.

Investigating the Optical and Magnetic Interplay in $MnPS_3$: Temperature-Dependent Optical Spectroscopy and Structural Insights

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: antiferromagnetism, semiconductors, magneto-optical properties, material characterization

Transition metal phosphorus trichalcogenides (MPS_3, where M = V, Mn, Fe, Co, Ni, Cd, Mg, or Zn) are materials gaining more and more interest, as it is a novel category of layered magnetic semiconductors. Such materials have much to offer, and one of most interesting thing about them is correlation between magnetic and optical properties. In this research, complex relationship between these properties has been studied in $MnPS_3$.

The bulk sample has been carefully investigated in temperature dependence, using advanced optical methods such as absorption and photoreflectance, in conjunction with X-ray diffraction. Results have been compared with those derived from density functional theory (DFT) calculations. The four primary optical transitions were determined and described with changing temperature, showing magnetic phase transitions and their impact on lattice parameters change and optical spectra.

The precise determination of these transitions and broadening parameters demonstrates the sensitivity of photoreflectance to magnetic phase transitions, potentially serving as a novel marker for such transitions.

These results highlights the importance of further exploration of the optical and magnetic behaviors not only in $MnPS_3$, but also MPS_3 family, to discover whole potential of these layered materials in future advanced technological implementations, particularly in spintronics and magneto-optical technologies.

LIFE AT NANOMETER RESOLUTION: SURVIVAL OF BACTERIA UNDER TEM CONDITIONS

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: bacterial viability, electron dose, LIVE/DEAD fluorescence assay, radiation

Transmission electron microscopy (TEM) is a powerful tool for imaging microorganisms at nanometer resolution. It enables detailed visualization of bacterial ultrastructure, providing insight into cell wall organization and membrane integrity.

However, the high-energy electron beam used in TEM may damage biological samples, raising questions about the relationship between imaging conditions and microbial survival. In particular, structural differences between Gram-positive and Gram-negative bacteria may influence their sensitivity to electron irradiation. Despite the widespread use of TEM in microbiology, quantitative data linking electron dose to bacterial viability remain limited.

In this study, we evaluated the effect of increasing electron dose on the viability of representative Gram-positive and Gram-negative strains using TEM and a fluorescence-based live/dead assay (SYTO 9/propidium iodide). By correlating irradiation parameters with membrane integrity, we aimed to determine thresholds at which TEM conditions, such as vacuum and high intense radiation, begin to induce bactericidal conditions.

These findings demonstrate that electron dose is a critical parameter influencing bacterial survival during imaging. Understanding beam-induced damage not only improves interpretation of TEM data but also contributes to understanding how vacuum and radiation affects organisms.

Lunar Pit Slope Stability: Mare Tranquillitatis Pit Under Regolith Variability and Interface Uncertainty

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Lunar pits, Mare Tranquillitatis Pit (MTP), slope stability, Finite Element Limit Analysis (FELA)

Lunar collapse pits such as the Mare Tranquillitatis Pit represent key targets for future exploration due to their geological significance and potential as natural shelters. However, assessing their slope stability remains challenging due to the limited knowledge of the mechanical properties and internal structure of the lunar subsurface, the highly heterogeneous nature of lunar regolith and uncertainty in the depth and geometry of the regolith–bedrock interface. Operating on these slopes has been proposed as a one potential strategy for robotic exploration of lunar pits.

A numerical framework for evaluating the slope stability of the Mare Tranquillitatis Pit has been developed, addressing the need for stability assessment under uncertain lunar subsurface conditions. The analysis accounts for the spatial variability of regolith mechanical properties and explicitly considers uncertainty in the regolith–bedrock interface position. The model parameters are derived from available in-situ data from the Apollo and Chang'e missions. This analysis provides a more robust basis for interpreting potential failure mechanisms and contributes to improved risk-informed evaluation of lunar pit slopes.

The results show how the pit edges respond structurally, showing that their stability varies depending on the cross-section and boundary conditions. These insights contribute to a better understanding of how slope-failure processes may develop around lunar skylights.

Next-Generation UV Light Sources: Blue-to-UV Upconversion for Disinfection and Sterilization

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: UVC disinfection, Mercury-free UV sources, Blue-to-UVC upconversion, Praseodymium

Ultraviolet C (UVC) radiation (100–280 nm) is highly effective for disinfection because it damages the DNA and RNA of microorganisms, preventing their replication. As a result, UVC light is widely used in healthcare, laboratories, and water treatment systems. However, conventional UVC sources, such as mercury lamps, raise environmental and safety concerns.

One unique and innovative strategy is the development of upconversion materials capable of converting safe visible light into germicidal UVC radiation. In this work, we synthesized and investigated visible-to-UVC upconversion phosphors based on inorganic host matrices doped with Pr^{3+} ions. Upon excitation with UV or visible light, these materials exhibit broad and intense emission in the 240–300 nm range, which is the germicidal range. The studies also provided the meaningful insight into the mechanism of this process enabling efficiency enhancement.

