NanoBio

International Conference on Nanotechnologies and Bionanoscience

3rd International Conference on Nanotechnologies & Bionanoscience

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Greece

ABSTRACT BOOK

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Monday 8th September

Plenary Session I

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(Plenary I) Structural Nanomedicine: Blueprints for Better Drugs

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Abstract:

Spherical nucleic acids (SNAs) are unique nanostructures composed of spherical nanoparticle cores densely packed with highly oriented oligonucleotides on their surfaces. Unlike other forms of nucleic acids, SNAs have no natural counterparts and exhibit distinct interactions with biological systems. These structural properties facilitate efficient cellular uptake, positioning SNAs as powerful tools for diagnostics, gene regulation and editing, and vaccine development. In fact, they form the basis of seven lead compounds currently being explored in clinical trials for treating diseases such as glioblastoma, Merkel cell carcinoma, squamous cell carcinoma, psoriasis, and various neurological disorders.

The modularity of SNA architecture has advanced the field of structural nanomedicine, where nanomedicines are defined not only by the identity of their active components but also by their structural arrangement and chemical connectivity. This approach has proven effective in the design and synthesis of highly potent SNA vaccines for multiple cancers and infectious disease. Importantly, in these studies, SNAs demonstrated minimal cytotoxicity, making them attractive candidates for medicinal applications. These advances reflect over three decades of progress in nanomedicine, highlighting the transformative impact SNAs have had on our understanding, tracking, and treatment of diseases, as well as their significance for science and society.

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(Plenary II) Supercharging Immunotherapy Through Nanotechnology: Chemical Structure Matters

Artzi Natalie[1,2,3*]

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Abstract:

The traditional "one-size-fits-all" approach to biomaterial design overlooks the dynamic and tissue- and cell-specific variations in surface chemistry and biology. Our laboratory develops biomaterials that respond to specific cues from tissues and cells to enhance therapeutic efficacy and biocompatibility.

In designing biomaterials across multiple length scales to overcome physiological barriers to the precise spatiotemporal delivery of immunotherapies, we enable synergistic combinations with existing and emerging therapeutic modalities. This transforms treatment paradigms for cancer, autoimmune disorders, and vascular diseases.

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Tuesday 9th September

Plenary Session II

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(Plenary III) Processing and Applications of 2D Nanomaterials Inks

Valeria Nicolosi[1*]

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Abstract:

Liquid phase exfoliation has been proved to be a cheap, scalable method for the mass production of 2D sheets. This talk will first discuss the galaxy of existent layered materials, with emphasis on synthesis, liquid-phase exfoliation, and characterization, focussing on some key applications recently developed in our laboratories, ranging from energy storage to printed electronics.

We will for example discuss how two-dimensional nanomaterials can be formulated in aqueous and organic viscous inks for extrusion printing, inkjet printing, and aerosoljet 3D printing, and demonstrate direct printing on various substrates. The additive- and binary solvent-free inks do not show coffee ring effect, enabling high-resolution printing without substrate pre-treatment. The resulting printed micro-supercapacitors showcase excellent charge storage performance, including areal capacitance up to 100 mF/cm2 and volumetric capacitance up to 800 F/cm3 in protic gel electrolyte, coupled with long lifetime and good flexibility. The versatile direct-ink-printing technique highlights the promise of 2D nanomaterials functional inks for scalable fabrication of easy-to-integrate components of printable electronics.

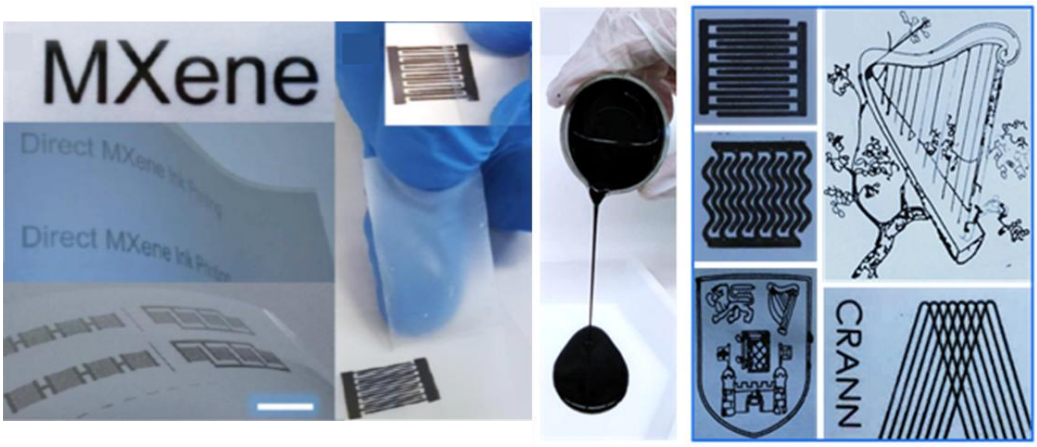

Figure 1: Printed devices based on MXenes inks

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(Plenary IV) Listening to light: Advances in Optoacoustic Imaging

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Abstract:

Biological discovery is a driving force of biomedical progress. With rapidly advancing technology to collect and analyze information from cells and tissues, we generate biomedical knowledge at rates never before attainable to science. Nevertheless, conversion of this knowledge to patient benefits remains a slow process. To accelerate the process of reaching solutions for healthcare, it would be important to strongly complement this culture of discovery with a culture of problem-solving in healthcare. The talk focuses on recent progress with optical and optoacoustic technologies, including Multispectral Optoacoustic Tomography (MSOT) and Raster-scan Optoacoustic Mesoscopy (RSOM), as well as computational methods, as the means to opening new paths for solutions in biology and medicine. Particular attention is given on the use of these technologies for early detection and monitoring of disease evolution. The talk further shows new classes of imaging systems and sensors for assessing biochemical and pathophysiological parameters of systemic diseases, complement knowledge from –omic analytics and drive integrated solutions for improving healthcare.

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Thursday 11th September

Plenary Session III

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(Plenary V) Human Nanomedicine: Eliminating Implant Failure in Over 30,000 Patients and Still Counting….

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Abstract:

This presentation will cover a close to 30year journey researching and commercializing nanotechnology for improving disease prevention, diagnosis, and treatment which has led to numerous products including nano spinal implants now in over 30,000 patients to date showing no signs of failure according to the FDA MAUDE database. Traditional orthopedic implants face a failure rate of 5 – 10% and sometimes as high as 60% for bone cancer patients. The talk will cover not only human clinical evidence of the unprecedented efficacy of nanotechnology in medicine but also fundamental evidence of how nanotechnology can be used clinically to kill bacteria, inhibit inflammation, and promote tissue growth (if needed) without drugs. This talk will also describe the future of nanotechnology and how it will in the not too distant future combat traditional failures in our global healthcare system including reversing the current decrease in global average life expectancy, creating a reactive compared to predictive healthcare system, transforming a healthcare system that relies too much on drugs and pharmaceutical agents to treat ailments, facilitating a non-personalized healthcare system, combating increasing costs, treating a growing global population, and more through the future use of implantable nano sensors, 4D printed nano materials, smart nano materials, environmentally-friendly nanomaterials, and AI as well as other predictive models in medicine and more.

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(Plenary VI) Automated Atomic Scale Data Analysis and Modelling for (Scanning) Transmission Electron Microscopy

Jordi Arbiol[1,2]

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Abstract:

The discovery, optimization, and application of new materials is a complex and multifaceted process that encompasses identifying technological needs, reviewing existing literature, proposing candidate materials, engineering devices, characterizing structures, and testing performance. This workflow becomes particularly time-consuming and costly when atomic-level precision is required to understand the functionality of materials and heterostructured devices.

To address these challenges, we introduce an AI-enhanced analytical workflow based on machine learning and deep learning techniques that automate the analysis of transmission electron microscopy (TEM) data. This workflow enables comprehensive characterization of materials and device architectures, with a focus on energy and environmental applications, as well as quantum materials and their associated heterostructures.

Our pioneering workflow autonomously identifies material composition, crystallographic phases, and spatial orientations across diverse regions of (S)TEM images and datasets through advanced model comparison. It also incorporates automated strain analysis, offering a detailed understanding of structural properties. The extracted data is used to generate 3D atomic and finite element models, which facilitate theoretical simulations and provide critical physical and chemical insights into device performance under real-world conditions.

This methodology is highly versatile and demonstrates strong generalization capabilities across different material systems. Beyond addressing the urgent need for automation in materials characterization, it enables the generation of accurate physical models and simulations of complex devices with unprecedented precision. [1-3]

[1] M. Botifoll, et al *Nanoscale Horiz.* 7, 1427–1477 (2022)

[2] M. Botifoll, et al *arXiv* 2411.01024 (2024)

[3] I. Pinto-Huguet, et al *arXiv* 2505.01789 (2025)

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Monday 8th September

Nanomaterials and Applications I

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Metal Nanoparticles, Clusters, Single Atom or their Combinations for Sustainable Catalysis

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Abstract:

Heterogeneous catalysts are generally based on nanoparticles, that nowadays can be synthesize with uniform size and shape. The precise structural and morphological control, coupled with the possibility to modulate the metal-support interactions, allowed us to have a step change increase in the activity. Sustainability considerations force to move from high metal loaded catalysts to low metal loaded systems, and possibly to metal free materials. (1) Single atom catalysts represent a great opportunity in this trend of maximization of specific catalytic performances (2-4). Recent debate is focused on the specific role of single site vs clusters and nanoparticles-based catalysts, with identification of cooperative effects. (5)

Acknowledgments: Financial support from European Union (projects HORIZONWIDERA-2021-ACCESS-03-01, Grant No. 101079384, and HORIZON-EIC-2023- PATHFINDEROPEN-01, Grant No. 101130717).

[1] M. Monai, et al *Adv. Catal.* 63, 1 (2018)

[2] M. Melchionna, et al *J. Am. Chem. Soc.* 147, 2275 (2025)

[3] H. Hong, et al *Science* 388, 497 (2025)

[4] Z. Xu, et al *Nature* (2025)

[5] Z. Gao, et al *J. Am. Chem. Soc*. 146, 24440 (2024)

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Advanced Optical Waveguide Design via Encapsulation of 2,4,6-Triphenylpyrylium Chloride in Oxide Glasses

Eleni Agapaki[*1], Ioannis Konidakis[1], Egor Evlyukhin[1], Klytaimnistra Katsara[1], Georgios Kenanakis[1], David King[2], Haesook Han[2], Pradip K. Bhowmik[2] and Emmanuel Stratakis[1]

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Abstract:

Pyrylium ion ($C_5H_5O^+$) based salts are known for their unique, stimuli-responsive optical properties, making them attractive for nanoscale optoelectronic applications. However, their typical solid powdered form hinders practical integration into functional devices. In this work, we introduce a low-temperature, post-melting encapsulation method to embed 2,4,6-triphenylpyrylium chloride salt into transparent phosphate glass matrices containing dispersed silver nanoparticles. This approach enables spatially controlled vitrification, forming high-refractive index optical pathways within the glass. Crucially, the pyrylium salt maintains its structural and optical integrity post encapsulation, while the silver nanoparticles enhance light transmission through scattering. The resulting composite glass exhibits strong waveguiding behaviour, demonstrating significant potential for advanced nano-engineered optoelectronic components.

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Laser-Induced Graphene: A Scalable 3D Material Advancing Proton Exchange Membrane Water Electrolysis for High-Efficiency Green Hydrogen Generation

Maria Pervolaraki[1*], Theodora Gounela[1], Sofía Luján [2], Alba Rubí [2], Bruno Branco [2], Diogo Garcia[2] and Emmanuel Stratakis[1]

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Abstract:

Among graphene-related materials (GRMs), laser-induced graphene (LIG) distinguishes itself as a multifaceted, three-dimensional porous graphene structure, fabricated through a single-step, scalable, and eco-friendly laser process. By directing a laser onto carbon-rich polymers such as polyimide under ambient conditions, LIG is formed via thermal decomposition and sp^2 carbon hybridization, generating an extensively porous network characterized by exceptional electrical conductivity, substantial surface area and mechanical flexibility. This direct laser carbonization approach allows for precise pattern creation, rapid production, and cost efficiency eliminating the need for chemical treatments.

Due to its remarkable properties and straightforward synthesis, LIG is particularly well suited for incorporation into proton exchange membrane water electrolysers (PEMWE), especially within microporous layers and as catalyst supports where increased conductivity, corrosion resistance, and engineered porosity are vital for optimal water splitting. Recent research highlights LIG's effectiveness as both an electrocatalyst and a support for oxygen and hydrogen evolution reactions, showcasing favourable kinetics and promising long-term stability. Additionally, the innate porosity and mechanical pliability of LIG enhance gas transport and electrode robustness, directly addressing fundamental performance challenges in PEMWE systems.

In conclusion, the innovative laser-based fabrication of LIG offers a promising route to elevate PEMWE technologies, paving the way for more affordable, durable, and high efficiency hydrogen production systems that are crucial for the global transition to green energy.

Acknowledgements: The GIANCE project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101119286 and UKRI under Grant Agreement No 10090645 and No 10101683.

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Monday 8th September

BRIDGE Workshop - Nanocrystals I

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Heterostructures involving Metal Halide Nanocrystals: Synthesis, Growth Mechanisms, Reactivity

Liberato Manna[1*]

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Abstract:

Halide perovskite, and metal halides in general, can merge the highly efficient operational principles of conventional inorganic semiconductors with the low-temperature solution processability of emerging organic and hybrid materials, offering a promising route towards cheaply generating electricity as well as light. Following a surge of interest in this class of materials, research on colloidal metal halide nanocrystals (NCs) has gathered momentum in the last decade. This talk will highlight several findings of our group on their synthesis, for example our recent study on the influence of various exogenous cations and of acid-based equilibria on the growth of halide perovskite NCs, which can lead to the formation of NCs with peculiar shapes (for example core-shell and hollow structures) and to NC heterostructures (for example perovskite-chalcogenide or perovskite-chalcohalide dimers) by promoting/suppressing the heterogenous nucleation of selected materials. The reactivity of these heterostructures towards exchange reactions and their potential use in catalysis will also be discussed.

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Automated Nanomaterials Engineering

Milena P. Arciniegas[1*]

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Abstract:

Semiconducting nanocrystals—celebrated by the 2023 Nobel Prize in Chemistry—are reshaping the landscape of functional materials. Among these, low-dimensional organic-inorganic metal-halide perovskites offer a uniquely tunable platform for designing efficient light emitters.

In this talk, I will present a data-driven framework for the robotic synthesis and digital exploration of layered perovskites, aimed at uncovering the molecular rules that govern their structural and optical properties. Using a robust, low-temperature protocol compatible with open-air conditions developed by our group, we have collected more than 200 distinct structural entries from a variety of organic cations guided by rational molecular parameters such as chain length and heteroatom identity, combined with solvent type. We extended this strategy to Pb-free tin-based analogues, overcoming key challenges of oxidation and instability with a novel low-temperature, air-compatible synthetic route. These structures demonstrate robust yellow-orange emission and high quantum yields, showcasing the potential for environmentally sustainable alternatives.

Our real-time data integration and analysis, which includes sorting, interactive exploration, and data graphical representation, offer new pathways for developing efficient energy-related structures and open scalable, tunable pathways for future optoelectronics and photonic technologies.

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The Effect of Non-solvent Post-Processing Induced Structural and Morphological Changes on the Optoelectronic Properties of CsPbBr3 Nanocrystals

Bapi Pradhan[1*], Irina Skvortsova[1,2], Sumea Klokic[3], Amitrajit Mukherjee[1], Alexis VillanuevaAntolí[4], Andrés F. Gualdrón-Reyes[4], Michael Paulus[5], Christian Sternemann[5], Heinz Amenitsch[3], Iván Mora Seró[4], Elke Debroye[1], Sara Bals[2], Eduard Fron[1] and Johan Hofkens[1]

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[4]*Institute of Advanced Materials (INAM), Castellón, Spain*
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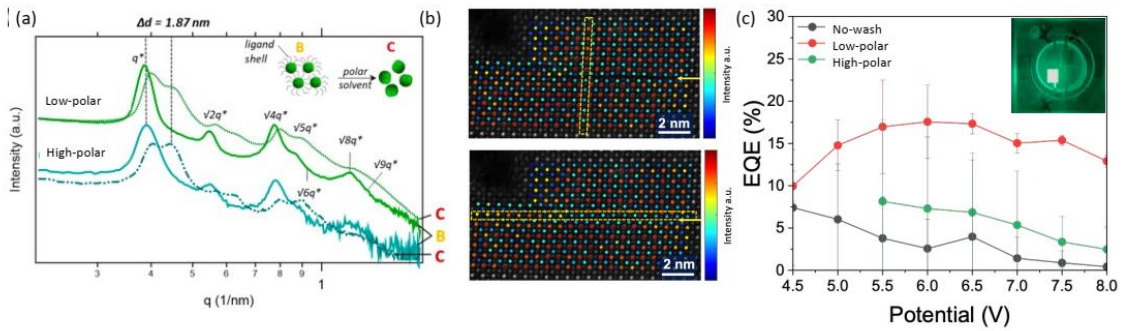
Abstract:

Significant efforts have been devoted to the optimization of the post-synthesis processing of all-inorganic colloidal $CsPbBr_3$ nanocrystals (NCs) to achieve stable and ultrapure green light emission. However, these NCs harbor a range of compositional, structural and surface defects which further undergo dynamic changes during the nonsolvent purification process. Despite recent advances, the mechanisms driving degradation during this purification process and its impact on the photophysical properties of $CsPbBr_3$ remain elusive. In this study, we investigate how non-solvent polarity influences NCs' integrity, structural defects, packing, photoluminescence blinking, and charge-carrier recombination dynamics. Using synchrotron-based in-situ small-angle X-ray scattering, we have elucidated that the evolution of ligand shell removal around the NCs at the purification stages goes through a hierarchical, turbostratically stacked assembly. Ex-situ grazing incident X-ray scattering analysis shows the atomic and nanoscale orientation ordering of the NC thin films. Transmission electron microscopy (TEM) revealed rapid disordered NCs aggregation accompanied by the planar defects for ketone washing, whereas slow aggregation with no stacking faults was evidenced for ester. Our findings suggest that ketone-processed NCs are barely illuminating in LEDs, while the ester-processed NCs demonstrate a remarkable external quantum efficiency (EQE) of ~17.6%.



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Exploring the Potential of Perovskites in Water-Based Batteries and Capacitors

K. Brintakis[1*], A. Kostopoulou[1], D. Vernardou[2] and E. Stratakis[1]

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Abstract:

Metal halide perovskites (MHPs) are rapidly gaining attention for their potential to revolutionize energy storage. This work presents three studies demonstrating their exceptional performance and stability as electrode materials in Li-air and Zn-ion batteries. We report the use of Cs4PbBr6-CsPbBr3 nanohexagons and CsPbBr3 microcubes synthesized using a simple, rapid, and low-temperature method as energy storage materials. The nanohexagons were deposited on ITO substrates and annealed to enhance stability, while the microcubes were grown directly on the same substrates. The nanocubes were conjugated with reduced graphene oxide (rGO) sheets to increase the stability and the conductivity of the perovskites. These structures were used to create anode electrodes for Li-air batteries and Zn-ion capacitors, exhibiting high specific capacity, superior stability, and excellent performance.
The Cs4PbBr6-CsPbBr3 nanohexagon electrodes, investigated in an aqueous Li-based electrolyte, showed a specific discharge capacity of 377 mAhg-1 and high electrochemical stability for 40 consecutive scans [1]. In contrast, the CsPbBr3 microcube-based electrodes achieved a specific capacity of 549 mAhg-1 and maintained superior operational durability for up to 1500 cycles [2]. For Zn-ion capacitors, the nanocube-based electrodes showed a specific capacitance of 107 Fg-1 with 100% capacitance retention after 100 continuous cycles [3]. The high surface area and flexibility of the rGO sheets allowed for the conjugation of individual metal halide perovskite nanocrystals, resulting in new synergetic functionalities. The use of an aqueous electrolyte in these studies offers advantages in terms of cost, safety, and environmental friendliness.
These studies demonstrate the potential of MHPs perovskites as electrode materials in energy storage applications. The synthesis method, coupled with the remarkable electrochemical properties, makes them promising candidates for next-generation energy storage devices.

[1] A. Kostopoulou et al. *Nanoscale* 11, 882–889 (2019)

[2] A. Kostopoulou et al. *J. Power Sources Adv.*3, 100015 (2020)

[3] A. Kostopoulou et al. *Nanoscale*, 16, 6455–6463 (2024)

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In-Depth TEM Characterization of Selective Area Epitaxy Zn_3P_2 Nanopyramids and Thin Films Grown via MOCVD

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In a world where the need for clean energy is higher than ever, zinc phosphide (Zn_3P_2) has been proposed as an alternative semiconductor for the realization of thin and flexible solar cells. Thanks to its favourable optoelectronic properties, which include the quasi-optimal direct bandgap and long carrier diffusion lengths, theoretical studies and simulations have shown the potentialities of Zn_3P_2 in terms of PCE [1]. Moreover, its earth-abundance can support the development of a sustainable technology and ultimately reduce the impact on global warming [2]. Recently, the limitations related to its growth process have been successfully mitigated by utilizing selective area epitaxy for the production of Zn_3P_2 nanopyramids and thin films. In fact, restricting the growth area inhibits the formation of defects at the interface with the substrate, favouring high quality single crystal epitaxy once the material outgrows the mask openings. Moreover, it was shown for the growth via MBE that, by controlling the growth conditions and the size of the mask openings, the composition can be varied substantially while maintaining the same crystal structure [3,4].

Herein, we perform a complete scanning transmission electron microscopy (STEM) characterization of SAE Zn_3P_2 nanopyramids and thin films grown via MOCVD. The study covers the structural and compositional analysis of the as grown structures and highlights the main differences and similarities with their counterparts grown via MBE. In the specific, geometrical phase analysis (GPA), supported by simulation-based results, evidences the absence of misfit dislocations and other types of interface defects, similar to the material grown via MBE. Moreover, as reported for the MBE case study, we show the presence of rotated domain for a series of samples characterized by different growth parameters. The information retrieved from the power spectrum analysis, confirms their origin mechanism and settle their stochastic nature. Next, using EDX analysis we determine the exact composition of both the Zn_3P_2 nanopyramids and thin films grown at different temperatures and phosphine (PH_3) to diethyl zinc (DEZn) ratios (V/II ratios). Any off-stoichiometric composition is related to the growth conditions and mask holes size together with the appearance of defects within the crystal. Finally, this study successfully indicates the optimal growth parameters of Zn_3P_2, thus helping enhance its applicability in solar cells.

[1] *Mater. Adv.* 3, 1295-1303 (2022)
[2] *Nanoscale Adv.* 3, 326–332 (2021)
[3] *Nanoscale Horizons 5*, 274-282 (2020); [4] *Nanoscale* 12, 22534-22540 (2020)

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Monday 8th September

Nanomaterials Applications II

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Two-Dimensional Metal Halide Perovskite Microcrystals: Heterostructures, Optical Properties and Photonic Functionality

Martina Borreani[1], Mehrdad Faraji[1], Sudhir Saini[1], Alexander Schleusener[1], Lin-Han Li[2], Miao-Ling Lin[2], Ping-Heng Tan[2], and Roman Krahne[1*]

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Abstract:

Metal-halide perovskites (MHP) emerged as highly interesting materials for photovoltaics and light emission with highly competitive efficiencies.[1] Lowdimensional MHP, where semiconductor octahedra are sandwiched in between organic molecules, feature several highly attractive properties: (i) strong quantum and dielectric confinement, and therefore strongly bound excitons; (ii) a huge parameter space to design their composition, providing an extensive toolbox to tailor their structural, mechanical, and optoelectronic properties.[2] While 2D-MHP thin films have been successfully implemented in LEDs and solar cells, developing high quality single crystals for photonics is another very promising direction. Single crystals allow for a distinct correlation of their optical properties to their structural properties, thereby providing deep insight into their exciton level structure, electron-phonon coupling, and relaxation dynamics. [3-6]

We have developed a microcrystal growth process based on dissolution and recrystallization that allows to fabricate 2D-MHP microcrystals with rectangular shape and highly homogeneous thickness in the few 100 or sub-100 nm range. [7] The tunable band gap and high refractive index renders such microcrystals extremely promising for photonics and polaritonics. Recently, we extended the microcrystal fabrication to heterostructures, [7, 8] either by solution-based anion exchange, or by sequential growth of different phases (for example with different halides) in a single microcrystal, in core-shell or core frame geometries.

[1] H. Dong, et al., *eLight* 3, 3, (2023)

[2] L. Mao, et al., *J. Am. Chem. Soc.* 141, 1171 (2019)

[3] R. Krahne, et al., *Nano Lett.* 24, 11124 (2024)

[4] R. Krahne, et al., *Acc. Chem. Res.* 57, 2476 (2024)

[5] S. Kutkan, et al., *Nanoscale* 15,12880 (2023)

[6] B. Dhanabalan, et al., *Adv. Mater.* 33, 2008004 (2021)

[7] A. Schleusener, et al., *Adv. Mater.* 36, 2402924 (2024)

[8] A. Griesi, et al., *Nanotechn.* 35, 105204 (2024)

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High Pressure, Light, and Biofunctionality: Toward a New Platform for Materials Research at Extreme Conditions at IESL-FORTH

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Abstract:

High-pressure (HP) science offers unique opportunities for synthesizing novel materials and exploring reaction pathways that remain inaccessible under ambient conditions. By applying extreme pressures, the physical and chemical properties of materials can be dramatically altered, enabling the formation of new phases, changes in bonding, and enhanced reactivity. These conditions enable researchers to probe fundamental transformations and initiate reactions that facilitate the development of innovative material functionalities. Several examples from previous work on HP synthesis of biocompatible polymers [1, 2] and functional nanocomposites [3], as well as X-ray induced photochemistry [4, 5], are presented. These studies demonstrate how pressure and light can synergistically guide the formation of complex, functional materials with biomedical and photonic applications. Furthermore, the establishment of a new laboratory infrastructure for extreme-conditions materials research at the Institute of Electronic Structure and Laser of the Foundation for Research and Technology–Hellas (IESL-FORTH) is highlighted. It is now fully operational and aims to become a hub for advanced investigations of light–matter interaction, in situ synthesis, and real-time probing of matter under extreme conditions. Finally, the vision for future research at the new HP platform at IESL-FORTH is outlined.

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NanoBio
International Conference on Nanotechnologies and Bionanoscience

Enabling Atomic-Scale Imaging of Fragile Materials through Dose Efficient Ptychography

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Abstract:

Many nanomaterials, including hybrid perovskites such as $MAPbI_3$ and $FAPbI_3$ [1], exhibit exceptional optoelectronic and structural properties but are inherently sensitive to electron beam exposure. This beam sensitivity presents a significant barrier to atomic-scale characterization, especially using high-resolution transmission electron microscopy (TEM).
Given these challenges, dose-efficient imaging techniques have become essential for studying sensitive materials. Among them, scanning transmission electron microscopy (STEM)-based methods particularly electron ptychography have shown great promise. Electron ptychography is a coherent diffractive imaging (CDI) technique that enables reconstruction of a specimen's projected potential by retrieving the phase shifts of the electron beam before and after it interacts with the sample. This method provides high sensitivity even at low electron doses. Its practical application has been made possible by advances in direct electron detectors, especially event-driven models based on the Timepix3 chip [2], which play a crucial role in data acquisition for such delicate systems.
To explore the suitability of ptychographic imaging for beam-sensitive materials, we investigated thin $MAPbI_3$ specimens (~2.5 nm in thickness) under low-dose conditions (~50 $e^-/Å^2$). The study revealed that accurate structural reconstructions could be achieved with carefully optimized external parameters in the ptychographic reconstructions, emphasizing the critical balance between algorithmic stability and reconstruction fidelity, especially under constrained dose budgets.
Simulations and experimental reconstructions alike demonstrate that these beamsensitive materials require not only low-dose imaging conditions, but also data processing strategies tuned to prevent noise amplification and artefactual solutions, resulting from local minima in the optimization problem.

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NIR-emitting Electrochromic Windows with Red and Green Emission

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Abstract:

The electrochromic (EC) effect involves reversible changes in optical properties, such as transmittance and reflectance, induced by application of a specific electric voltage. In recent years, electrochromic devices (ECDs) have gained widespread application across various technologies, including smart windows and energy storage systems. These devices represent a promising solution for addressing the energy crisis and tackling environmental pollution, contributing to advancing energy-efficient technologies.

Hybrid electrolytes composed of acrylate/ionosilica (AC/IS) doped with anionic Eu^{3+}, Tb^{3+}, and Er^{3+}complexes, which are known to emit in the red, green, and NIR regions, respectively, have been synthesized by the sol-gel method. This study aimed at evaluating the performance of a glass-based ECD incorporating the AC/IS-EuTbEr electrolyte. Additionally, for comparative purposes, ECDs based on AC/IS-Er and non-doped AC/IS were used. Studies of the effect of the scan rate on the current and electrochemical impedance spectroscopy were carried out. The ECD@AC/IS-EuTbEr exhibited excellent overall performance with high transmittance modulation (46.1/47.3 % at 555/1200 nm), fast switching speeds (bleaching: 5 s and coloration: 2 s), and high coloration efficiency (-CEin: 1873/2489 and CEout: 1909/2537 cm2 C-1 for 555/1200 nm, respectively, 425th chronoamperometry cycle for ±2.5 V) with superior cycling stability. Transmittance decayed by approximately 40 % within 10 days. The ultimate goal of this work is to fabricate analog ECDs using polycarbonate (PC) substrates.

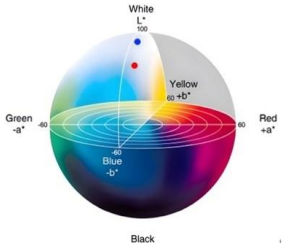

Fig.1. *CIE L*a*b* color coordinates of ECD@AC/IS-EuTbEr in the colored (-2.5 V, red) and bleached (+2.5 V, blue) states*

Acknowledgements: CQ-VR: UIDB/00616/2020 e UIDP/00616/2020. A-MoVeR-"Mobilizing Agenda for the Development of Products & Systems towards an Intelligent and Green Mobility", operation n.º 02/C05-i01.01/2022.PC646908627-00000069, financed by European funds provided to Portugal by the Recovery and Resilience Plan (RRP), in the scope of the European Recovery and Resilience Facility (RRF), framed in the Next Generation UE, for the period from 2021-2026.

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Defects that Magnetize: Quantum Control of Spins in $PtSe_2$ and Heterostructures

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Abstract:

Monolayer $PtSe_2$ is a prime example for defect engineering in transition-metal dichalcogenides–in its pristine form it is non-magnetic while the creation of a Pt vacancy leads to the occurrence of localized magnetic moments in the surrounding Se atoms [1,2]. This expands $PtSe_2$ applicability to fields such as quantum computing and spintronics. Large-scale fabrication techniques such as 3D printing result in few-layer devices for which the interplay between structure and magnetism is underexplored. Previous studies indicated the quenching of magnetic moments for individual point defects when the thickness increases [3]. However, until now, the impact of complex defects on the magnetism in $PtSe_2$ thin films is unclear. Here, we use a synergistic approach that includes low-voltage aberration-corrected scanning transmission electron microscopy (STEM) and density functional theory calculations to unveil the effect of realistic complex defects. Different types of defects were distinguished during the imaging and guided the ab initio calculations. The most characteristic defect was a complex defect that includes a Pt vacancy and a neighboring PtSe antisite, which can be attributed either to the exfoliation procedure or to the beam irradiation due to the convergent electron beam in STEM imaging. This defect leads to a semiconducting-tometallic transition with either a ferromagnetic (FM) or a non-magnetic spin state, depending on the surrounding environment and the presence of further Se vacancies. The FM state increases the number of magnetic moments, providing an indirect way to recover the quenching that occurs due to the interlayer interaction when the thickness increases [4].

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[2] A. Avsar et al., *Nature Communications* 11, (2020)

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NanoBio
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Monday 8th September

Bioelectronics I

NanoBio
International Conference on Nanotechnologies and Bionanoscience

Synthetic and Bioderived Electroactive 3D Architectures Enabling Smart Wound Care and Therapeutic Intervention

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Abstract:

Conducting polymers (CPs) and hydrogel architectures are converging into a new generation of intelligent, on-skin devices that can simultaneously treat and monitor tissue pathologies. Here, we present a drug-loaded CP/MXene composite scaffold whose antibiotic release is composition-dependent. By adjusting the MXene content, we finely tune release kinetics and achieve targeted intervention at both early and late stages of bacterial proliferation. The scaffold's intrinsic conductivity further enables real-time electrochemical tracking of bacterial respiration, turning it into a high-throughput sensing platform for probing scaffold–microbe interactions. Extending the concept to softer matrices, we have engineered stretchable, adhesive, and self-healing CP composite hydrogels that combine high conductivity with pH- and glucose-responsiveness. In vitro scratch assays confirm that these hydrogels accelerate wound closure, underscoring their potential for advanced wound management. Finally, we introduce an eco-friendly scaffold derived from the marine tunicate; Phallusia nigra. Its nanocellulosic–protein framework is patterned with octopus-derived conductive nano-ink, yielding a 3D tunicin architecture that is fabricated by a simple, shape-retentive process and remains mechanically stable under physiological conditions. Animal studies show markedly fast epithelialization and wound closure on par with standard dressings, highlighting the clinical promise of marine biopolymers. All together, these three platforms, porous CP/MXene scaffolds, multifunctional hydrogels, and renewable tunicin matrices, form a modular toolbox for creating responsive, antimicrobial, and sensing-enabled wound patches that shift the paradigm from passive coverage to dynamic, feedback-driven therapy.

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Natural Lignocellulose Scaffolds for Sustainable Electronics

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Abstract:

The pursuit of *Responsible Electronics* is driven by the urgent need to reduce the ecological footprint of electronic devices - across material sourcing, manufacturing, and operational phases. This imperative has become increasingly critical in the age of IoT (Internet of Things), where printed and flexible electronics are rapidly entering the mainstream. A key challenge lies in developing novel substrate materials that not only emulate the mechanical, optical, and chemical properties of conventional materials such as glass and plastic films but also offer biodegradability and sustainable manufacturability.

Meeting this demanding set of criteria has long been considered a formidable challenge. However, at the Institute for Applied Physics, TU Dresden, we have made significant strides toward this goal through the development of a new paradigm: Leaftronics.

Leaftronics leverages the natural quasi-fractal vascular structures of green leaves as a reinforcing and sequestering matrix for solution-processable biodegradable polymers. This bio-integrated approach results in substrates that are over 85% transparent, flexible, and exhibit excellent thermal and mechanical stability [1]. With surface roughness below 4 nm (RMS), these substrates are compatible with cutting-edge thin-film electronic technologies - including OLEDs, OPDs, and both printed and soldered circuitry.

First introduced to an international audience at NanoBio 2023, Leaftronics has since evolved significantly, expanding into applications such as water purification [2], biodegradable pressure sensors [3] and biodegradable thin-film battery technology. At NanoBio 2025, we will present the latest developments in this field, highlighting how nature-inspired, resource-efficient materials can offer viable solutions to complex technological challenges.