Our results demonstrate that appropriate host engineering enables efficient tuning of the luminescence properties in visible-to-UVC upconversion Pr^{3+}-doped materials, allowing their performance to be tailored to specific application requirements. Moreover, this approach facilitates the miniaturization of UV light sources.

By enabling UVC generation using blue LEDs or even sunlight instead of mercury lamps, these materials open a pathway toward environmentally friendly and energy-efficient disinfection technologies.

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STRUCTURAL SAFETY OF TEMPORARY STRUCTURES: EXPERIMENTAL AND NUMERICAL INSIGHTS INTO SCAFFOLDING ANCHOR BEHAVIOUR

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Steel, Scaffold Structure, Anchor, Stability, Safety

Scaffold structures are essential temporary systems in the construction industry, providing access and safety for works carried out at height. Due to their temporary nature, scaffolds are highly sensitive to external actions. The overall stability of these systems strongly depends on the performance of anchoring elements that connect the scaffold to the building façade.

Although scaffolding systems are widely used, current European standards provide limited information on the mechanical properties and behaviour of various anchor connections. This lack of detailed guidance increases uncertainty in design and has been associated with real scaffold failures and accidents observed in construction practice.

This study investigates the behaviour of typical scaffolding anchors using a combined experimental and numerical approach. Full-scale laboratory tests were carried out to measure load–displacement response. Numerical analyses were developed to evaluate various factors. The results show that very little change in the geometrics of the anchors can affect the results significantly.

The outcomes of this research provide a clearer understanding of how scaffolding anchors work under realistic loading conditions. The findings can support future improvements of design recommendations and safety of temporary structures as well as reducing uncertainty and increasing the predictable behaviour of scaffolding anchors.

Temperature and Pressure Driven Phase Transition in Hybrid Perovskites

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: hybrid perovskites, phase transitions, broadband dielectric spectroscopy, high pressure

Over the last decade, three-dimensional hybrid perovskites have attracted increasing attention due to their phenomenal optoelectronic properties, with potential applications in photovoltaics, lasers, and bioimaging. Structurally, they consist of a metal-organic or all-inorganic framework containing voids occupied by cage cations. Due to the various possible combinations of molecules, hybrid perovskites form a diverse array of structures with tuneable properties. Research into their fundamental properties is crucial for tailoring these characteristics for specific applications. One of the most intense discussions in the field concerns the mechanism of phase transitions, which remains not fully understood. Using broadband dielectric spectroscopy in wide ranges of pressure and temperature, we demonstrated that the motion of the organic cation inside the metal-organic framework is nearly pressure-independent and does not affect phase transition conditions. Thus, we can exclude relaxation as the driving force of the phase transition. Additionally, we showed that pressure can be a successful tool to effectively tune physicochemical properties without affecting organic cation dynamics. This research challenges the well-established hypothesis that the motion of the cation and the breaking of its hydrogen bonds with the metal-organic cage determine phase transition parameters.

Lem Next Gen Science Forum at Wrocław Tech
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POSTERS

Accelerating Knowledge Discovery in Sparse Reward ALCS via Consistency Prioritization and Pareto-Based Rule Optimization

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Learning classifier systems, Explainable artificial intelligence

Sparse rewards create a critical bottleneck for Anticipatory Learning Classifier Systems (ALCS), as rare feedback leads to high discovery latency and incomplete environmental models. This paper introduces ACS2VCP, an enhanced framework that integrates Value Consistency Prioritization (VCP) with a Pareto-based rule fitness mechanism inspired by HEROS. VCP accelerates learning by prioritizing transitions with high consistency, while the Pareto layer guides the genetic algorithm using accuracy and coverage metrics to optimize rule selection and deletion. We evaluate ACS2VCP on a comprehensive suite of benchmark mazes against standard ACS2, ACS2 extend by Experience Replay (ER), and by Hindsight Experience Replay (HER). Our results demonstrate that ACS2VCP matches the performance of top-tier HER variants in knowledge acquisition and path optimization, while maintaining a more robust population of reliable classifiers. By providing a stable transition from exploration to exploitation, ACS2VCP establishes multi-objective consistency-driven prioritization as a powerful alternative for model-based reinforcement learning in complex, reward-sparse domains.

Comparative Analysis of Numerical Integrators for Low-Energy Trajectory Design in the PCR3BP

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: PCR3BP, low-energy trajectories, numerical integration, Julia programming language

Modern space exploration relies on advanced methods of celestial mechanics to design fuel-efficient trajectories for international lunar missions. The planar circular restricted three-body problem provides a simplified but effective model for studying spacecraft motion under the gravitational influence of the Earth-Moon system. Efficient trajectory computation in rotating frames remains challenging due to non-separable Hamiltonians, which limit the applicability of standard symplectic integration methods and create a trade-off between numerical accuracy and computational cost.