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NanoBio
International Conference on Nanotechnologies and Bionanoscience

On-fiber Printed Polymeric Tapers for Chronically Implantable Neural Interfaces

Stella Aslanoglou [1*], Barbara Spagnolo [1], Cinzia Montinaro [1], Alberto Perna [2], João F. Ribeiro [2], Claudia Latte Bovio [1], Marco Pisanello [3], Luca Berdondini [2], Tommaso Fellin [2], Ferruccio Pisanello [1,†], Massimo De Vittorio [1,4,5,†]

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Abstract:

To capture the dynamics of brain activity, the neuroscience community requires the use of bidirectional neural probes able to monitor and modulate neural signals simultaneously at the cellular level [1]. Among them, tapered fibers (TFs) have emerged as a promising tool for delivering light and collecting fluorescence to and from the brain tissue with high spatial resolution. Compared to their flat-cleaved counterparts, TFs are less invasive for the brain tissue and offer controlled light emission along the taper. Moreover, TFs can be patterned to control the modal content and host electric elements for optogenetic stimulation, fiber photometry and electrophysiological recordings [2]. However, silica TFs induce inflammation and neuronal death, when applied in chronic settings, due to the mechanical mismatch in place [3]. This adverse immune response could be minimized by replacing silica with a polymeric material. To this aim, here, we demonstrate a method for the fabrication of soft and flexible polymeric air-clad tapers using two-photon polymerization. This versatile fabrication approach enables the realization of 3D structures of arbitrary shape with sub-diffraction limit resolution. In particular, we used IP-PDMS photoresin, to print 3D tapers on top of polished multimode fiber facets. Polymeric tapers were then characterized in terms of light delivery performance *in vitro*. Using an angle-selective injection system, we demonstrated that polymeric tapers exhibit spatially resolved illumination; a favourable feature for optogenetic applications. We further investigated their prospective use in fiber photometry by characterizing their light collection properties *in vitro* and *ex vivo*. Additionally, we evaluated their impact on mechanically induced trauma by performing insertion force measurements using phantom brains. Our results suggest that IP-PDMS tapers hold great promise as chronically implantable neural probes (**Fig.1**).

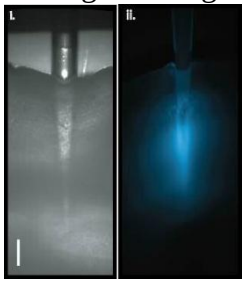

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Figure 1: *Polymeric taper implanted into a fixed mouse brain slice.*

NanoBio
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Monday 8th September

Bioelectronics II

NanoBio
International Conference on Nanotechnologies and Bionanoscience

Point of Care Devices for the Early Diagnosis of Brain Stroke in the Ambulance and at the Triage Emergency units: the POC4Triage Project's Biosensor

Giulio Rosati[1*], Alejandra Ben Aissa Soler[1], Ramon Santiago Herrera Rastrepo[1], Ellen Yadira Cotrina Celis[1], Robert S. Marks[2,3] and Ana Moya Lara[1]

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Abstract:

Brain stroke is a medical condition that can lead to severe consequences if not treated promptly. Although several interventions are available after diagnosis, their effectiveness is highly dependent on how much time has passed since the onset of symptoms. Currently, diagnosis typically occurs only after hospital arrival, and not all facilities are equipped with specialized stroke units, which often leads to patient transfers and further delays.
The POC4Triage project aims to provide four technologies to enable early diagnosis of stroke, both in ambulances and in hospital triage units. One of these four devices is an immunosensor designed to detect a key biomarker associated with stroke. In this work, we present the structure of the device and some preliminary results.
The device is developed using a hybrid approach that combines inkjet printing and screen-printing techniques with lab-on-a-chip technology, resulting in a complex yet scalable system supported by dedicated, customized, and portable electronics.

NanoBio
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A Scalable Approach for Integrating Microelectronics on Tapered Optical Fiber-Based Neural Interfaces

Claudia Latte Bovio[1,*], Stella Aslanoglou[1], Barbara Spagnolo[1], Vincenzo Mariano, Mastronardi[1,2], Sneha Pottekkad[1,2] , Ferruccio Pisanello[1,2,+] , Massimo de Vittorio[1,2,3,]

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Abstract:

The development of high-resolution organic electrochemical transistors (OECTs) on flexible fiber substrates opens new avenues for advanced neural interfaces and implantable bioelectronics. [1,2] Achieving precise microscale patterning of functional materials on curved, compliant geometries requires novel bioprinting approaches and carefully formulated bioinks. In this work, we investigate the use of High-Precision Capillary Printing (HPCP), a next-generation inkjet-like technique that exploits capillary forces for additive manufacturing with sub-micrometer resolution. This method enables the direct deposition of functional and biocompatible materials onto both flat surfaces and tapered optical fibers, addressing the major challenge of maintaining pattern fidelity on non-planar, curved substrates. A conductive ink based on PEDOT:PSS was developed and optimized for HPCP, widely used for its stability and mixed ionic-electronic conductivity. Each formulation was tailored to achieve optimal viscosity, surface tension, and wettability to ensure consistent droplet formation and controlled spreading during deposition. PEDOT:PSS inks yielded conductive films with uniform morphology and reliable electrical performance. These properties are critical for the fabrication of high-performance OECTs directly on fiber substrates, where mechanical flexibility and miniaturization are essential. [4,5] Our results demonstrate that capillary-driven printing, combined with rational ink formulation, enables the scalable fabrication of fiber-integrated OECTs with high spatial fidelity. The ability to pattern materials accurately on both planar and tapered fiber geometries significantly expands the versatility of this approach, paving the way for next-generation implantable neural probes and bioelectronic devices.

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NanoBio
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Monday 8th September

Bio-nanomaterials I

NanoBio
International Conference on Nanotechnologies and Bionanoscience

Single-Cell Nanoencapsulation: Past, Present, and Future

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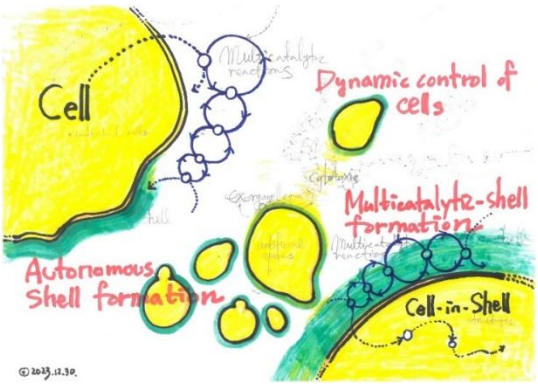
Abstract:

Nature has devised a remarkable strategy known as cryptobiosis to survive under stressful and often lethal environmental conditions. For instance, certain bacteria undergo sporulation, transitioning from a metabolically active vegetative state to an ametabolic endospore state. Encased within resilient biomolecular shells, the spores can withstand extreme stressors, such as radiation, desiccation, and nutrient deprivation, for prolonged periods. They return to their vegetative state by breaking apart the cytoprotective shells, when conditions become favorable. Inspired by cryptobiosis, researchers have developed a chemical approach called single-cell nanoencapsulation (SCNE), in which individual living cells are confined cytocompatibly within ultrathin (< 100 nm), tough shells in three-dimensional space. The created artificial spores provide cytoprotection, regulate the metabolic behaviors of non-spore-forming cells, and enhance their resilience to adverse conditions. Since its introduction in 2013, the field of SCNE has advanced rapidly and recently entered its second stage of development. In this phase, artificial shells not only protect cells from external stressors but also actively augment and complement innate cellular metabolism and functions. This talk provides a concise overview of the past, present, and future of SCNE.



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Nanomaterials as Antimicrobial Agents

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Abstract:

There is an urgent need to tackle antimicrobial resistance because this is a significant threat for the global health and costs billions of dollars per year. Common strategies to overcome bacteria resistance, related to antibiotics, involve the discovery of new antibiotics, which utilize different mechanisms to minimize the development of resistance. However, the research for the discovery of new molecules that can effectively tackle the most resistant bacteria, is quite challenging and slow, which may prove inefficient in years to come. Nowadays, there are types of bacteria that they have developed resistance even to our most powerful antibiotics such as vancomycin. Therefore, alternative strategies to tackle bacteria resistance is necessary.
Research on the use of different types of nanomaterials to tackle antimicrobial resistance is highly active and promising. For example, nanoparticles of different types (e.g. copper oxide, gold, zinc oxide and silver) are investigated. The reason is that nanoparticles utilize multiple ways and mechanisms to kill bacteria, which can be complementary to the mechanisms followed by common antibiotics. Nanoparticle efficacy is strongly correlated to their size and surface coating making the customization of nanomaterials' synthetic routes critical to combat antimicrobial resistance.
In this presentation I will discuss our current research developments in the synthesis and use of nanomaterials to fight against a range of bacteria (1-4).

[1] I. Cook, et al. *Submitted* (2025)

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Electrospun Biopolymeric Nanofiber Systems for the Local Delivery of Natural Extracts: A Novel Approach for Oral Infections

Magdalena Paczkowska-Walendowska[1*], Judyta Cielecka-Piontek[1]

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Abstract:

Electrospinning is emerging as a versatile and promising method for designing advanced local drug delivery systems based on natural bioactive compounds [1]. Our research focuses on the development of electrospun nanofiber scaffolds incorporating plant-derived extracts with proven antimicrobial, anti-inflammatory, and antioxidant properties, such as *Scutellariae baicalensis*, *Centella asiatica* and *Punica granatum* [2]. These natural substances were successfully embedded in biocompatible polymer matrices, including chitosan, PCL, PVP and HPβCD, forming mucoadhesive and wound-healing structures tailored for oral applications.

The physicochemical characterization, drug release kinetics, and bioactivity assessments revealed enhanced and controlled solubility, and biological efficacy of the encapsulated extracts. Special emphasis was placed on optimizing the formulation process via the Design of Experiments (DoE) approach to ensure reproducibility and efficiency. The developed systems demonstrated significant potential in managing oral infections (e.g., periodontitis) and supporting wound healing, highlighting their clinical relevance as alternative, nature-based therapeutics.

Our findings underline the synergy between nanotechnology and phytotherapy, paving the way for innovative, targeted, and patient-friendly therapies in localized drug delivery.

Acknowledgement: This research was funded by the National Science Center (Poland), under the Sonata grant (number 2020/39/D/NZ7/01824).

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NanoBio
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Tuesday 9th September

Nanophotonics

NanoBio
International Conference on Nanotechnologies and Bionanoscience

Resonant Light Trapping in Nanoparticle Structures via Electromagnetic Coupling

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Abstract:

The possibility of concentrating strong light fields on the subwavelength scale is of great importance for their use in biological research. In this work, we demonstrate and discuss multipole mechanisms of the light energy concentration in metasurfaces composed of dielectric or hybrid nanoparticles supporting the electric and magnetic optical resonances. First, a general strategy for the realization of electric and magnetic symmetry-protected bound states in the continuum (s-BIC) located at the same spectral position is presented [1]. This strategy's application makes it possible to design metasurfaces allowing switching between the electric and magnetic quasi-BIC modes by changing the polarization of the incident light wave. Such polarization switching provides possibilities to change and control the localization and distribution of strong optical energy at the subwavelength scale. Then a general multipole mechanism of the resonant mode trapping effect in metasurfaces composed of isotropic disk-shaped nanoparticles is demonstrated. Its implementation does not require any special irradiation conditions for the incident light or geometrical distortion of the symmetry of the periodic structures. It is shown that the trapping effect leads to a strong concentration of light energy in the plane of the metasurface under the condition of its complete transparency (induced transparency) [2]. The mechanism of realization of random BIC (a-BIC) in symmetric metasurfaces is also discussed. Excitation of quasia-BIC leads to high-quality resonances in the reflection-transmission spectra of metasurfaces and leads to a strong concentration of energy on the subwavelength scale [3].

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NanoBio
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Multiphoton Lithography for Active 3D Micro-Optics

Mangirdas Malinauskas[1*], Artūr Harnik[1], Robertas Virkėtis[2], Dominykas Dapšys[1], Dimitra Ladika[1], Simas Šakirzanovas[2], and Greta Merkininkaitė[2]

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Abstract:

This talk will be dedicated to multiphoton lithography as an enabling technique for nanostructuring of active 3D microoptics [1,2]. Recently, this advanced laser additive manufacturing technique gained more attention due to its capacity to be combined with high-temperature post-treatment processes, which enables the production of inorganic substances at the nanoscale and true 3D architectures. Such advances allow the creation of high laser-induced damage threshold (LIDT) and low optical losses microoptical and nanophotonics components for diverse applications [3], examples shown in Fig. 1. This, in turn, opens new avenues for realizing customized devices based on optically active technical-grade materials. For instance, YAG:Ce^{3+} as a promising candidate for 3D luminescent functional structures will be highlighted in this presentation [4].

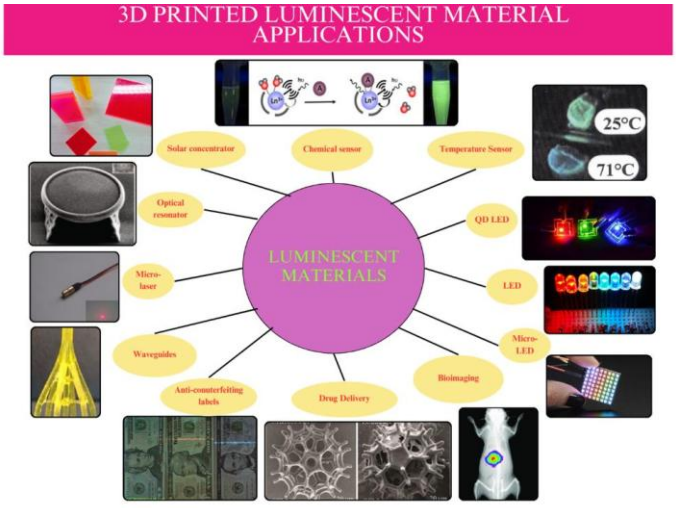

Figure 1. Perspective applications for 3D micro-/nano-printed luminescent materials [2].

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[2] A. Harnik, et al. *Adv. Opt. Mater*., 2500316 (2025)

[3] D. Astrauskytė, et al., to be submitted.

[4] G. Merkininkaitė, et al., in preparation

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Chiral Propagation of Plasmon Polaritons in Twisted Anisotropic Photonic Heterostructures

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Abstract:

Chirality, which refers to the breaking of mirror symmetries, is a fundamental concept. It plays a critical role in nanophotonics by governing selective light– matter interactions, and in biology by underpinning molecular recognition and function. While significant attention has been given to the chiral propagation of polaritons, such as chiral shear phonon polaritons [1– 3], we demonstrate that plasmon polaritons offer more accessible and tunable control over chirality [4]. In this presentation, we explore chiral propagation of plasmon polaritons created in an anisotropic two-dimensional (2D) material, twisted with respect to an anisotropic substrate, to best exploit the competition between anisotropic electron-electron interactions and the anisotropic electronic structure of the host material. By regulating the Fermi level or the twist angle, these new chiral plasmon polaritons demonstrated here can be efficiently controlled, thus resolving present challenges and restrictions of chiral phonon polarizers.
Our findings open feasible opportunities for efficient, tunable nanophotonic platforms and chiral bio-nanosensors, offering a new pathway toward integrative technologies at the intersection of photonics and biology.

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[2] *Nature Nanotechnology* 18, 64 (2023)

[3] *Nature Communications* 14, 5240 (2023)

[4] *Nano Letters* 24, 15745 (2024)

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Deterministic Aperiodic Metasurfaces as Plasmonic Platforms for Polaritonic Systems

Marzia Ferrera[1*], Vincenzo Aglieri[1], Xin Jin[1], Thomas Girardet[1], Jacopo Stefano Pelli Cresi[1], Elena Ghidorsi[1,2], Maria Ashraf[1,2], Muhammad Sohaib[1,2], and Andrea Toma[1*]

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Abstract:

Many key processes in nature and technology are driven by light-matter interaction. While typically weak, the coupling between photons and matter excitations (e.g. excitons, phonons, etc.) can be properly controlled to fundamentally alter the photophysical properties of materials. In particular, when the light-matter energy exchange rate becomes faster than any other relaxation pathway, the system can enter the strong-coupling regime and composite light-matter quasiparticles referred to as polaritons emerge in the hybrid architecture [1]. The inherent light-matter duality of polaritonic systems makes them extremely promising into the realms of chemistry, photonics and quantum technologies. Within the polariton panorama, the research and development of polaritonic devices in which quantum emitters, such as dye molecules and low-dimensional semiconductors, are integrated with plasmonic architectures to form plexcitons is at the cutting edge of nanophotonics [2].
Within this context, this contribution focuses on the potential offered by deterministic aperiodic metasurfaces integrated with quantum emitters to realize plexcitonic systems with tailored properties. In particular, the use of ordered nanohole arrays sustaining collective resonances will be discussed [3], addressing close attention towards nanohole arrangement without periodic translational order [4]. It will be demonstrated how these systems can provide additional degrees of freedom in the design of the plasmonic component to realize strongly coupled hybrid devices that go beyond crystal-like systems.

Acknowledgments: This work is part of the REPLY project that received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 101002422). X. J. and A. T. acknowledge support from the European Union's Horizon Europe Research and Innovation program under the Marie Skłodowska-Curie grant agreement No. 101105312 (DELATOP).