This work investigates Newtonian and Hamiltonian integration schemes implemented in the high-performance Julia environment to enable rapid prototyping of low-energy transfers. Particular attention is given to the comparison of implicit symplectic Gauss and Lobatto integrators with the explicit 9th-order Verner method.

The results show that the Verner integrator provides the best balance between speed and accuracy for preliminary trajectory optimization, achieving a transfer cost of approximately 388 m/s to a Lyapunov orbit around the L1 point.

By combining invariant manifold theory with logarithmic-complexity k-dimensional tree search algorithms, the developed GRAVITy library significantly accelerates trajectory identification compared to classical grid-based approaches. These results align with modern lunar mission design strategies, including those used in the NASA Artemis program, and demonstrate a scalable framework for efficient mission planning.

DESIGN AND PRELIMINARY VALIDATION OF A LOW-COST, MODULAR OPTICAL CHOPPER PLATFORM

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: optical chopper, beam modulation, field-oriented control (FOC), BLDC motor

Most instrumentation used in optical spectroscopy remains expensive and difficult to access due to stringent metrological requirements. The goal of this project was to develop an open, low-cost optical chopper capable of performance comparable to commercial solutions, while offering greater flexibility and modularity. To achieve this, a custom BLDC motor controller implementing field-oriented control (FOC) was designed, enabling compatibility with a range of motors and encoders. In parallel, a mechanical assembly was developed, featuring a rigid, 3D-printable base and a mounting system for interchangeable, custom chopper wheels. The designed system provides an adjustable chopping (modulation) frequency from 10 to 5000 Hz. Preliminary testing demonstrated promising performance and operational stability, although further optimization is required. Overall, the project presents an open-hardware solution that significantly reduces the cost of an optical measurement setup, while enabling straightforward customization and offering the potential for performance comparable to established commercial instruments.

DETECTING HILBERT SPACE FRAGMENTATION IN THE FRAMEWORK OF SPECTRAL GRAPH THEORY

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Hilbert space fragmentation, graph theory, clustering algorithms, quantum many-body dynamics

The Hilbert space provides the mathematical framework of quantum mechanics. Understanding its structure is crucial for analyzing properties and dynamics of quantum systems, particularly in strongly correlated fermionic systems. Hilbert space fragmentation describes a phenomenon, in which the Hilbert space of a system's Hamiltonian splits into dynamically disconnected subspaces. In this project we investigate this case by applying methods from graph theory. The key assumption is to interpret the Hamiltonian as the adjacency matrix of a graph whose vertices correspond to basis states, and edges represent allowed transitions. Within this framework we use clustering methods based on spectral analysis of the Laplacian and modularity matrices to identify substructures in graphs representing quantum systems. Testing these algorithms on the Hubbard and t-J models showed the applied algorithms correctly reconstruct the corresponding cluster structure in regimes exhibiting fragmentation, and most importantly, remain reliable even for nearly-fragmented models. Our results demonstrate that spectral graph methods provide an effective tool for detecting non-trivial structures of Hilbert spaces in many-body systems. More broadly, the approach illustrates how techniques developed for network analysis and data science can be adapted to problems in theoretical physics, offering new insights in the structure and dynamics of complex quantum systems.

DISPERSION RELATIONS FOR FEYNMAN INTEGRALS

Frontiers of Science: Extreme Technologies and Fundamental Research

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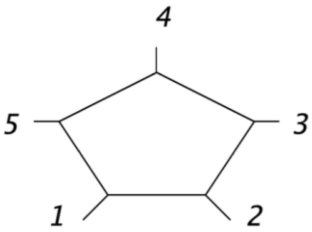
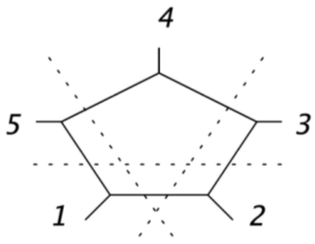
Keywords: Feynman integrals, dispersion relation

Feynman integrals are a necessary ingredient in providing state-of-the-art precise theoretical predictions for the scattering processes at the Large Hadron Collider (LHC), e.g., for the production of the Higgs boson. They arise from higher-order quantum corrections to scattering amplitudes in the Standard Model of Particle Physics. Throughout the past decades, there has been tremendous progress in understanding their properties, developing techniques for computing them, and discovering new emerging mathematical structures. A particularly interesting description of Feynman integrals are the dispersive representation. It reflects their physical properties by the virtue of unitarity.