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Single Glass and Polymer Coated Microwire Photoactuators with Instant Response Times and Large Actuating Angles

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Abstract:

Over the years significant scientific attention has been given towards the design of advanced photoactuating architectures as they are important elements for various optical tweezers, grippers, and soft robot applications. Most of the currently available photoactuators, rely on the existence of a free-space illumination pathway from the light sources to the device or on the employment of bendable optical fibers, while consisting of two or more elements, i.e. the photoactuating material and the substrate. Herein, we report on a facile method of preparing single-component pristine microwires (MWs) that exhibit photoactuating features upon utilizing a soft phosphate glass doped with silver nanoparticles (AgNPs), without the need of any additional photoactuating element [1]. The developed photoactuators exhibited bending angles of around 110◦, within a couple of seconds. In addition, we have fabricated double-component polymercoated phosphate glass MWs photoactuators, upon employing PDMS coatings on the surface of the so-formed glass MWs. The introduction of the polymer component boosts the bending angle of the photoactuating device to over 200◦ within the a few seconds upon modest laser irradiation [1]. The presence of AgNPs within the glass MWs, play a key role on the remarkable performance of the developed photoactuators, both in terms of actuating angles as well as of the respective response times, since they assist on the effective transmission of laser irradiation energy to thermal energy. The fabrication method reported here appears promising for the development of highperformance and low-cost free-space, as well as fiber-based photoactuators.

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Tuesday 9th September

BRIDGE Workshop - Nanomaterials Applications III

NanoBio
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Organic Hydrogen Sensors for the Future Hydrogen Industries

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Abstract:

Hydrogen is an abundant and clean energy source that can help decarbonize sectors of the global economy that are difficult to electrify. However, its safe deployment relies on reliable and affordable hydrogen detection technologies. Unfortunately, most existing hydrogen detectors are expensive and consume high power, limiting their wider use, especially in emerging applications. In this talk, I will discuss the development of a novel hydrogen sensor based on organic semiconducting materials that can operate across a wide range of temperatures and humidity. I will describe the novel sensing mechanism these sensors rely on and the prospects for further developments through new materials and device concepts. The new lightweight and flexible sensors exhibit high responsivity, ultra-low power consumption, and record-short response times. Compared to commercial hydrogen detector technologies, our printed sensors demonstrate superior performance in various real-world sensing scenarios, making them suitable for use in distributed sensing networks for early warning of hydrogen leaks and prevention of potential explosions or fires.

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Making Sense of Gas Sensing Through Analytical Validation

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Abstract:

Gas sensing represents an engineering discipline that covers an extensive range of complexity, from the capture of simple inorganic molecules to the detection of multiple volatile organic compounds (VOCs). Concomitantly, it encompasses innumerable applications, spanning air quality surveillance to process monitoring in manufacturing. Moreover, the use of sensor arrays for VOC profiling has emerged as a promising alternative to complex analytical instrumentation in many areas of research, from food quality assessments, e.g., via spoilage markers [1], to health diagnostics, e.g., through non-invasive breath analysis [2]. Despite this potential, however, the detection of individual or sets of compounds within a rich mixture of VOCs remains a challenge. Although sensor systems are pitched to ultimately replace laboratory-based analytical instruments, that latter can provide essential support in achieving this goal through analytical validation of sensor performances.
Two analytical technologies that are established in the conventional detection of VOCs are gas chromatography-mass spectrometry (GC-MS) and proton transfer reaction mass spectrometry (PTR-MS), with both deployed in manifold research areas, including food science, atmospheric chemistry, and medicine. Both technologies have specific strengths in detecting VOCs, and these can be exploited to support gas sensing developments for molecule detection. On the one hand, untargeted analysis via GC-MS provides a comprehensive elucidation of the volatile composition of (gas) samples that can facilitate the identification of individual marker compounds of interest for sensing applications. On the other hand, the online analytical capability of PTR-MS complements GC-MS analysis to allow dynamic processes to be characterized and thus enable testing and validation of gas sensing systems for subsequent *in situ* deployment.
This talk will cover VOC detection and address how established analytical tools can be utilized to support sensor development and validation.

[1] P.C. Wanniarachchi et al. *Food Chem.* 436, 137733 (2024)

[2] A.T. Güntner et al. *ACS Sensors* 4, 268-280 (2019)

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Optimizing a Perovskite-Based Gas Sensor: Sensitivity, Stability and Selectivity

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Abstract:

Metal halide perovskites (MHPs) are attracting significant attention for gas detection technologies due to their simple manufacturing and unique optoelectronic properties. Their electrical and optical characteristics change reversibly in oxidizing or reducing environments, making them ideal sensing materials. However, despite recent progress, the fundamental mechanisms of perovskite-gas interactions, which are vital for optimizing sensor performance, are not fully understood.

This research provides a comprehensive evaluation of the sensing performance and long-term stability of MHPs by examining key factors like crystal morphology [1,2], halide composition, and doping [3]. For instance, by synthesizing both well-defined and more rounded microcubes of $CsPbBr_3$, we found that rounded cube-shaped crystals (RC) exhibit superior gas sensing capabilities. These RC-based sensors demonstrated an exceptional response, detecting ozone concentrations as low as 4 ppb with fast response and recovery times. We also discovered that mixed-halide perovskites, created by substituting bromide with chloride, show greater long-term stability, while doping with manganese (Mn) significantly enhances the sensing response by facilitating gas adsorption, a finding supported by both atomistic simulations and experimental results. Long-term evaluation of these sensors offers valuable insights into their dynamic instabilities and evolving performance, representing a significant step toward engineering low-cost, high-performing, and durable room-temperature gas sensors.

However, a major challenge hindering the widespread adoption of these materials is the toxicity of lead. To address this, we explored the potential of the lead-free double perovskite $Cs_2AgBiBr_6$ as an alternative sensing element [4]. This eco-friendly sensor is synthesized at room temperature without harmful organic solvents and operates at a very low voltage (0.1 V), minimizing energy consumption. Crucially, it demonstrates high selectivity for ozone over other gases, establishing it as a viable, safer alternative for next-generation sensor technology.

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[2] K. Brintakis et al. *Nanoscale Advances* 1, 2699-2706 (2019)

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2D Material-Based Photodetectors for Near-to-Far-Infrared Applications

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Abstract:

Infrared (IR) photodetection is essential for applications ranging from environmental monitoring and medical diagnostics to security imaging and high-speed communications [1]. "Conventional" semiconductor detectors—such as InGaAs for the near-IR or HgCdTe for the mid-IR—are expensive, spectrally narrow, mechanically rigid, and in some cases, toxic [2]. Two-dimensional (2D) materials offer a unified ultra-broadband alternative [3]: atomically thin layers with strong light–matter coupling, tunable optoelectronic properties, and seamless integration into flexible, wearable, or on-chip platforms.

In this seminar, I will present 2D-material-based solutions that span the infrared spectrum. For example, in the near-IR (785 nm), hybrid devices combining naturederived carbon dots with graphene channels exploit photogating [4,5] to deliver mA/Wlevel responsivities, maintain performance under repeated bending, and ensure skin compatibility—ideal for wearable sensors. In the mid-IR (8–12 μm), large-area CVD graphene embedded in a Salisbury-screen architecture harnesses the photothermoelectric effect [6] to achieve zero-bias, zero-power-consumption thermal sensing on flexible, skin-compatible substrates, with detectivities potentially rivalling or surpassing those of commercial microbolometers. Finally, in the mid-to-far IR (up to 4 THz), patterned polaritonic resonators [7] integrate plasmon-polaritons in graphene and phonon-polaritons in hexagonal boron nitride, offering gate-tunable resonances and enhanced sensitivity at cryogenic temperatures.

Together, these demonstrations illustrate how a single 2D-material platform can replace multiple specialist semiconductors, yielding compact, broadband, and potentially flexible and environmentally friendly infrared photodetectors. This talk will review device architectures, discuss material-integration challenges, benchmark performance metrics, and outline pathways toward fully integrated 2D-material photonic sensor systems.

[1] C. L. Tan et al., *Nanophotonics* 7, 169 (2018)

[2] C. Downs et al., *Sensors* 13, 5054 (2013)

[3] M. Long et al., *Adv. Funct. Mater.* 29, 1803807 (2019)

[4] D. De Fazio et al., *ACS Nano* 10, 8252 (2016)

[5] D. De Fazio et al., *ACS Nano* 14, 11897 (2020)

[6] M. Asgari et al., *ACS Nano* 15, 17966 (2021)

[7] S. Castilla et al., *Nat. Commun*. 15, 8635 (2024)

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Tuesday 9th September

Bio - fabrication I

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High-Resolution 3D Printing with Femtosecond Lasers for Biomedical Applications

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Abstract:

Additive manufacturing (AM) technologies, often referred to as 3D printing, open exciting perspectives for biomedical applications and tissue engineering. Among the myriad of possible approaches multiphoton lithography (MPL) stands out as technique enabling true 3D structuring with spatial resolution unmatched by other AM technologies [1]. MPL relies on the nonlinear absorption of femtosecond laser pulses to induce photochemical processes. An increasing portfolio of available materials enables utilization of the versatile capabilities of MPL, from producing complex volumetric 3D structures by means of cross-linking, to creating void patters within hydrogels already containing living cells, via photocleavage. Among other things, high resolution of MPL recently enabled realization of a novel tissue engineering approach, employing scaffolded spheroids for bottom-up assembly of tissue constructs with high initial cell density [2-4]. Our recent breakthroughs on the material development side enabled the use of MPL for direct fabrication of cell-containing constructs, giving rise to High-Definition Bioprinting [5-7].
Recent advances in system and material development allow to substantially increase the throughput of MPL, making this technology highly relevant for industrial applications. In this contribution, the recent progress in this area will be discussed.

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Additive Manufacturing and Bioprinting: From Tissue Engineered Implants to In vitro Models

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Abstract:

Biofabrication technologies, including additive manufacturing1 and bioprinting[2], are poised to transform the future of healthcare. The ability to create tissue specific implants through additive manufacturing, also known as 3D printing, enables personalized treatment strategies. These approaches combine pre-design scaffolds with living cells promoting *de novo* tissue formation while the scaffolds gradually degrade.
Bioprinting takes this concept further by positioning cells as central components in the fabrication of complex tissue and organ-like constructs. By integrating cells with biomaterials such as hydrogels, bioprinting allows the creation of highly cellularized and physiologically relevant models. These engineered tissues can replicate disease conditions in vitro and hold promise for the development of novel therapeutic strategies.
In this talk, I will present examples of scaffold fabrication for skeletal tissue regeneration[3], as well as the development of bioengineered kidney in vitro models[4-6]. These cases illustrate the potential of biofabrication not only in regenerative medicine but also in advancing drug discovery and pharmaceutical research through the creation of predictive and tissue specific analogues.

Acknowledgements: This research has received funding from the European Union's Horizon Europe ERC-CoG NEPHRON project under the grant No. 101171952.

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[3] R. Sinha, et al, *Nature Communications* 12, 500 (2021)

[4] C. Formica, et al, *Biofabrication* 17, 035016 (2025)

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3D-printed Immersion Micro Optics for Life Science Applications

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Abstract:

Multiphoton 3D-printing allows flexible manufacturing of high-quality micro optics. Combined with single-mode fibers or coherent fiber bundles, they enable construction of highly miniaturized endoscopic devices with diameters < 1 mm. Their application in Life Sciences and endoscopic tissue imaging, however, requires 3D-printed micro optics that can operate in liquid immersion – so far, this challenge has been unresolved.
We address this issue with microfluidic sealing of monolithic 3D-printed micro optics within a post processing step. This approach prevents wetting of crucial optical surfaces with the environmental liquid, to preserve the surfaces' high refractive power. Compared to previous immersed 3D-printed refractive optics we achieve substantially higher numerical apertures and improved optical performance [1].
Experimentally, we apply our 3D-printed immersion optics in various Life Science fields: A 3D-printed immersion lithography lens at the tip of a single mode fiber enables endoscopic multiphoton 3D-printing of acrylate photopolymers and biogenic hydrogels. A hybrid refractive/diffractive lens, mounted at a transparent glass substrate, enables holographic tweezing for particle trapping and detection, applicable in microfluidic channels and analytical devices [2]. Placed at the tip of single mode fibers, 3D-printed immersion optics enable ultrathin probes for *in-vivo* optical coherence tomography of cardiac vessels. At the tip of coherent fiber bundles, they enable ultrathin endoscopic microscopes that can resolve structures on the scale of single cells [3] to pave the way for ultracompact endoscopes for non-destructive optical biopsies.

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3D Bioprinted Cellulose Acetate – Hydroxyapatite Scaffolds for Bone Tissue Engineering

Eleni Kanakousaki[1,2*], Panagiotis Daskalakis[1,3], Paraskevi Kavatzikidou[1], Stella Maragkaki[1], George Kenanakis[1], Emmanuel Stratakis[1,4] and Anthi Ranella[1]

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Abstract:

3D bioprinting offers the capability to replicate native biological and mechanical cues through bioink formulations and optimized printing parameters. Recent advancements have introduced the concept of bioactive scaffolds, which dynamically respond to their environment, enhancing the functional outcomes of engineered constructs. In this study, an innovative 3D printing system incorporating fluid-deposition modelling (fluid form, piston-driven extrusion) was developed. Main focus was to create functional composites targeting bone mimetic scaffolds. The 3D scaffolds were constructed using composites of cellulose acetate (CA) and hydroxyapatite (HA), chosen for their high mechanical properties, good printability, and multifunctionality in bone tissue engineering (BTE). Morphological characterization of the scaffolds was performed by Scanning Electron Microscopy (SEM), while physicochemical and mechanical properties were studied via Fourier-Transform Infrared Spectroscopy, water contact angle measurements, etc. Finally, the effect of the scaffolds on mouse Mesenchymal Stem Cells (MSCs) was evaluated in terms of adhesion, proliferation and osteogenesis. Cell studies indicated excellent cytocompatibility of the scaffolds, while the great osteogenic potential of CA-HA scaffolds proved promising for BTE. This custom-made 3D printing system could provide valuable insights for further biomaterial design and fabrication for the development of patient-specific applications.

Acknowledgements: The authors would like to thank the European Project NFFA-Europe-Pilot (n. 101007417 from 1/03/2021 to 28/02/2026), the EnterBio EIC Pathfinder grant (GA number: 101129720) and the "Theodore Papazoglou" FORTH Synergy Grant 2024 for providing financial support to this project.

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[2] X. Chen et al., *Small*, 18, 2106824 (2022)
[3] E. Stratakis et al., *Biomicrofluidics*, 5, 1 13411, (2011)
[4] A. Ranella, et al., *Acta Biomaterialia*, 6, 2711 (2010)

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Self-Oscillating Smart Bio-Nanomaterials for Mechanical Maturation of Human Induced Pluripotent Stem Cell-Derived Cardiomyocytes

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Abstract:

Ever since their introduction, human induced pluripotent stem cell-derived cardiomyocytes (hiPSC-CMs) have been considered a promising source of functional cells for heart muscle regeneration. One of the main advantages of utilizing hiPSC-CMs in clinics is the ability to generate the cells in a patient-specific manner for personalized medicine. However, due to their immature phenotype, many issues arise with such a source of cells. Thus, to overcome these limitations, different strategies for hiPSC-CM maturation have been implicated. By far the most frequently used approach is metabolic maturation, which yields insufficient results. Recently, mechanical maturation has been found to improve performance of hiPSC-CMs. However, such an approach requires complex machinery that is impractical for large-scale use. Therefore, in order to bring hiPSC-CMs closer to clinics, new methods of mechanical maturation have to be developed. In recent years, self-oscillating polymers have been extensively studied as smart bio-nanomaterials for their potential application in tissue engineering. Despite significant research efforts, little is known on the biocompatibility of these materials. In this study, we cultured hiPSC-CMs on polymer thin films used for self-oscillation. The films were made from polymer brushes grafted on glass coverslips utilizing the surface-initiated atom transfer radical polymerization technique. We found that such polymer substrates exhibited high biocompatibility towards hiPSC-CMs, with no cytotoxic effects being observed. Surprisingly, these materials did not require any additional coating unlike glass or polystyrene that are normally used for hiPSC-CM culture. Moreover, the cells had typical morphology and structure composed of densely packed and aligned myofibrils. Finally, the cells exhibited undisrupted calcium flow and contractility. The obtained results demonstrate significant potential of selfoscillating smart bio-nanomaterials for tissue engineering, particularly in mechanical maturation of hiPSC-CMs. However, further work is necessary, especially in reducing the toxicity of the initiators of self-oscillation.

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Tuesday 9th September

Bio-nanomaterials II

NanoBio
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Addressing Healthcare Disparities with Nanotechnology

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Abstract:

Biology functions at the nanoscale. Thus, there are special opportunities not only to make biological measurements using nanotechnology, but also to interact directly in order to influence biological outcomes. I describe how we fabricate and use nanostructures to advance high-throughput gene editing for cellular therapies targeting genetic diseases and cancer immunotherapy. We exploit molecular recognition and phase transitions to create molecular treadmills to grow three-dimensional co-cultured tissue efficiently for personalized medicine, testing potential therapeutics, and growing meat and fish sustainably. Nanoscience and nanotechnology developed from chemistry, physics, biology, engineering, medicine, toxicology, and a host of other fields. Along the way, we taught each other our problems, challenges, and approaches. The interdisciplinary communication skills that were developed and are now part of our training remain unique to the field. As a result, nanoscience contributes to a wide range of other fields, such as neuroscience, the microbiome, oncology, cellular agriculture, and more.