In this project, we explore reconstructing Feynman integrals from their maximal unitarity cut starting from one loop order. This requires a geometric understanding of the integration region. The analytic calculations are performed using Mathematica, while the numerical checks of the expressions are carried out with additional packages.



$$= \int_0^\infty \frac{ds'_{23}}{s'_{23} - s_{23}} \int_0^\infty \frac{ds'_{12}}{s'_{12} - s_{12}} \int_0^\infty \frac{ds'_{51}}{s'_{51} - s_{51}}$$



Effect of the Anionic-to-Cationic Surfactant Ratio on Quartz Flotation Recovery

The Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: surfactant mixtures, synergy, flotation

Flotation is a process for the selective separation of solid particles dispersed in a liquid by means of gas bubbles. Surface hydrophobicity constitutes a key parameter governing the efficiency of particle-bubble attachment. Control of surface hydrophobicity is achieved through the application of chemical reagents referred to as collectors.

In response to increasing pressure from environmental regulations, it has become necessary to seek ways to reduce the consumption of flotation chemicals. One possible approach is the use of surfactant mixtures in which synergistic interactions occur between their components and the mineral surface.

The present study was undertaken to evaluate the effect of the cationic-to-anionic surfactant ratio on the flotation behavior of quartz particles and on changes in electrokinetic potential. The results indicated that comparable flotation yields were obtained over a range of anionic-to-cationic surfactant ratios exceeding 0.40. Quartz recovery was sufficiently high over the concentration range of $5.00 \cdot 10^{-3}$ to $5.00 \cdot 10^{-2}$.

The identification of an optimal cationic-to-anionic surfactant ratio enables improved control of the flotation process and may contribute to a reduction in operating costs by minimizing the excessive use of costly reagents. In addition, appropriate surfactant proportions help prevent mutual neutralization.

This work was supported by the National Science Centre, Poland (project no. 2023/49/N/ST8/04259), *Surfactant synergy in flotation process: Exploring the impact of anionic/cationic surfactants mixtures on thin liquid film stability*

EMERGENCE OF MAJORANA MODES IN STRONGLY CORRELATED QUANTUM CHAINS

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Majorana Zero Modes, Solid State, Topological Quantum Computing, Kitaev Chain

Majorana zero modes are exotic quasiparticles predicted to emerge at the edges of topological superconductors. Due to their non-local character and resilience to local decoherence, they are considered promising building blocks for fault-tolerant quantum computing. Understanding how these states behave in the presence of strong electronic interactions remains an important challenge in condensed matter physics.

In this work we investigate a strongly interacting extension of the one-dimensional Kitaev chain. The model includes spin degrees of freedom and on-site Coulomb interaction between fermions of opposite spin, resulting in two coupled spin channels. This framework allows us to analyze three possible triplet pairing configurations and study how pairing symmetry and electronic correlations influence the emergence of Majorana edge states.Using the Density Matrix Renormalization Group (DMRG) method, we analyze fermionic correlation matrices and long-range edge-to-edge correlations to identify topological phases in the interacting regime.

Our results show that increasing interaction strength significantly modifies the structure of spin-resolved correlations and leads to interaction-induced coupling between spin sectors while preserving weak end-to-end correlations.These findings provide new insight into the stability of Majorana modes in strongly correlated systems and contribute to the theoretical understanding of interacting topological superconductors relevant for future quantum technologies.

Experimental and Theoretical Investigation of Normally-off AlGaN/GaN Transistors Obtained by Using Polarization Doping

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: HEMT, GaN, Polarization doping, Wide bandgap semiconductors

GaN-based semiconductors are nowadays considered as outstanding materials for the future high power electronics. GaN-based High Electron Mobility Transistor (HEMT) devices are investigated for usage in high power electronics and high frequency applications where normally-off operation of transistor is necessary for maintaining security of electronic devices. Although many GaN-based devices reached the market, many problems regarding normally-off HEMTs are yet to be solved.

Normally-off operation of HEMT face many problems such as long term stability and proper ohmic contact fabrication. In this work a new approach applying polarization doping is considered for achieving normally-off operation of HEMT as a means to overcome significant problems in the area.

In this work four different heterostructures with different gradient layer thicknesses and one with p-GaN layer were simulated, prepared and thoroughly examined revealing great impact of polarization doping in achieving normally-off HEMT operation.

Performed simulations give overview of applicability of polarization doping for normally-off operation. Structural and electrical properties of the MOVPE-grown structures were investigated using X-ray diffraction and Hall mobility measurements, respectively. Hall mobility measurements reveal decreasing 2DEG concentration with increasing gradient layer thickness, and structural characterization give insight into structural integrity and good quality of prepared structures.

Formation of Three-Phase Contact in a System Containing a Mixture of Ionic Surfactants

The Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: bubble-surface adhesion, thin liquid film, flotation

Flotation is a separation process widely employed in industry. Despite its apparent simplicity, the mechanism of flotation has not yet been fully elucidated. Physicochemistry of the surfaces of both solid particles and gas bubbles, which may form a flotation aggregate, is undoubtedly the most critical aspect of the process.