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Non-Viral Cell Transfection Using Nanoneedle Injection Technology: Fabrication, Mechanistic Insights and Key Applications

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Abstract:

Engineered cell–nanostructured interfaces driven by vertically aligned silicon nanoneedle arrays have become a promising platform for orchestrating key cell function, behaviour and cell fate conversion[1]. The key advantage of ordered vertically aligned nanoneedle arrays lies in their enhanced interaction at the interface between cells and nanoneedles, enabling the bidirectional informational flow – biochemical/biophysical signals from or to the intracellular environment. The nanoneedle–cell interface open possibilities for implementing applications in biological applications such controlling cell behaviour or gene and protein delivery. We have recently developed a suite of nanofabrication technologies combining colloidal or electron beam lithography techniques with wet or dry etching to fabricate arrays of silicon- and polymer-based nanoneedles and nanotubes with adaptable and programmable designs[2]. And we have developed microscopy-based tools to study the effects of interfacing our nanoneedles with adherent and non-adherent cells to study the mechanisms by which cargo is taken up into cells9,10. The thrust of our current research is to establish nanoneedle injection-mediated gene delivery as a useful and scalable tool and explore therapeutic approaches in cell therapy including in CAR-T therapy, iPSCs and for CRISPR based gene editing[3].
.

[1] Y. Chen, et al. *Acc. Chem. Res.* 57, 1722–1735 (2024)

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NanoBio
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Single Atom Engineered Antibiotics Overcome Bacterial Resistance

Aristides Bakandritsos[1,2*], David Panáček[1,2], Jan Belza[1], Milan Kolář[3], Michal Otyepka[1,4], and Radek Zbořil[1,2]

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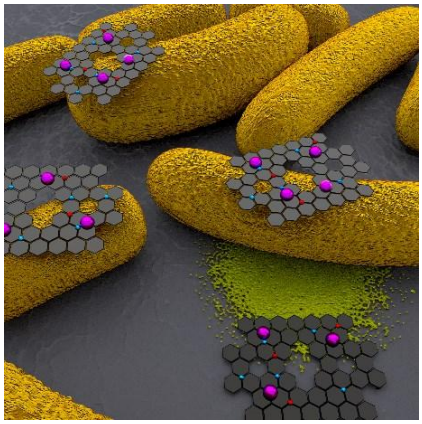
Abstract:



A class of antibiotics are developed with the potential to bypass bacterial resistance. [1]. By leveraging single atom engineering, we embedded manganese into a covalently modified graphene, yielding a material capable of targeting and eliminating a broad spectrum of bacterial pathogens, including multidrug-resistant strains from the ESCAPE group. The material exerts its antimicrobial activity by chemically attacking carbohydrates in bacterial cell walls, a mechanism that disrupts key physiological functions and prevents resistance development. This innovative approach enables potent bactericidal action at low, non-toxic concentrations.
In vivo studies on mouse models demonstrated rapid and effective healing of skin infections caused by resistant Staphylococcus aureus, highlighting its therapeutic promise for localized applications such as wound dressings or antimicrobial coatings on medical devices. The findings mark a significant advance in the fight against antibiotic resistance and underscore the transformative potential of single atom engineered materials in modern medicine.

Acknowledgments: The work was supported from the ERDF/ESF project TECHSCALE (No. CZ.02.01.01/00/22_008/0004587) and from the European Union project 2D-BioPAD (project no. 101120706). All the coauthors of this work are also acknowledged: Lucie Hochvaldová, Zdeněk Baďura, Giorgio Zoppellaro, Martin Šrejber, Tomáš Malina, Veronika Šedajová, Markéta Paloncýová, Rostislav Langer, Lukáš Zdražil, Jianrong Zeng, Lina Li, En Zhao, Zupeng Chen, Zhiqiang Xiong, Ruibin Li, Aleš Panáček, Renata Večeřová, Pavla Kučová.

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Exosomes Detection using Graphene Field Effect Transistors

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Abstract:

Exosomes are nanoscale (50-150nm) extracellular vesicles and released by cells and serve as key mediators of intercellular communication under both physiological and pathological conditions. Moreover, graphene and related biosensors exhibit great biocompatibility can be used as reliable diagnostic tools [1]. In this work, Graphene Field Effect Transistors (GFETs) (Fig.1a) were properly functionalized (L1CAM) [2]) for selective binding of brain exosomes onto the graphene layer. Through electrical measurements (Fig. 1b) the evolution of exosomes' detection was investigated due to successive binding shifting the Dirac voltage. We demonstrate that GFETs are promising diagnostic devices for brain diseases through exosome detection.

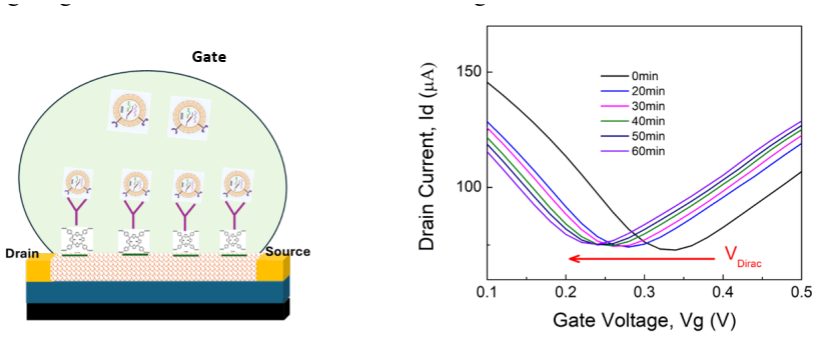

Figure 1: Drain Current – Gate Voltage (Id-Vg) electrical measurements were utilized in order to detect the evolution of exosomes in time segments of 10-minutes.

Acknowledgements: This work was supported by the research project "LIMA-chip" (Proj. No. 2748) which is funded by the Hellenic Foundation of Research and Innovation (HFRI). Sample provided through ASCENT+.

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NanoBio
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Tuesday 9th September

Bio-nanomaterials Characterization

NanoBio
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Integrated Analytical Research Infrastructures Impacting Nano-Biology Research

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Abstract:

Analytical Research Infrastructures (ARI) have impacted biology offering methods based on radiation sources, electron beams, or magnetic fields, and sample preparation. Recently the multi-method integrated offer made available by e.g. NFFA, allow to combine the unique of ARI methods with those available at specialized academic laboratories, therefore providing the basis of multi-messenger research in nano-biology. The "classical" field of structural determination has largely exploited methods developed by hard science research at the nanoscale. Other nano-lab methods like force probes based on scanning proximity interactions or optical response are at the basis of e.g. mechanical fingerprinting of cells and tissues expanding from fundamental understanding to diagnostics of diseases. The impact of access to integrated ARI and nano-bio labs is discussed.

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Characterization of the Delivery of Nanoparticles

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Abstract:

Nanoparticles (NPs) are being developed for disease treatment and diagnosis (1), for example, as carriers for mRNA, agents that induce photothermal radiation of prostate cancer, or contrast agents for magnetic resonance imaging (MRI). However, the use of NPs in clinic is still limited. This is in part due to the challenge associated to deliver the NPs specifically to their target site and to control when they are effective, and when they are cleared from the body. This is related to controlling their biodistribution and pharmacokinetics. Requirements vary depending on their application, but in general, improved biodistributions would reduce side-effects (for example, to off-target tissues) and improved pharmacokinetics would lower the required doses and reduce potential long-term toxicity (for ex-ample, through improved clearance). However, although most mechanisms of NP interaction with cells and tissues have been unravelled, the quantitative details are missing.
The team works towards developing new nanomedicines and drug delivery functionalized with target ligands to provide specific properties for tailoring precision medicines (2-3), as well as developing nanoparticle-based probes for in vivo and ex vivo imaging (4).

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NanoBio
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Raman Spectroscopy for Characterization of Brain Thrombi

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Abstract:

Strokes are among the leading causes of death worldwide, with brain strokes being the primary cause of disability and the third leading cause of mortality. Depending on the etiopathogenic origin of the clot causing the occlusion of the cerebral vessel (atherosclerotic or cardiac-related), its cellular and molecular composition can vary. Fibrin (involved in coagulation mechanisms), red blood cells (RBCs), and platelets are its major constituents, while white blood cells are the secondary components [1]. A deep understanding of clot composition is crucial for selecting the most appropriate endovascular tools for recanalization, and we propose Raman spectroscopy as a label free technique for molecular characterization of blood clots in real-time. Both synthetic and human blood clots were used for acquiring signals in the fingerprint and in the high wavenumber spectral ranges. Preliminary results highlight the presence of the heme prostetic group as it displays strong Raman scattering because of its high symmetry, with bands assigned to the methin bridges and pyrrole rings stretching vibrations. Thanks to the high sensitivity and molecular specificity of Raman spectroscopy in identifying signals associated to the presence of the heme group, we are approaching a systematic analysis and classification of human blood clots. Leveraging on the use of tapered optical fibers for reliable Raman spectroscopy analysis [2], we foresee the possibility of accessing thrombi via the surgical catheter, for *in vivo* real-time etiopathologic diagnosis of brain clots.

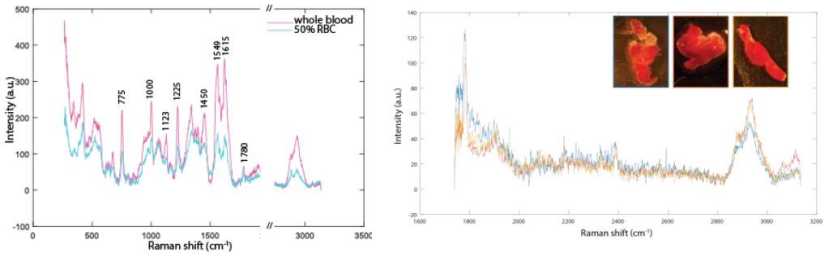

Fig. 1: *Raman spectra of artificial blood clot; Raman spectra of human clots*

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A Fluorescent Ratiometric Potassium Sensor Based on IPG4-silica Microparticles for Selective Detection and Fluorescence Imaging of Potassium Cations

Francesco Colella[1]*, Stefania Forciniti, Valentina Onesto, Giuliana Grasso, Helena Iuele, Giuseppe Gigli and Loretta L. del Mercato

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Abstract:

Potassium cations (K^+) play a fundamental role in many biological processes. In living organisms, K^+ is essential for maintaining cellular homeostasis, generating action potentials in nerve and muscle cells and regulating enzyme activity. Its ionic radius and charge density make it selectively permeable through specific ion channels, a property crucial for cellular signalling and osmoregulation [1]. There is also evidence that K^+ ions accumulation might play a role in cancer, by creating a hostile environment for immune cells. We report the development of a ratiometric fluorescent microsensor for K^+ live imaging, based on the fluorescent probe ION potassium green 4 (IPG4, ION Biosciences). Silica (SiO_2) was chosen as the starting material for the synthesis of K^+ sensitive fluorescent microparticles, due to its physicochemical properties and its biocompatibility [2, 3]. We obtained silica-based microprobe with a size in the micrometre range, spherical shape, good monodispersity and a sensitivity range between 0 to 40 mM. The efficacy of this sensing tool in detecting variations in K^+ concentration, was tested in different conditions and in *in vitro* biological model, proving its compatibility with live imaging analysis performed by means of confocal laser scanning microscopy (CLSM). The developed sensing platform offers new possibilities regarding the study of K^+ dysregulation in human diseases in *in vitro* platforms.

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Nanoengineered Fullerene–PLA Films for Light-Triggered Biofouling Resistance

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Abstract:

The increasing threat of microbial contamination and infection, particularly in clinical and food processing environments, necessitates the development of advanced antimicrobial surfaces. In this study, we explore a nanobioengineering approach utilizing the self-assembly of fullerene (C_{60}) nanoparticles with poly(lactic acid) (PLA) to fabricate thin films exhibiting anti-biofouling properties. The self-assembly process enables the uniform distribution of fullerenes within the PLA matrix, creating a stable nanocomposite surface with enhanced physicochemical characteristics. The nanocomposite films were structurally characterized by scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), Atomic Force Microscopy (AFM) and water contact angle measurements, confirming homogeneity and interaction between the components.

The antimicrobial efficacy of the PLA–fullerene films was evaluated against three clinically and industrially relevant microorganisms: *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Candida albicans*. Quantitative microbial adhesion tests demonstrated a significant reduction in microbial attachment compared to pure PLA control films, with over 80% inhibition for *S. aureus*, 75% for *P. aeruginosa*, and 70% for *C. albicans*. Notably, the antimicrobial activity of the films relies on the generation of reactive oxygen species (ROS) by the fullerene nanoparticles under ambient light exposure, as detected by ROS measurements using dimethylformamide (DMF). This light-dependent mechanism enhances microbial inhibition while avoiding the use of chemical biocides, making the system both efficient and environmentally friendly.

Given the film's biocompatibility, photoreactivity under ambient conditions, and proven efficacy in reducing biofouling, it holds strong promise for applications in highrisk contamination environments. Potential implementation areas include food packaging surfaces, medical device coatings, and high-touch surfaces in hospitals and processing facilities. This study presents a sustainable and scalable strategy to reduce microbial contamination and infection transmission, supporting global efforts toward safer healthcare and food systems.

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Wednesday 10th September

Workshop on Emerging PVs

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Next-Generation Energy-Harvesting Systems Based on Metal Halide Perovskite Nanohybrids

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Abstract:

The integration of semiconductor nanocrystals with photo- and redox-active organic molecules has emerged as a promising strategy to harvest visible-light and use them in several applications, such as photovoltaics, light-emitting devices, and sensing. A comprehensive understanding of photoinduced processes such as exciton dynamics, charge transfer, and energy transfer is essential for the continued development of these technologies.

Metal halide perovskite nanocrystals (NCs) are well known for their exceptional and tunable optical and electronic properties. Surface engineering at the nanoscale plays a critical role in enhancing their interaction with light, as well as improving the efficiency of energy absorption, transfer, and conversion. The merging of $CsPbBr_3$ NCs with photoactive molecules such as BODIPYs derivatives and Zn-phthalocyanine (ZnPc) and perylendiimides (PDIs) dyes can be used to modulate the photophysics of both components in the nanohybrids. [1-3] The potential of Iodine-BODIPY dyes to efficiently extract the hot hole carrier from the NCs in the NC@I2BODIPY nanohybrids was used as energy transfer photocatalyst for oxidizing α-terpinene to ascaridole. Moreover, an efficient concerted Dexter-energy transfer from the NCs to ZnPC in the NC@ZnPC nanohybrid produced singlet oxygen ($^1O_2$) almost quantitatively while in the presence of PDIs a long-lived charge-separated states was obtained. All these findings highlight the potential of nanohybrid materials to enhance the capability of light-driven processes and will be discussed in this presentation.

Acknowledgement: Financial support by Generalitat Valenciana (CIPROM/2022/57), MICIN (MRR/MFA/2022/051) and Laserlab-Europe (EU-H2020 871124).

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Interface Engineering Strategies for Robust and Efficient PSCs

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Abstract:

The development of third generation photovoltaics requires holistic approaches comprising the design, synthesis and advanced characterization of photoactive materials (molecular and nanostructured), process engineering and device fabrication and scaleup. Particular effort exists on hybrid organic-inorganic halide (OD, 1D, and 3D) perovskites (lead-based and lead-free/tin-based) with exceptional structural, optoelectronic and morphological properties via both solution and solid-state chemistry [1-7]. Targeting robust and efficient devices, very innovative interface engineering strategies are under implementation [8], supported by process simulation and machine learning insights [9]. The dye sensitization [10-12], the dimensionality engineering and passivation approaches [13,14] were introduced to functionalize the ETL/absorber and absorber/HTM interfaces and prepare stable and highly performing perovskite solar cells [15-18]. Such promising innovations overcoming stability issues and technological challenges, are expected to bring new products to market.

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Comprehensive High-Throughput DFT Study of Intrinsic Defects and Dopability in p-type Zn_3P_2 for Photovoltaic Applications

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Abstract:

Zn_3P_2 has attracted significant interest as a thin-film absorber material for photovoltaic applications due to its intrinsic *p*-type conductivity and earth-abundant constituents. However, the nature of the dominant native defects, whether phosphorus interstitials or zinc vacancies, remains a subject of debate, with implications for the material's electronic structure and dopability. These intrinsic defects play a pivotal role in determining the efficacy of extrinsic doping by mechanisms such as Fermi-level pinning and defect compensation, which can hinder targeted modifications to carrier concentration and type.

In this work, we perform a high-throughput density functional theory (DFT) analysis to systematically investigate both intrinsic point defects and potential extrinsic dopants. By resolving the ground-state configurations and formation energies of key native defects, we provide a clearer understanding of their impact on the electronic landscape, particularly in relation to Fermi-level stabilization. This insight is then applied to evaluate a range of extrinsic dopants, predicting their incorporation and activation potentials in the presence of native defects.

Our study offers a comprehensive framework that links intrinsic defect behaviour with extrinsic doping strategies, providing critical guidance for tuning the electrical properties of Zn_3P_2. The findings present experimentally actionable insights that can drive the optimization of Zn_3P_2 for next-generation photovoltaic devices.

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A Volatile Additive to Control Crystallization of $CuInS_2$ Quantum Dots

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Abstract:

$CuInS_2$ quantum dots (CIS-QDs) are attractive candidates for LED applications due to their low toxicity and tunable emission across the visible spectrum. However, their relatively low photoluminescence quantum yield (PLQY), in the absence of ZnS shell passivation, remains a key limitation for practical applications. To address this, researchers have explored various ligand passivation strategies (including ZnS itself) and compositional tuning approaches [1]. However, there is no literature data on incorporating additives during synthesis in order to control crystallization and enhance radiative recombination; this is a common strategy in lead halide optoelectronics [2]. Here, a volatile additive, formamidinium acetate (FAAc), was employed in the reaction solution. The chemical interactions between FAAc, the precursors (CuI and In(Ac)3) and solvent (dodecanethiol), at high temperatures up to 220 0C, control the optical bandgap, stoichiometry and size of the as-formed nanocrystals. The incorporation of the additive, even if it finally vanishes from the nanostructure, finally leads to a dramatic increase in photoluminescence lifetime from 0.2 μs to 7.2 μs as well as in PLQY from 43% to 94%. Preliminary LED devices fabricated with FA-treated CISQDs exhibit strong red emission, demonstrating their potential as efficient and environmentally friendly materials for next-generation light-emitting technologies.

Acknowledgements: We acknowledge the financial support from the European Research Council (ERC) through Consolidator Grant (818615-MIX2FIX). TS also thanks the Action "Flagship Research Projects in challenging interdisciplinary sectors with practical applications in Greek Industry", implemented through the National Recovery and Resilience Plan Greece 2.0 and funded by the European Union – NextGenerationEU (project code: TAEDR-0537347).

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Memristive Switching in Mixed-Halide Perovskite Transistors

Konstantinos Rogdakis, [1,2*] George Psaltakis[1], Konstantinos Chatzimanolis[1], Konstantinos Blazakis[1], Leadros Spachis[1] and Emmanuel Kymakis [1,2]

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Abstract:

Memristors are candidates for scaled-down brain-inspired neuromorphic circuits because of their simple two-terminal (2T) device geometry and in-memory computation capability which can overcome the power limitations of the von Neumann architecture. Crossbar circuits based on 2T memristors typically require an additional unit such as a transistor for individual node selection. Although highly effective, this approach significantly increases circuit footprint and manufacturing complexity. A memristive device with gate-tunable synaptic functionalities would not only integrate selection functionality at the cell level but could also lead to enriched on-demand learning schemes. Here, a three-terminal (3T) mixed-halide perovskite memristive device with gate-tunable synaptic functions operating at low potentials is demonstrated [1]. The device operation was controlled by both the drain (V_D) and gate (V_G) potentials, with an extended endurance of >2000 cycles and a state retention of >5000 s. Applying a voltage (V_{set}) of 20 V across the 50 μm channel switches its conductance from a highresistance-state (HRS) to low-resistance-state (LRS). A memristive switching mechanism is proposed that is supported by current injection models through a Schottky barrier and Kelvin probe force microscopy data. The simultaneous application of a V_G potential is found to further modulate the channel conductance and reduce the operating V_{set} to 2 V, thus requiring a low electric field of 400 V/cm, which is by a factor of 50× less compared to state-of-the-art literature reports. Gate-tunable retention, endurance and synaptic functionalities were demonstrated, further highlighting the beneficial effect of V_G on device operation. By setting appropriate current compliance current, the devices can be operated in volatile I-V switching mode demonstrating extended endurance characteristics [2]. In this diffusive memristor mode, the devices exhibit pulse-amplitude and -frequency characteristics allowing linear conductivity modulation opening the path for the implementation of a leaky integrate-and -fire (LIF) neuron with light and gate tunable functions.

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Semiconducting Polymers for Organic Electronics

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S. Giosi,[1] M. Karra,[1] K. Koumoutsou,[1] J. K. Kallitsis[1]

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Abstract:

Organic semiconducting materials of high efficiency, integrity and processability are necessary for the evolution of organic electronics, such as OPVs, OLEDs, OFETs etc. Semiconductors of various structural combinations and architectural patterns are needed to impose the required optoelectronic properties and morphology characteristics for each specific end-application.
In this respect, in our laboratory, we have focused on the development of semiconductors of extended conjugation length and enhanced absorption profiles via synthetic routes that do not necessitate toxic intermediates such as stannanes, via employing simpler reaction schemes and by reducing to a minimum the use of metal catalysts. Polymeric semiconductors of structural and molecular integrity, high molecular weights, enhanced solubility and processability, and well-defined and tuneable electronic properties have been created based on various conjugated moieties. Polymers of fully aromatic or conjugated-non conjugated architectures have been created, and the developed materials have been evaluated regarding the respective application prerequisites as printable electronics like OPVs, PLEDs and agrivoltaics.

Acknowledgements: "Flagship actions in interdisciplinary scientific fields with a special focus on the productive fabric"; Greece 2.0-National Recovery and Resilience Fund: Advanced Materials for Energy/Materials for Photovoltaics; TAEDR-0537347 "Development of efficient third generation PV materials and devices to enhance the competitiveness of enterprises to the green energy production"_3GPV-4INDUSTRY.

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Wednesday 10th September

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Efficient Structures And Processes for Upscaling of Perovskite Modules and Tandems

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Abstract:

The unprecedented fast rise of power conversion efficiency (PCE) of perovskite-based solar cells (PSC) in recent years has created a vast worldwide research activity in this material class for photovoltaic and other opto-electronic applications. Several materials compositions and device architectures have been described and best reported PCE's yield recently more than 27%. Also improved stability under specific conditions has been shown for specific architectures. Whereas all these results indicate a high potential for this novel solar technology, further steps must be taken to convince industry and even the whole PV community that perovskite-based photovoltaics can really emerge from the lab into industrially applicable solar module processing. Our R&D program works actively on the upscaling of perovskite solar modules with scalable processes up to sizes of 35x35 cm^2.

Similarly, the perovskite PV technology has boosted the tandem research whereby perovskite cells and modules are placed on top of other PV devices like Si or CIGS solar cells. Impressive lab scale results exceeding 34% PCE have been reported. New challenges arise when this needs to be upscaled to full wafer or module size. It will be discussed how we approach these challenges.

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Enabling the Factory Floor: Industrially Relevant Strategies for All-Printed Carbon-based Perovskite Photovoltaics

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Abstract:

Fully printed carbon-based perovskite solar cells are emerging as a transformative platform for next-generation, commercially viable photovoltaics. Bridging the gap between lab-scale innovation and industrial-scale production, this work presents scalable manufacturing routes compatible with ambient-air processing, bringing perovskite photovoltaic technology a step closer to commercialization. The focus is placed on inkjet printing as the primary deposition method for nearly all functional photovoltaic layers, offering precise material control, digital patterning and compatibility with highthroughput manufacturing. Complementary scalable techniques such as slot-die coating, blade coating and screen-printing are also explored for the development of specific photovoltaic layers, including the carbon electrode. The distinct processing requirements and printing challenges associated with each method are critically assessed, and a suite of advanced ink formulations — engineered for high performance, extended shelf life, process compatibility and lower environmental footprint — are proposed.

Demonstrated materials include perovskite precursor inks formulated from centimeter-scale perovskite single crystals, low-lead content solutions using green solvent systems, as well as stable colloidal inks and carbon pastes with benign perovskite compatibility for the fabrication of the charge transport layers and back contact, respectively. Scaling up from the small-area devices to the module level demonstrates minimal efficiency losses and competitive manufacturing cost projections, with ongoing efforts to focus on 1 m² scale devices, using either standard and bifacial configurations, tailored for emerging applications such as agrivoltaics.

Acknowledgments: This work was carried out within the framework of the Action “Flagship Research Projects in challenging interdisciplinary sectors with practical applications in Greek Industry”, implemented through the National Recovery and Resilience Plan Greece 2.0 and funded by the European Union–NextGenerationEU (project code: TAEDR-0537347).

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Unveiling the Impact of Molecular Doping on the Efficiency and Optoelectronic Properties of Fully Printed Flexible Organic Solar Cells

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Abstract:

Organic Photovoltaics (OPVs) offer key advantages over traditional silicon-based solar cells, including flexibility, light weight, semi-transparency and compatibility with roll-to-roll (R2R) printing for low-cost, large-scale production. Enhancing their light absorption and charge transport is critical for commercial viability. Molecular doping is a promising strategy to improve OPV performance, though its impact on charge transport requires further understanding.

In this study, we demonstrate a fully printed flexible OPV using a PBDB-T:BTP-12 photoactive blend doped with the p-type dopant F4-TCNQ (2,3,5,6-Tetrafluoro-7,7,8,8-tetracyanoquinodimethane). We investigate the effects of doping on hole mobility in both hole-only and full OPV devices fabricated via slot-die coating. Comprehensive optical, electrical and structural characterizations reveal that F4-TCNQ facilitates trap filling and enhances hole mobility at optimal concentrations. As a result, the power conversion efficiency of the OPV devices increased by 20% compared to those without doping. Our findings underscore molecular doping as an effective approach for improving OPV performance and advancing scalable manufacturing.

Acknowledgments: This work has been supported by the projects: “Development of efficient third generation PV materials and devices to enhance the competitiveness of the productive sector in green energy" (3GPV-4INDUSTRY) (TAEDR code 0537347), the Horizon Europe COPE-Nano (GA 101059828)

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Outdoor Evaluation of Perovskite Photovoltaics: Long-Term Stability and Performance

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Abstract:

Power conversion efficiencies (PCE) exceeding 26% have been achieved by perovskite photovoltaics (PePVs), which have emerged as a promising alternative energy solution. These efficiencies are comparable to classical silicon solar cells. They are appropriate for both low-power applications and large-scale solar farms due to their adaptability. As a vital step towards the industrialization of perovskite solar cells, outdoor field tests of large-scale perovskite modules and panels represent a mandatory step to be accomplished. The complexities of outdoor exposure are not adequately captured by conventional lab-based testing protocols, as the performance and stability of the system are significantly influenced by fluctuating weather patterns and variable peak sun hours. The long-term performance of perovskite modules and panels in outdoor conditions will be the primary focus of this presentation, with an emphasis on the origins of a variety of degradation factors. Some of these factors are intrinsic to the perovskite active layer, while others are extrinsic, such as lamination failure[1]. The effects of gloomy storage and light soaking on the panels and their partial recovery are investigated using detailed measurement protocols. The sensitivity of perovskite panels to environmental conditions such as humidity, high temperatures, and light exposure, which are significant degradation sources, poses a challenge to their long-term stability. However, it was found[2] that this degradation was partially reversible following a period of dark storage. Changes in the light soaking phenomenon (LSP) were observed, as well as enhancements in the electrical parameters of the solar farm following dark storage. This suggests a multifaceted interplay of degradation and recovery mechanisms that are contingent upon dark storage and light exposure. Visual inspections revealed that the panels had developed defects over time, which were linked to lamination failure and the penetration of oxygen and moisture. Also in this research was ensured that solar modules always operate at their maximum power point, compensating for changing weather and load conditions, thereby maximizing efficiency, energy yield, and system reliability.This research demonstrates that the electrical properties of the panels can be restored provided that the lamination prevents the penetration of external factors (including moisture and oxygen). Nevertheless, it is imperative to conduct additional research on the ageing process in outdoor environments in order to distinguish between recovery scenarios in terms of the extent of degradation and long-term stability. [1] E. Spiliarotis, et al. *EES Solar* 1, 295–309 (2023); [2] S. Pescetelli, et al. *Nat. Energy* 7, 597–607 (2022)

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Towards Scalable Synthesis of High-Quality Zn_3P_2 Thin Films for Photovoltaic Applications

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Abstract:

Advances in crystal epitaxy methods have led to re-emergence of $Zn3P_2$ as a potential candidate for photovoltaics. $Zn3P_2$ is an earth-abundant absorber that shows promising material properties for thin film solar cell applications: direct bandgap of 1.5eV, high optical absorption and long minority carrier diffusion length. Historically, the synthesis of high-quality thin films of $Zn3P_2$has been problematic due to its mismatching lattice constant and thermal expansion coefficient with most available substrates. However, recently it has been shown that by using selective area epitaxy (SAE) it is possible to reduce defect formation in $Zn3P_2$ thin films. This was initially achieved using molecular beam epitaxy and electron beam lithography (EBL) on InP substrates.1 As these methods have relatively low synthesis throughput, alternative methods are needed to achieve industrial scale production. Metalorganic vapor phase epitaxy (MOVPE) is a well-established growth technique in the V/III semiconductor industry and can handle several 4" wafers at the same time which is a more scalable alternative. Displacement Talbot lithography (DTL) is a promising alternative to EBL, as it is an optical lithography technique using parallel illumination for high throughput and is capable of creating periodic patterns with feature sizes down to sub 100 nm.

We have successfully produced high-quality thin films of $Zn3P_2$ using MOVPE and DTL. However, to maintain the earth abundance aspect of $Zn3P_2$ solar cells, indium is not a suitable element to have in the finished solar cell and alternative substrate material is needed. Thus, besides InP(100) and InP(111)B we have investigated and succeeded in epitaxially growing $Zn3P_2$ on Si(100) and Si(111). V/II and temperature ranges were explored to find the optimal growth conditions resulting in good growth selectivity and control of the growth rate. To evaluate the crystal structure and composition of the $Zn3P_2$ thin film, we are using aberration corrected transmission electron microscopy (TEM) and electron energy loss spectroscopy (EELS).

[1] S. Escobar Steinvall *et al*., *Nanoscale Adv*., 3, 326-332 (2021)

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Fabrication of Fully Printed Flexible Perovskite Solar Modules and Investigation of Stability and Degradation Mechanisms

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Abstract:

Perovskite solar cells (PSCs) are rapidly emerging as a leading technology in solar energy due to their high-power conversion efficiencies and potential for low-cost, scalable fabrication. This work focuses on the development of fully printed perovskite photovoltaic (PPV) modules using $MAPbI_3$ active layer. PET/IMI/PEDOT:PSS/$MAPbI_3$/$PC_{60}BM$/AgNWs device structure was employed for the fabrication via slot-die coating technique. To address the scalability challenge of conventional patterning methods, ultra-fast laser scribing has been introduced instead of chemical etching, enabling compatibility with roll-to-roll (R2R) manufacturing. The fabricated modules achieved a PCE of 4.27% over a 25 cm^2 active area, demonstrating a promising pathway for scalable, printed PPV technology. Stability assessments were conducted for PPV solar cells and modules using the ISOS-L1 protocol from the International Summit on Organic Photovoltaic Stability (ISOS). Complementary characterization through Spectroscopic Ellipsometry (SE) and Laser Beam Induced Current (LBIC) provided insights for the degradation mechanisms and phase-change dynamics. A strong correlation was observed between PCE decline and phase transitions in the perovskite film as evaluated through SE, particularly the formation of PbI_2 phase and evolution of voids, which stabilized after approximately 660 minutes. This work demonstrates the feasibility of scalable fabrication technology of fully printed, large-area PPV modules, whereas it highlights the importance of advanced stability analysis in accelerating their commercial implementation to sustainable energy applications.

Acknowledgements: This work has been supported by the projects: “Development of efficient third generation PV materials and devices to enhance the competitiveness of the productive sector in green energy" (3GPV-4INDUSTRY) (TAEDR code 0537347), the Horizon Europe COPE-Nano (GA 101059828)

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Lead-Free, Optoelectronic Memristive Perovskite Solar Cells for Selfpowered Neuromorphic Edge Computing

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Abstract:

The on-going growth of perovskite photovoltaics brings closer their commercial use. Solutionprocessed perovskites are currently being utilized in optoelectronics beyond solar cells due to their inherent rich ion dynamics and hysteresis [1], enabling their implementation in the field of Resistive Switching (RS) memories. To mitigate the use of toxic lead, research efforts are also focused on eliminating lead (Pb) to transition toward environmentally friendly electronics [2]. In this work, we demonstrate the use of lead-free, planar structured and efficient memristive solar cells. We show that the type of RS can be tuned from volatile to non-volatile through electrode engineering, while demonstrating a series of synaptic and neuron functionality. Furthermore, both volatile and non-volatile systems possess low switching voltages below 1 Volt. In addition, the device can be utilized for photodetection. The light tunability is also demonstrated by altering the switching response of the RS device toward optoelectronic memristive systems. As a next step, the light response of the memristive solar cell is altered using electrochromic materials, depending on its state (Blocking or Transparent). Finally, the same device geometry is used for neuromorphic computing tasks such as classification and associative learning. These results showcase the potential use of self-powered, environmentally friendly optoelectronic memory systems toward IoT edge computing [2, 3, 4].

[1] M.H. Futscher, et al. *Front. Energy Res.* 9, (2021)

[2] Y. Fang, et al. *ACS Appl. Mater. Interfaces* 13, 17141–17157 (2021)

[3] K. Rogdakis, et al. *Mater. Adv.* 3, 7002–7014 (2022)

[4] M. Loizos, et al. *Nanoscale Horiz.* 9, 1146–1154 (2024)

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Rational Design of New Conjugated Polymers with Main Chain Chirality for Efficient Optoelectronic Devices: Carbo [6] Helicene and Indacenodithiophene Copolymers as Model Compounds

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Abstract:

The unique properties of conjugated polymers (CPs) in various optoelectronic applications are mainly attributed to their different self-assembly processes and superstructures. Various methods are utilized to tune and control CP structure and properties with less attention paid to the use of chirality. CPs with main chain chirality are rare and their microscopic and macroscopic properties are still unknown.

In this work, the first experimental results are provided along these lines by synthesizing a series of racemic and enantiopure CPs containing statistical and alternating carbo[6]helicene and indacenodithiophene moieties and evaluating their microscopic (optical, energy levels) and macroscopic properties (hole mobilities, photovoltaic performance). It is demonstrated that a small statistical insertion of either the racemic or enantiopure helicene into the polymer backbone finely tunes the microscopic and macroscopic properties as a function of the statistical content. The microscopic properties of the enantiopure versus the racemic polymers with the same helicene loading remain similar. On the contrary, the macroscopic properties, and more interestingly those between the two enantiomeric forms, are altered as a function of the statistical content. Once incorporated into a solar cell device, these chiral CPs display better performance in their enantiopure versus racemic forms.[1]

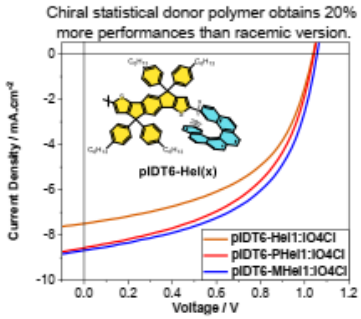

Figure 1. *J-V* curves of the cells based on racemic and enantiopure polymers on 1% helicene loading.