Advanced approach to investigating the flotation mechanism is the observation of bubble collision with a solid surface. Since this process occurs within only a few milliseconds, it requires the use of a dedicated image acquisition system. The use of such a system makes it possible to determine the time required for the occurence of stable contact between a solid surface and a gas bubble, referred to as the three-phase contact formation time (TPC).

This study presents investigations into the effect of a mixture of ionic surfactants, namely dodecylamine hydrochloride (DAH) and sodium dodecyl sulfate (SDS), on the formation of TPC. Preliminary experiments identified the molar ratios of ionic surfactants in the mixture at which a synergistic effect becomes apparent (SDS:DAH = 0.25–0.50). Further research will focus on correlating the measured TPC with flotation recovery in order to determine the optimal mixture composition that ensures the highest process efficiency.

This work was supported by the National Science Centre, Poland (project no. 2023/49/N/ST8/04259), *Surfactant synergy in flotation process: Exploring the impact of anionic/cationic surfactants mixtures on thin liquid film stability*

Growth of Near-Infrared VCSEL Structure for Telecommunication Applications

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: VCSEL, semiconductor lasers, epitaxy, near-infrared

Vertical-Cavity Surface-Emitting Lasers (VCSELs) are compact semiconductor lasers that emit light perpendicular to the surface of the device. Owing to their low power consumption, high efficiency, and compatibility with wafer-level fabrication and testing, they have become key components in modern optoelectronic technologies [1].

VCSELs operating in the near-infrared spectral range are particularly important for telecommunication applications. The epitaxial growth of such devices is technologically demanding because the structure consists of a complex multilayer architecture that includes distributed Bragg reflectors and a carefully engineered active region. Precise control of layer thickness, composition and interface quality throughout the entire growth process is therefore essential for obtaining reliable and reproducible device performance.

In this work, we report on the growth of a VCSEL structure designed for near-infrared emission using metal–organic vapor-phase epitaxy (MOVPE), demonstrating high structural and optical quality of the epitaxial layers and stable growth conditions. These findings provide valuable feedback for further optimization of complex VCSEL structures and support the development of reliable VCSEL technologies for photonic and data-communication applications.

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Impact of Informed Agent Ratio on the Efficiency of Collective Swarm Navigation

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Swarm Robotics, Navigation Efficiency, Swarm Robotics Systems, Leader and Follower Dynamics

Swarm robotics is a rapidly developing field of technology due to its scalability, flexibility, and robustness This technology provides different approaches to a wide range of areas, including logistics, exploration, agriculture, medical care, and search and rescue, among others. Swarm systems typically utilize decentralized mechanisms for coordinating tasks, with many of these systems being described as leader-follower dynamics.

The goal of our study was to determine the optimal proportion of leaders in a swarm. This work is important in order to achieve the best performance possible for the system while still balancing out the cost-effectiveness of having leadership within the swarm.

Our findings show that in bigger swarms there are less than 15% of leaders required to successfully lead a swarm and allow it to maintain effective collectivism and overall system cohesion.

Overall, these findings provide additional insight into how collective decision-making occurs in decentralized systems such as animal groups and robotic swarm systems. An understanding of how to determine an optimal leader-to-follower ratio can help to create larger, more robust robotic swarm systems. Additionally, this study can help to shape future applications of swarm robotics technologies in other areas of the industry, such as search and rescue, environmental monitoring, and autonomous exploration.

Influence of Measurement on the Dynamics of Quantum Systems

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Keywords: quantum measurements, spin chains, Bell measurements, nonequilibrium dynamics

Understanding how measurements influence quantum many-body systems is an important problem in modern quantum physics, particularly in the context of quantum information and controlled quantum experiments. In this work, we investigate the effect of different measurement strategies on the dynamics of one-dimensional spin-1/2 chain models.

The study compares two types of measurements – single-spin and Bell measurements – and examines how their frequency and spatial distribution affect the evolution of the system. The analysis considers different initial states, including the Néel state and domain-wall configurations, to explore how the initial structure of the system modifies its response to measurements.

Our results show that even infrequent measurements introduce noticeable deviations from unperturbed dynamics, with Bell measurements generally producing stronger changes in both the order parameter and local spin observables. For the Néel state, increasing the measurement frequency suppresses oscillations and drives the system toward vanishing expectation values. In contrast, domain-wall states display qualitatively different relaxation dynamics, where Bell measurements accelerate decay while single-spin measurements may slow the relaxation process.

These findings provide insight into how monitoring strategies influence quantum dynamics and suggest that rare measurements distributed over many sites can reduce disturbance while still enabling effective observation of the system.

INFLUENCE OF SUBSTRATE MATERIAL ON IPA DROPLETS EVAPORATION

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Keywords: droplets, evaporation, low-pressure, isopropyl alcohol

Droplet evaporation is a ubiquitous process used in spray cooling, electronic cooling, and thermal management system operations. The evaporation dynamics strongly depend on liquid–solid interactions, substrate properties, and ambient pressure.