[1] C. Gedeon, et al *Adv. Mater.* 36, 2314337 (2024)

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Wednesday 10th September

Workshop on Emerging PVs

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Standardizing Data, Workflows, and Executions in a Modelling Platform for Organic Electronic Materials and Processes

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Abstract:

Modelling and simulation of organic optoelectronic materials and devices are important tools and accelerators of innovation. Validated models spanning multiple scales and domains of physics are coupled together creating a unique open innovation modelling ecosystem, i.e., an open innovation platform (OIP) for materials modelling. OIPs are intended to increase the EU industry competitiveness and its digital transformation. I'll present our recent activities in modelling optoelectronic devices, and our achievements in establishing an OIP through the H2020 MUSICODE project. The latter includes tools and methodologies for predicting/optimizing organic nanomaterials properties, relating structure-property to process conditions, designing/optimizing device functionalities, as well as a novel data management system facilitates its operation including a database of material and device property records, modelling workflow editing tools, interoperable modelling workflow execution, data analysis etc.

Acknowledgements: This work has been supported by the H2020 DT-NMBP-11-2020 project MUSICODE (GA 953187) http://musicode.

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Material and Device Engineering Concepts for Enhancing the Performance of Inverted Perovskite Photovoltaics

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Abstract:

The advantages of hybrid perovskite photovoltaic technologies, such as their light weight, mechanical flexibility in addition to the small energy demand, and low-cost equipment requirements for roll-to-roll printing mass production, characterize them as interested candidate sources for future electrical power. The presentation aims to cover a range of scientific and engineering issues needed to bring inverted perovskite photovoltaics to commercial viability in terms of power conversion efficiency (PCE) and lifetime performance. Within the European Union's Horizon Europe Research and Innovation Programme LUMINOSITY project [1], large-scale and industrially compatible methods are applied for the development of inverted perovskite photovoltaics. A systematic understanding of the relationship between additive, interfaces and buffer layers engineering that enhances the performance of hybrid inverted perovskite photovoltaics will be presented [2,3].

Acknowledgments: This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101147653 (project LUMINOSITY).

[1] LUMINOSITY Horizon EU Research and Innovation project, https://luminosity-project.eu/

[2] A. Ioakeimidis, et al. *Materials* 13, 3289 (2020)

[3] F. Galatopoulos, et al. *ACS Appl. Electron. Mater.* 5, (2023)

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Two-Dimensional Nanomaterials Materials for Energy Devices

Katerina Anagnostou[1*], Christos Polyzoidis[1], Michalis Loizos[1], Kyriakos Mouratis[1], Konstantinos Rogdakis[1,2], Emmanuel Kymakis[1,2]

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Abstract:

Two-dimensional (2D) nanomaterials are progressively arising as key components in emerging energy technologies, offering new possibilities for improving the performance, efficiency, and stability of a wide range of energy devices. This presentation focuses on the development of graphene-based materials and Transition Metal Dichalcogenides (TMDs) for energy applications following user-friendly, liquid processable techniques.[1] These methods are not only scalable and cost-effective but also utilize non-toxic, environmentally friendly solvents, eliminating the need for harsh chemicals or high-temperature treatments.[2] This eco-conscious methodology supports the green fabrication of nanomaterials, aligning with the principles of sustainable nanotechnology. This talk demonstrates the preparation methods for stable and printable 2D nanomaterial inks for up-scalable deposition methods such as inkjet printing, spray coating, and roll-to-roll manufacturing. Lastly, the versatility and value of these developed material inks is highlighted in the presentation of our recent research and publications. [2-6] **Acknowledgements:** The research describes above is implemented in the framework of H.F.R.I call “Basic research Financing (Horizontal support of all Sciences)” under the National Recovery and Resilience Plan “Greece 2.0” funded by the European Union – NextGenerationEU (H.F.R.I. Project Number: 14728).

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High-Power Optical Field Modulation Based on Micro/Nanostructures and Its Applications

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Abstract

High-power optical field manipulation technology has shown great potential for application in laser-driven particle acceleration, advanced light source generation, laser manufacturing, and three-dimensional printing, enabling enhanced performance without increasing laser power. [1-4] This, in turns, motivates the development of high-damage-threshold optical elements for generating and manipulating high-power complex optical field. Conventional structured light generation methods face many challenges, such as complex system, bulky volume, and limited modulation capability, which hinder the integrated, high-precision control of complex beam. Recently, subwavelength micro/nanostructures have offered integrated and flexible control over optical field parameters including the amplitude, phase, and polarization at the subwavelength scale, which break through the limitations of the classical laws of refraction and reflection. However, due to the intrinsic threshold properties of the materials constituting subwavelength structures, interface mismatch, and local field enhancement within these structures, the laser-induced damage threshold (LIDT) of micro/nanostructures is relatively low, which restricts their application in high-power laser fields. In recent years, femtosecond laser-induced birefringent nanostructures (nanogratings and nanopores) have been demonstrated as a new type of subwavelength structure for polarization and geometric phase modulation, offering high LIDT, high transmittance, and high stability [5,6]. In this talk, we will discuss the principle of optical field modulation with micro/nanostructures [7], progress on the high-efficiency fabrication of large-aperture, high-LIDT optical elements based on femtosecond laser-induced birefringent nanostructures, and novel applications including vortex-field enhancement [6] high-security optical information encryption, broadband and high-accuracy polarization detection and ultraviolet optical field modulation. These results provide new approaches for high-efficiency optical field modulation. [1] W.P. Wang, et al *Phys. Rev. Lett.* 125, 034801 (2020); [2] T. Sun, et al *Phys. Rev. Lett.* 132, 045001 (2024); [3] M. Meier, et al *Appl. Phys. A* 86, 329–334 (2007); [4] T.U. Tumkur, et al *Sci. Adv.* 7, eabg9358 (2021); [5] M. Sakakura, et al *Light Sci. Appl.* 9, 15 (2020); [6] Q. Wang, et al *Opto-Electron. Adv.* 7, 240112 (2024); [7] Y. Guo, et al *Photon. Insights* 1, R03 (2022

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Wednesday 10th September

Bio-fabrication II

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Real-Time Thermometry in Femtosecond Laser Microfabrication

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Abstract:

Femtosecond direct laser writing (fs-DLW) holds great potential for crafting intricate microstructures for biomedical and cellular applications *in vivo*, but careful monitoring of heat exposure in living systems is essential. This study investigates the temperature dynamics at the focal spot during fs-DLW within a protein-based photoresist, employing advanced thermometry techniques. We developed a versatile platform utilizing $NaYF_4$:Yb^{3+}/Er^{3+} luminescent nanoparticles as temperature sensors to track localized temperature changes under varying writing conditions. The fs-DLW was conducted with a pulsed femtosecond laser at 755 nm, while a continuous wave laser diode at 976 nm collinearly used for temperature monitoring. Our results highlight the influence of scan rate, laser power, and photosensitizer (methylene blue) concentration on localized heating. Notably, higher scan rates minimized thermal buildup, with a scan rate of 20 µm/s yielding a modest temperature rise of $\Delta T \approx 11$ °C, confined to a sub-femtoliter volume, indicating a safer process for biological applications. However, elevated laser power intermittently caused unpredictable temperature spikes, posing potential risks to cellular integrity. These findings offer critical insights for optimizing fs-laser parameters to achieve precise and safe microfabrication for biomedical purposes. The proposed thermometry approach can be routinely integrated into laser writing processes in biological settings to manage thermal loads effectively. This work advances the control of laser-assisted bioprinting and related technologies while deepening our understanding of thermal effects induced by fs-DLW in protein-based photoresists.

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Laser-Ablative Processing for Biomedical and Tissue Engineering Applications

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Abstract:

Based on its flexibility, precision, repeatability and eco-friendliness, laser-based technologies have attracted great interest to engineer innovative nanomaterials in various fields including biology and medicine [1]. In our group, we have investigated the ultrafast laser beam in liquid ambiance (e.g., aqueous solution) to develop novel nanotherapeutics tools made from metallic and inorganic NPs (e.g., SiNPs, TiNNPs, etc.) with modulate physicochemical properties in terms of diameter, size distribution, surface chemistry and oxidation rate [2,3]. We have evidenced their complete safety properties using *in vitro* and *in vivo* nude mice animal model. Their therapeutic properties as efficient agents for radiofrequency (RF)-induced hyperthermia and TPEPDT modalities were demonstrated [4,6]. Moreover, their ability to modulate cells behavior and to promote proliferation and differentiation. We have thus demonstrated the positive outcomes of the exposure of C2C12 myoblasts to SiNPs, leading to significant improvements in their proliferation, differentiation and motility, even at the lowest concentration, both in phenotypic and molecular analyses [7]. Currently, we are also developing an innovative laser-assisted printing approach to develop a network of micro-sensors integrated into electrospun nanofibres, enabling wounds to be monitored using physical parameters such as temperature, humidity and pH. This project is of great interest in the development of intelligent medical devices (e.g. dressings) for assessing the condition of wounds (traumatic or chronic), thereby facilitating their treatment and/or management.

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Architecturally Simple Organic Photodiodes for High Performance and Advanced Functionalities

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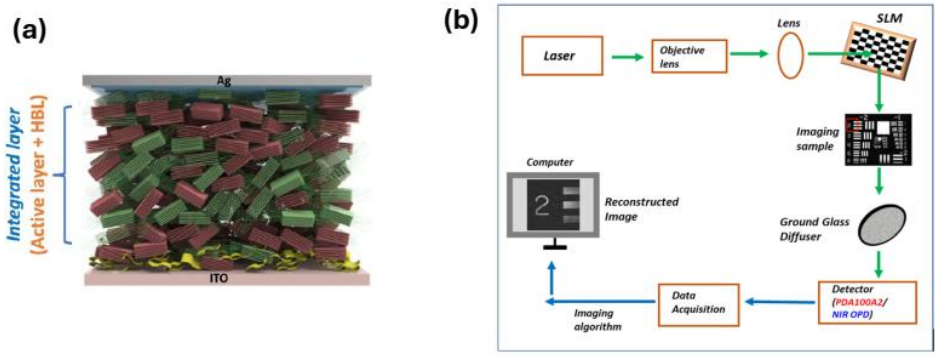
Abstract:

With the advent of the information era, photodetection has grown in importance as a tool of modern science and technology.[1] Though organic photodetectors (OPDs) offer enormous application potential, the commercial success is currently limited to inorganic semiconductor-based PDs due to their mature fabrication process and reliable performance metrics. In this talk, we discuss our efforts to improve the figures of merit of organic photodiodes while streamlining the device architecture. First, a facile and widely applicable "*self-assembly strategy*" is introduced to simplify the architectural design of organic photodiodes with competitive performance metrics, robust stability, and cost effectiveness. [2] Next, we introduce an all-polymer organic photodiode with broadband competence, enabled by a newly designed acceptor material. We further examine how adding a third component significantly improves the figures of merit. The proof-of-concept device demonstrates strong potential in *machine learning-based blood pressure estimation* and *single-pixel imaging in complex imaging environments*, achieving comparable performance to commercial silicon diodes. [3]



Schematic representations of (a) self-assembly strategy and (b) single pixel imaging setup in the scattering environment

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Metal Oxide-Doped Elastomers for Catheter Photodecontamination

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Abstract:

Healthcare-associated infections constitute an enormous healthcare burden, one of the main routes of transmission being via contaminated surfaces, including those of medical devices. Catheters are one example, with ~1 million catheter-associated urinary tract infections annually in the USA alone [1] and bacteriuria being ubiquitous in patients requiring longer-term (>30 days) catheterisation. Clinical improvements are urgently needed and could be achieved through new decontamination strategies.

Photodynamic inactivation using 405-nm violet-blue light [2] has received significant interest as a surface decontamination approach, offering broad-spectrum antimicrobial activity and mammalian cell compatibility. However, it has a lower germicidal efficacy than UV-light. We have previously shown [3] that 405nm light inactivation can be significantly improved by incorporating photocatalytic TiO2 nanoparticles into silicone materials, silicone elastomers being commonly used in catheters. We also demonstrated that etching the surface elastomer to expose embedded nanoparticles further improves efficacy, whilst the resulting nano-scale roughness can also inhibit bacterial attachment.

Here, we report our findings on the screening of alternative photocatalytic nanoparticles to further improve inactivation and on enabling fibre-optic decontamination in catheters, by reducing dopant levels to improve optical transmissibility (as both lumen and outer surface require decontamination) whilst maintaining effective bacterial inactivation. Using PDMS (Sylgard 184) doped with nanoparticles at a 110:1 (w/w, PDMS:particles) ratio, we developed a plate-based, crystal violet assay, with samples seeded with *S. aureus*, to screen the efficacies of TiO2, ZnO and SrTiO3 nanoparticles. Results showed increased photoinactivation (405nm, 31.5 J/cm2) with ZnO doping. Reducing dopant levels (ranging from 1:5 to 1:800) increased light transmission (<2% at 1:5, >35% at 1:800) whilst maintaining significantly enhanced decontamination efficacy compared to non-doped PDMS. Our findings suggest that integrating photocatalytic nanoparticles into catheters would facilitate robust photodecontamination.

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Synthetic Microbiome Platform for Living Cell Medicine

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Abstract:

Modern synthetic biology often focuses on single-cell designs, which can present challenges such as high design complexity, implementation difficulties, and adverse effects on cellular mechanisms. The development of whole-cell bacterial consortium models offers a more robust solution for implementing complex genetic circuits composed of multiple elements. In these adaptations, the tuning and optimization of each individual cell within the consortium are tailored to specific tasks, providing a more reliable, and feasible method with fewer risks of affecting the internal structure and behaviour of the cells. In our study, we demonstrate the advantages of using a consortium to address a real-world problem, namely inflammatory bowel disease (IBD). We present a synthetic microbiome model designed for the diagnosis and therapy of IBD. Our system allows some cells to detect inflammatory biomarkers and localize inflammation regions in the gut using quorum sensing, while other cells can locally produce and release anti-inflammatory drugs. This dual functionality shows efficacy not only in vitro but also in DSS-induced murine models that mimic IBD. Our model effectively reduces inflammation and enables the regulated release of therapeutics. We employ various biomarkers whose efficacy has also been demonstrated in vivo in DSS-induced murine models. Our system is highly flexible and can be easily expanded by incorporating new cells with additional functions into the consortium. This work highlights the promising potential of synthetic microbiomes for developing real-world applications in biomedicine and biotechnology.

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Development of Innovative MIP Based Sensors for Liquid Biopsy

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Abstract:

The development of simple and practical diagnosis methods for cancer biomarkers detection is largely related to huge demands that are emerging in medical diagnostics. In this sense, biochemical sensors yielded significant advancement in the field of biomedical analysis. In the biosensor design, molecular recognition is a fundamental property of biological processes and has been demonstrated to be a powerful analytical tool in the form of antibody/antigen recognition. However, systems based on natural recognition elements have several drawbacks, such as high cost and low stability. Thus, the development of biomimetic receptors able to replace natural antibodies and which can offer improved stability, cost-effectiveness and means of rapid fabrication has received a great deal of attention. In this respect, molecular imprinted polymers (MIPs) are synthetic receptors utilized as memetic antibody for selective molecular recognition which offer valuable opportunities for biosensing purposes providing templates able to non-covalently bind to antigens with the corresponding (imprinted) molecular morphology.

In this study, the development of MIPs based sensors for interleukins detection is reported as potential tool for the realization of easy and portable devices for liquid biopsy. In particular, MIPs have been integrated on different type of sensors, namely Platinum microelectrodes, porous silicon and Bound states In Continuum (BICs) based nanophotonic devices. The biomimetic surface has been obtained by electropolymerization of o-phenylenediamine (o-PD) or chemical synthesis of polydopamine (p-PD) on sensors' surface, in the presence of template molecules. MIP synthesis, template removal and target rebinding have been monitored by electrochemical or optical characterization and Atomic Force Microscopy (AFM). The MIP sensors performance has been tested in both buffer solution and complex matrices demonstrating a high selectivity and LOD in the picomolar range. The novelty of our MIP-based approach relies on the fact that the developed sensors are sensitive and selective: in fact, they can detect molecules at very low concentrations and demonstrated no unspecific interaction with interfering molecules and complex biological matrices.

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Nanoparticles I

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Magnetic Nanoparticles for Magnetic Hyperthermia, Cancer Immune Therapy and Cell Tracking

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Abstract:

Immunotherapy has revolutionized cancer treatment by enrolling potentiated immune cells against tumours. On the other hand, magnetic nanoparticles (MNPs) are a versatile class of nanomaterials with applications in targeted drug delivery, real-time imaging by Magnetic resonance imaging (MRI) and/or magnetic particle imaging (MPI), tumour treatment by magnetic hyperthermia (MHT), and immune modulation via mild magnetic hyperthermia treatment (MHT).[4-6] However, MNP internalization in immune cells remains a challenge for diagnostic applications, including immune cell tracking or therapeutic purpose as for instance when employing immune cells as "Trojan horses" to deliver MNPs for hyperthermia and drug release.