This study presents an experimental investigation of isopropyl alcohol (IPA) droplet evaporation on superheated brass and bronze substrates under atmospheric and reduced pressure conditions (0.5–4 kPa). Static wettability measurements were conducted at atmospheric pressure to characterize surface–liquid interactions. The critical surface tension was determined as 10.12 mN/m for brass and 12.21 mN/m for bronze, confirming differences in interfacial properties. The influence of surface heating (10–80°C) was also quantified, revealing a decrease in contact angle with increasing temperature.

Evaporation experiments under reduced pressure showed significant acceleration of the phase-change process compared to atmospheric conditions. The dominant evaporation mechanism was identified as stick–slip contact line dynamics, with measurable differences in spreading behavior and evaporation time between the two substrates. The results demonstrate that substrate material and ambient pressure substantially affect droplet deformation, contact line stability, and heat transfer intensity.

LEVEL SENSITIVITY IN QUANTUM SYSTEMS WITH HILBERT SPACE FRAGMENTATION

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Keywords: quantum many-body, Hilbert space fragmentation, level sensitivity, spin transport

Quantum systems exhibiting Hilbert space fragmentation constitute an important class of nonergodic systems, which makes them particularly interesting in the context of potential applications in quantum information storage. In this work, the dependence of energy levels on changes in boundary conditions is investigated numerically for the basic models of strongly correlated electrons: one-dimensional Hubbard model and its limit $U \to \infty$, i.e., the t-model. The sensitivity of energy levels provides valuable information about transport properties in the system. In the present study, spin current transport through the system is considered. It is shown that the t-model exhibits complete Hilbert space fragmentation and is insensitive to changes in boundary conditions. This intriguing and not yet fully understood insensitivity of energy levels has previously been demonstrated for the "folded" Heisenberg XXZ model. In this work, it is numerically demonstrated for a system with similar properties, but significantly simpler and more widely used. The influence of additional terms in the Hamiltonian is also investigated and it is shown that perturbation that destroys fragmentation also eliminates the model's insensitivity to boundary conditions, suggesting that these two properties are intrinsically linked. Finally, the relationship between level sensitivity and spin current transport is demonstrated using a numerical solution of the Lindblad equation – master equation for quantum open systems.

Light Amplification in ESIPT-Based Organic Dyes

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: ESIPT, random lasing, liquid crystals, polymer thin films

ESIPT-based organic dyes are of great interest for lasing applications due to their unique dual nature reflected in the coexistence of their enol and keto forms. Therefore, upon excitation they can undergo intramolecular proton transfer from the enol to the keto form, resulting in two distinct emissive states. This causes a large Stokes shift – up to 200 nm in the visible spectrum – and the formation of a natural four-level energetic system. Classical dyes suffer from a small Stokes shift, leading to self-reabsorption, making light amplification more difficult. Consequently, using ESIPT-based dyes for light amplification is particularly promising, as they are able to lase efficiently even at high concentrations.

In this work, we conducted measurements of random lasing (RL) and amplified spontaneous emission (ASE) phenomena of selected, commercially available ESIPT chromophores in various organic matrices, including liquid crystals and polymeric thin films at different concentrations. It was possible to achieve random lasing in all examined matrices, demonstrating their unique versatility. The dyes' performance was also compared with their RL in powdered form. Although the lowest lasing thresholds were not reached in the liquid crystal host, achieving RL there is encouraging, as this organic matrix allows dynamic, voltage-driven tuning of the emission. These results highlight the unique advantages of ESIPT-based dyes for solid-state laser applications, combining a high Stokes shift, efficient light amplification at high concentrations, and tunable emission in responsive matrices. By enabling ASE and RL across diverse host materials, this work opens new avenues for voltage-controlled and environmentally adaptive organic laser devices.

Low-Cost Fourier Ptychography System for High-Resolution Computational Microscopy

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Keywords: Fourier ptychography, computational imaging, phase retrieval, deep learning

Fourier ptychography is a computational imaging technique that enables high-resolution optical microscopy beyond the limitations of conventional lens-based systems. By combining multiple low-resolution images acquired under different illumination angles, it improves spatial resolution while preserving a large field of view. This approach makes it possible to design cost-effective imaging systems without relying on expensive high-numerical-aperture optics.

However, Fourier ptychography is sensitive to noise, optical imperfections, and reconstruction artifacts, which may reduce the interpretability of reconstructed images. In this work, these limitations were addressed by combining classical physics-based reconstruction methods with modern artificial intelligence techniques. A complete experimental Fourier ptychography system was designed and implemented, including optical hardware, control electronics, and dedicated software for data acquisition and processing.

The results show that applying a U-Net–based neural network as a post-processing step significantly improves the visual quality and clarity of the reconstructed microscale structures.

These findings demonstrate that the integration of computational imaging with data-driven methods can improve the robustness and accessibility of high-resolution optical microscopy. The proposed approach contributes to the development of low-cost computational microscopy systems for future research in materials science, microelectronics, and nanotechnology.

Optimization of the synthesis of Au@Pd nanorods

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Keywords: plasmonic nanoparticles, nanoparticle synthesis, bimetallic nanoparticles, optimization

Plasmonic nanoparticles find applications in various fields, such as photocatalysis [1], medicine and imaging [2], due to their unique optical properties arising from the localized surface plasmon resonance (LSPR) phenomenon [2]. The position and profile of the LSPR band can be tuned by altering the nanoparticle morphology, which can be achieved by modifying the synthesis parameters. Understanding the relationship between reaction conditions and resulting nanoparticle morphology is crucial for designing nanomaterials with optimized properties for specific applications. Even minor variations in synthesis parameters may result in significant differences in nanoparticles characteristics. Consequently, systematic efforts to explore and map out the chemical space have attracted increasing attention [3].

This poster presents results of investigations into the optical properties of gold nanorods with palladium-coated tips, synthesized via wet-chemical approach [1] under systematically varied reaction conditions. UV-Vis absorption spectroscopy served as the primary characterization technique. Main results include a substantial reduction in synthesis time and validation of the method's reliability. The protocol demonstrates high tolerance to experimental variability, ensuring reproducibility across laboratories, scalability, and potential of automation. Furthermore, it enables preparation of Au@Pd nanorods in a single workday, thereby accelerating subsequent experimental studies and facilitating practical applications.

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Organic Dyes for Tunable Emission and Lasing

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: organic dyes, tunable emission, host-guest systems, electrospun nanofibers

Organic dyes with tunable emission are of significant interest for fluorescence and lasing applications, including advanced photonics, sensing and novel displays. This study explores the potential of organic dyes in diverse host environments.

Although emission tunability is a well-recognized phenomenon, systematic studies directly comparing emission behavior across different organic matrices remain relatively limited. Here we demonstrate that newly synthesized Benzothieno-S,S-Dioxide-Benzofuran BTBOF dyes exhibit fluorescence shifts when incorporated into different hosts (polymeric thin films, liquid crystals). We compare these properties with their behavior in powder and solution. Beyond these synthetic systems, we also investigate commercially available organic dyes incorporated into electrospun nanofibers, and liquid-crystal infiltrated fibers. These materials are well known for their high surface-to-volume ratio, making them an excellent host for achieving multicolor, tunable random laser emission. Key results demonstrate significant tunability through matrix-dependent emission modulation and efficient lasing performance across all nanofiber systems. The presented results demonstrate the technological potential of adaptable dye-lasing platforms for developing wavelength-tunable lasers in optical sensing, and high-resolution systems.

Phase Singularities Spot Diagrams as a Tool to Assess Optical Aberrations

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: wavefront sensing, phase singularity, optical vortex, aberration

Accurate measurement of optical aberrations is essential for characterizing and optimizing the performance of optical systems. Here, we propose introducing a new analysis tool that provides another perspective to assess optical aberrations. We study the behavior of singular points under manually introduced aberrations using off-axis optical vortex scanning. By shifting the vortex-generating element and tracking the resulting singular points at the Fourier plane, we construct a dark ray spot diagram, being a singularity analogue of classical ray spot diagrams.

Off-axis scanning was previously proposed as a beam-quality marker, distinguishing aberrated from unaberrated beams. To function as a reliable aberrometer, however, quantitative links between trajectories and specific aberrations are required. We previously showed that two perpendicular trajectories – from *x*- and *y*-axis shifts – respond uniquely to particular Zernike polynomials, enabling aberration-specific quantities and an autofocusing algorithm.

Here, we extend this approach from two trajectories to a full circular grid. The resulting dark ray spot diagrams offer a novel tool for examining optical aberrations, where each "ray" is a phase singularity – a physically meaningful and sensitive probe of optical system quality. We believe that the presented work offers a new perspective on wavefront sensing and represents a significant research step.

REPRODUCIBLE ELECTROCHEMICAL ETCHING OF TUNGSTEN PROBE TIPS: SYSTEM DESIGN AND VALIDATION

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: electrochemical etching, automation, tip fabrication, tungsten probe

Tungsten probe tips, depending on the apex geometry and sharpening quality, can be employed in a range of measurement techniques, including scanning tunneling microscopy (STM), where an atomically sharp apex is required, as well as in electrical characterization of semiconductor structures. The motivation for this work was to enable the fabrication of precise measurement probes while reducing the cost, which for commercial tips can reach several hundred US dollars per piece.

This paper presents a system for tungsten tip fabrication and reports the results of a series of experiments aimed at developing and stabilizing the manufacturing process. The quality of the fabricated tips was assessed using scanning electron microscope (SEM) imaging, and their practical utility was validated by performing electrical measurements with the produced probes. The results indicate that the proposed approach enables reproducible fabrication of probe tips with geometries suitable for measurement applications and has the potential to improve accessibility and standardization of probe preparation workflows.

THE IMPACT OF UNIT LOSS ON COHESION AND TASK ACCOMPLISHMENT

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: Swarm robotics, Fault tolerance, Artificial potential fields, Anchoring effect

Robotic swarms offer immense potential for complex, distributed tasks such as search-and-rescue operations and environmental monitoring, relying on the fluid coordination of multiple agents without a central leader. While these bio-inspired systems possess inherent redundancy, real-world deployments inevitably expose them to unpredictable hardware malfunctions, posing a significant challenge to long-term mission sustainability.

This study systematically evaluates the performance degradation of a non-holonomic robotic swarm-controlled via artificial potential fields and second-order dynamics-as immobilized machines become static physical obstacles for the remaining active group.

Experimental data reveals that the swarm maintains optimal navigation times to a shared target at failure rates up to 15%; however, beyond this critical threshold, damaged units induce a paralyzing “anchoring effect” that drastically reduces collective efficiency, leading to total mission failure when approximately 45% of the agents fail.

These findings clearly demonstrate that swarm reliability in crowded spaces is severely constrained by agents passively blocking optimal paths. Consequently, this research highlights the urgent necessity of designing control systems capable of autonomously detecting and isolating damaged units, which is crucial for ensuring safe, resilient deployments in high-risk, dynamic environments.

TOWARDS STANDARDIZED METHODS FOR ASSESSING MICROPLASTICS POLLUTION AND ITS LINK TO LAND USE IN THE LOWER SILESIA REGION OF POLAND

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: microplastics, soil, land-use, Nile Red

Microplastics (MPs) were detected in numerous environments. However, MPs pollution in soil is much less recognized than pollution in aquatic environments, despite their potential impacts on soil health and terrestrial food webs. One of the major limitations in this field is the lack of standardized methods for sampling, extraction, purification, and identification/quantification of microplastics fragments in soil samples, which hinders comparison across studies.

The aims of this study are to optimize a high-performance method to isolate, identify and quantify MPs in soil samples. This study also aims to explore if there is a link between land-use and dominant synthetic polymers and concentration of MPs in soil. Soils were collected from 5 different types of land-use: agricultural soils fertilized or not fertilized with sewage sludge, areas near traffic routes, areas near factories, urban greenery and areas with limited antropopression.

The optimization process focuses on improving organic matter removal, density separation efficiency, and polymer identification reliability through sequential H_2O_2 pre-digestion, $ZnCl_2$ flotation, post-digestion using Fenton's reagent, preliminary visualization of MPs using Nile Red staining, and quantification and identification of synthetic polymers using μFTIR.

By developing a reproducible and efficient extraction workflow, this study aims to contribute to methodological harmonization in soil microplastics research.

TWO-PHOTON ABSORPTION OF ATOMICALLY-PRECISE AG-DNAS NANOCLUSTERS

Frontiers of Science: Extreme Technologies and Fundamental Research

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Keywords: 2PA, Silver nanoclusters, NIR emission

DNA-stabilized silver nanoclusters (Ag_N-DNAs) are new class of nanomaterials, which expanded in recent years, due to purification methods and the application of machine learning approaches [1, 2]. Ag_N-DNAs possess unique photoluminescence properties mostly in near-infrared (NIR) range of wavelengths, beneficial for applications in fluorescence microscopy [1]. Two-photon absorption (2PA) is simultaneous absorption of two photons to excite an electron from the ground to the excited state. 2PA process is a basis of two-photon fluorescence microscopy (2PFM).

Here, we investigate 2PA properties of Ag_N-DNAs. For the first time, we quantitatively explore 2PA in a wide range of wavelengths and determine two-photon absorption cross-sections (σ_2). We chose DNA-stabilized silver nanoclusters, which are representatives of four different groups of clusters characterized on the basis of number of Ag atoms, valence electron count and DNA ligand composition [3]. All measured nanoclusters had determined 2PA spectra in a 810–1400 nm range and show significant differences between one-photon and two-photon response [4]. Comparison of representatives of 4 different groups of Ag_N-DNA nanoclusters help to identify similarities between them (e.g., particularly high 2PA cross-sections (σ_2) in higher-energy transitions). Unique cluster was $(DNA)_2[Ag_{16}Cl_2]^{8+}$, which presented particularly high values of σ_2 in longer wavelengths (>1000 nm).

In conclusions, Ag_N-DNA nanoclusters present record values of two-photon brightness ($\sigma_{2,b}$) together with other properties beneficial for bioimaging (emission in NIR-I window, large Stokes shifts, water-solubility), which makes them unique fluorescent markers for 2PFM [4].

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