I will here present our recent progress on synthesis of magnetic nanoparticles for efficient magnetic hyperthermia treatment and for MRI and MPI imaging techniques. [4] I will also summarize on our recent progress on magnetic nanoparticles-based immunotherapy studies. More in details, I will focus on a new magnetic method to induce the MNP internalization in immune cells while maintaining viable and functional immune cells. [5] This study has employed Natural killer (NK) cells including either the cell line NK-92 cells, or primary NK cells from healthy donors, but also it has been implemented on T cells as part of adoptive cell therapy. Moreover, it has been validated across different magnetic nanoparticles formulations. We do show that this internalization approach provides to immune cells a magnetic tag useful for magnetic imaging and the nanoparticles uptake does not compromise physiological immune cell functions. Indeed, NK cells carrying MNPs retained their degranulation ability and cytotoxicity against glioblastoma (U87) and neuroblastoma (SH-SY5Y) targets, demonstrating preservation of their physiological functions. This test-tube method for loading nanoparticles offers a simple and clinically usable way to label immune cells. These labelled cells can then be reintroduced into the body to track them and target tumours, combining nanomedicine with cancer immunotherapy. *Acknowledgement*: This work was partially funded by the European Research Council (Consolidator grant GIULIa, contract no. ID N. 101044020).

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Immunomodulatory Nanoplexes: Polycationic and Lipid-Based Platforms for Targeted Drug and Nucleic Acid Delivery

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Abstract:

Oligonucleotides, such as antisense oligonucleotides (ASOs) and small interfering RNA (siRNA), offer powerful strategies for gene silencing and therapeutic intervention across a range of pathological conditions. However, their clinical translation is hampered by systemic instability, rapid degradation, and off-target effects. To overcome these limitations, nanocarrier systems capable of precise and efficient delivery to target cells are essential. Recent advances in lipid-based and cell membrane–derived nanoplexes present a promising strategy to address the shortcomings of traditional delivery platforms. These biomimetic systems enhance nucleic acid protection, extend circulation time, and improve targeting efficacy by leveraging the innate properties of their source cells. In this presentation, we describe our recent work on three classes of immunomodulatory nanoplexes: (1) nanoliposomal formulations for synergistic drug delivery in melanoma; (2) poly(amino-beta-ester) (PBAE) nanoplexes for evaluating biodistribution and metastatic cancer therapy; and (3) extracellular vesicle–mimetic nanoghosts (NGs), derived from plasma membranes of donor cells, which retain surface functionality for targeted delivery.

We demonstrate that liposome-polymer nanoparticles loaded with copper diethyldithiocarbamate and 6-bromo-indirubin-3'-oxime lead to a significant 47% reduction in tumor burden in B16F10 and 76% in YUMM1.7 syngeneic mouse melanoma models—without major acute toxicity [1]. Furthermore, PBAE nanoparticles encapsulating augmented ASOs show potent silencing of oncogenic pathways and improved therapeutic efficacy in metastatic cancer models. Additionally, we explore the osteogenic potential of mesenchymal stem cell–derived NGs (MSC-NGs) for bone tissue engineering. Using a 0.5 mm femoral defect model in C57BL/6J mice, longitudinal live µCT imaging revealed that MSC-NGs significantly accelerated fracture healing, enhanced callus mineralization by day 14, and promoted bone marrow reconstitution by day 21[2]. Finally, we highlight the development of a versatile microfluidic platform for high throughput nanoplexes synthesis and cell spheroid formation [2] as a step forward to clinical translation of our immunomodulatory nanoplexes in oncology, regenerative medicine, and metabolic disease.

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Biological Activity of Silver Nanoparticles Stabilized with Low-Molecular-Weight Polyphenols Against Mouse Neuroblastoma (N2A) Cells

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Abstract:

Numerous studies have demonstrated that the surface properties of silver nanoparticles (AgNPs) play a critical role in modulating their biological activity. It has been shown that the chemical and biological properties of stabilizing agents can be imparted to AgNPs, enhancing their biocidal and anticancer properties. Considering that polyphenols exhibit biocidal properties, possess strong antioxidant activity, and have the potential to prevent the progression of neurodegenerative diseases, it was hypothesized that stabilizing AgNPs with polyphenols would result in synergistic effects. This study aimed to prepare stable AgNPs with comparable morphology but diverse surface properties using gallic acid (GA) and rosmarinic acid (RA) as stabilizing agents and to evaluate their effectiveness in deactivating a model mouse neuroblastoma cell line (N2A). Transmission electron microscopy (TEM) imaging revealed that GAAgNPs and RA-AgNPs were quasi-spherical, with an average size of 15 ± 8 nm. Electrokinetic measurements indicated that the nanoparticles were negatively charged across a wide range of ionic strengths and pH levels. Analysis of the recorded spectra obtained using surface-enhanced Raman spectroscopy (SERS), in comparison with spectra generated through DFT calculations, confirmed that the AgNPs were stabilized by polyphenols and their oxidized forms. The toxicity of AgNPs was evaluated using common biochemical assays, including XTT, LDH, and MDA, among others. Changes in the mitochondrial activity of N2A cells were most pronounced after 48 hours of treatment with an AgNP concentration of 60 mg/L. Disruption of membrane integrity was observed after 24 hours of treatment and was associated with lipid peroxidation, as indicated by the results of the MDA assays. Both types of AgNPs induced concentration-dependent inhibition of SOD activity in a similar manner. Likewise, the secretion of glutathione caused by each type of AgNP was comparable. It was determined that GA-AgNPs and RA-AgNPs were significantly less toxic than silver ions applied in the form of silver nitrate. These findings demonstrate that stabilization of AgNPs with polyphenols influences their toxicity toward N2A cells.

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Targeting tumor associated macrophages (TAM) with vectorized magnetic nanoparticles for anticancer therapies

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Abstract:

Tumor associated macrophages (TAMs) are capable to confer anti-apoptotic and proliferative properties to cancer cells, as well as protecting them against immune attacks and therapies. In lung cancer, they represent between 30 to 50% of the tumor mass. [1] Targeting these pro-tumoral TAMs is a major challenge. Different strategies are used, but they are not specific, potentially leading to adverse effects. Our team produced and patented a monoclonal antibody, 6-25, capable to specifically recognize pro-tumoral TAMs displaying an M2 phenotype. We showed that the 6-25 mAb was internalized in these TAMs without inducing any toxicity. The goal of the project is to produce a tool that specifically targets and kills pro-tumoral TAMs.
Magnetic hyperthermia or magnetomechanical ablation are emerging cancer treatment approaches. The first one induces cell death for cell containing magnetic nanoparticles by increasing the temperature through a high frequency alternating magnetic while the second uses mechanical forces under low frequency rotating magnetic field. We therefore developed a biocompatible and non-toxic magnetic nanoparticle functionalized with the 6-25 mAb (MNP-6-25) as a specific tool to target pro-tumoral TAMs.
To test the feasibility of this method, we performed a robust 3D model of co-cultures with the lung cancer cell line (A549) with M2 macrophages (M2M), or M1 macrophages (M1M) as a negative control. First, using flow cytometry and microscopy, we showed a specific binding of the MNP-6-25 for M2M and not for M1M in this model, and the death of these M2M following the application of a magnetic field. In parallel, we demonstrated that in this 3D model, the M2 phenotype for M2M was maintained as well as the potentiation of the cancer cell proliferation. Future research will focus on the targeting and death of pro-tumoral TAMs in an *in vivo* model.

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Boron-10-doped Carbon Dots for Neutron Capture Therapy – a Theranostic Nanosystem for the Treatment of Glioblastoma Multiforme

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Abstract:

Glioblastoma (GBM) is the most aggressive and prevalent malignant brain tumor, demanding highly targeted therapeutic approaches. Neutron capture therapy (NCT) is a promising modality that involves the accumulation of 10B isotopes in tumor cells, followed by irradiation with low-energy neutrons. This results in the emission of localized, high-linear energy transfer radiation, selectively destroying cancerous cells while sparing healthy tissue [1]. This work aimed to develop and evaluate a nanocarrier system based on 10B-doped carbon dots (CDs) encapsulated in liposomes for enhanced delivery, retention, and uptake in GBM cells. 10B-doped CDs were synthesized via hydrothermal methods and characterized for optical properties, chemical composition, and size distribution. Using a Y-junction microfluidic device, both empty and CDloaded liposomes were produced and purified by overnight dialysis. In vitro studies were performed using the U87 human glioblastoma cell line to assess cellular uptake (via flow cytometry) and cytotoxicity (CellTiter™ assay) of both bare and encapsulated CDs. CDs demonstrated favorable biocompatibility, with cell viability maintained at ~80% up to 1000 µg/mL, although with notable variability. Flow cytometry showed time-dependent uptake, increasing from 2 to 4 hours, and a marked enhancement in uptake for liposome-encapsulated CDs compared to bare CDs. Encapsulation of 10Bdoped CDs into liposomes improves cellular uptake without significant toxicity, supporting their potential for targeted NCT in GBM. Ongoing work includes evaluation in 3D tumor spheroids and preliminary in vivo studies in zebrafish to assess biodistribution and therapeutic efficacy.

[1] P. Singh, et al. *Physica E* 132, (2021)

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Assessing the Cytotoxicity of Zinc Oxide (ZnO) Nanoparticles Across Static and Dynamic Cultures

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Abstract:

In recent years, the growing use of nanomaterials has raised significant concerns about their potential short- and long-term health effects. The risks associated with nanomaterials depend on factors such as dosage, frequency, and duration of exposure [1]. Despite their wide applications, uncertainties regarding their safety may hinder future commercialization. Current nanotoxicology studies, which often rely on cell culture plates, frequently fail to replicate realistic exposure conditions. This limitation is largely due to nanoparticle aggregation and sedimentation, which result in inconsistent exposure levels and potentially misleading results [2]. Therefore, there is an urgent need for improved experimental approaches. To address these challenges, we designed a more physiologically relevant microfluidic system that integrates polymeric microgrooved substrates and can be inserted to a non-linear microscope for real-time imaging. Using this platform, we investigated the effects of zinc oxide (ZnO) nanoparticles on NIH 3T3 cells, focusing on their survival and proliferation under both static and dynamic conditions.

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Advanced Oxygen Sensing Platforms for Live Imaging and Hypoxia Mapping in Complex Cell Systems and Tumor Microenvironment

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Abstract:

The hypoxic microenvironment is a common and salient feature of most solid tumors [1]. Hypoxia has an important effect on the biological behavior and malignant phenotype of cancer cells, mediates the effects of chemo- and immunotherapy through complex mechanisms, and is closely associated with poor prognosis in patients [2]. Thus, monitoring the hypoxic microenvironment is fundamental due to its implication in tumor aggressiveness and progression. Here, we present two oxygen sensing systems for noninvasively measuring, with high spatial and temporal resolution, the extracellular concentration of oxygen in *in vitro* tumor models. The first one is based on core-shell silica-based microparticles functionalized with the oxygen-sensitive indictor probe, Tris (4,7-diphenyl-1,10-phenanthroline) ruthenium(II) dichloride (Ru(dpp)) and the rhodamine B isothiocyanate (RBITC), reference dye [3]. The second system is based on oxygen-sensing fibrous scaffolds of poly(trimethylsilyl)propine (polyPTMS), an oxygen permeable polymer functionalized with the indicator O2 probe Ru(dpp) and the reference dye RIBTC [4]. Both oxygen sensing systems were characterized for their morphology, photostability, reversibility, sensing performance and excellent cytocompatibility, allowing monitoring oxygen gradients over time and space in *in vitro* advanced tumor models. By employing computational analyses, we generated spatial oxygen maps during live cell imaging, revealing oxygen gradients in the extracellular microenvironment and indicating a significant decrease in oxygen level, characteristics of solid tumors. Overall, the optimized sensing systems based on fluorescent microparticles, and fibrous matrices hold potential for real-time and noninvasive assessments of dissolved oxygen levels in *in vitro* 3D cell culture models mimicking the complexity and heterogeneity of the tumour microenvironment.

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3D Pancreatic Cancer Models with Integrated Optical pH Sensors for Noninvasive Metabolism Monitoring and Drug Screening

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Abstract:

A distinct feature of pancreatic ductal adenocarcinoma (PDAC) is a prominent tumor microenvironment (TME) with remarkable cellular and spatial heterogeneity that meaningfully impacts disease biology and treatment resistance [1]. The dynamic crosstalk between cancer cells and the dense stromal compartment leads to spatially and temporally heterogeneous metabolic alterations, such as acidic pH that contributes to drug resistance in PDAC [2, 3]. Thus, monitoring the extracellular pH metabolic fluctuations within the TME is crucial to predict and quantify anticancer drug efficacy. Here, we present a simple and reliable alginate-based 3D PDAC model embedding ratiometric optical pH sensors and cocultures of tumor (AsPC-1) and stromal cells for simultaneously monitoring metabolic pH variations and quantify drug response.[4] 3D alginate microgels, embedding AsPC-1 tumor cells, PSC stromal cells, and FITC/RBITC pH sensors, were generated and treated with chemotherapeutic drugs used in PDAC standard therapy (paclitaxel, folfirinox, and gemcitabine). By means of timelapse confocal laser scanning microscopy (CLSM) coupled with a fully automated computational analysis, the extracellular pH metabolic variations were monitored and quantified over time during drug testing**.** Specifically, 3D tumor-stroma microgels were produced and imaged for 10 h through CLSM in time-lapse mode, with controlled temperature (37 °C) and 5% CO2. Compared to the untreated control, all drugs tested determined a general acidification of the extracellular compartment within the 3D tumour-stroma microgels. Interestingly, after 10 h of treatment more acidic pH values were observed (pH 5.2 for paclitaxel, pH 5.8 for folfirinox, pH 5.7 for gemcitabine) than in the first hour (pH 7.5). On the contrary, the untreated microgel shows a negligible acidification reaching a maximum value of 6.9. Taken together, these data provide a possible correlation between the observed extracellular acidification and the cell inhibition mechanisms induced by the chemotherapy treatments.

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Nanoparticles II

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Hybrid Nanoparticles for Delivery

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Abstract:

Polymers, (inorganic) nanoparticles, and biological molecules can be combined to multifunctional units. Two points will be addressed in particular. First, by integrating nanoparticles in biodegradable polymer matrices the size of the resulting particles can be designed to vary over time. Consequences for endo- and exocytosis will be discussed. This involves the efficiency of particle uptake, as the fate of the particles, which is important considering long-term toxicity. Second, polymers can used for the encapsulation of enzymes. In this way transport of the enzymes into cells is possible via endocytosis. Applications of such internalized enzymes will be discussed.

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Cell-Membranes Derived Nanoparticles as Biomimetic Strategy in Precision Medicine

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Abstract:

In the field of nanomaterials, biomimetic nanoparticles (BNPs) coated with cellular membranes are gaining success [1, 2] for their enhanced biocompatibility, prolonged half-life in bloodstream and targeting abilities to specific tissues [3, 4]. In this scenario, we produced glioblastoma (GBM)-membrane coated polymeric NPs that accumulate in tumours, not only for enhanced permeability and retention (EPR) effect but also for active homotypic targeting. These BNPs, by mimicking the surface antigenic diversity of source cells, exhibited precise drug delivery in 2D/3D *in vitro* models of human GBM revealing a specificity for the target cells four times higher compared to other cell lines. Additionally, the same strategy was used for the development of primary peripheral blood mononuclear cells (PBMCs)-BNPs and red blood cells (RBCs)-BNPs as safe and efficient non-viral gene delivery system for the engineering of CAR-T cells. PBMCs-BNPs showed enhanced uptake when interacting with target cells, thus exhibiting great potential to deliver nucleic acids. Furthermore, RBCs-BNPs modified with a cationic cholesterol derivative enable improved internalization efficiency in autologous PBMCs, when compared with non-functionalized ones. The incorporation of cell-derived membranes onto nanoparticles facilitates biomimetic interactions, mimicking native cell–cell recognition pathways and thereby improving targeting specificity. This technology holds promise for precision medicine applications, by using autologous membrane sources and supporting the development of patient-tailored nanomedicine strategies.

[1] A. Yusuf, et al. *Polymers (Basel)* 15, 1596 (2023)

[2] T. Joseph, et al. *Nanomaterials* 13, 574 (2023)

[3] C. Guido, et al. *Bioengineering* 7, 1 (2020)

[4] C. Guido, et al. *Appl. Sci.* 11, 2173 (2021)

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Towards Smart Scaffolds for 3D Cell Culture Models: Polymeric Nanoparticles as Reporters in Hydrogel Beads

Nikolas Galensowske[1*], Xuan Peng[1], Andreas Schurig[2], Dietmar Appelhans[2] and Larysa Baraban[1]

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Abstract:

Using a microfluidic droplet generation system, we generate polyethylene glycol diacrylate (PEG-DA) hydrogel microbeads with a size of approx. 500 µm by photoinitiated cross-linkage. This approach allows precise manipulation of relevant physical (e.g. stiffness) and biological (e.g. biomarkers) parameters within the hydrogel to mimic conditions of the extracellular matrix *in vivo*. Here, we explore the impact of polymersomes - polymeric hollow nanoparticles consisting of amphiphilic block copolymers [1] – on the proliferation of the tumor cells and *in situ* sensing of the tumor microenvironment. We load the beads with the exemplifying fibrosarcoma cell line HT1080 to show that polymersomes (1) do not influence the growth of cells/spheroids in size, shape or viability and (2) remain stable and detectable over the course of three weeks. First, we show that pyridyldisulfide ethylmethacrylate-(PDSM)-based polymersomes can be noncovalently retained in hydrogel-based 3D tissue culturing systems. Next, our polymersomes can penetrate both the intra- and intercellular space in our *in vitro* tissue models. This qualifies them as innovative intramatrix reporters for spatially high-resolved detection of conditional changes of biological (e.g. cytokines), chemical (e.g. pH) or physical (e.g. stress, light) nature. [1,2] We designed a pH responsive polymersome with the capability of reversible increased permeability at lower pH – a condition change known to occur in cancer tissue[3] - and the capability to encapsulate hydrophilic molecules for trigger-induced signalling. Furthermore, our group has formerly shown that our approach is adaptable for more complex multi-cellline combinations, too.[4] Therefore, our combinatory system can be a significant step in the direction of more comprehensive *in vitro* cancer models and the understanding of tumor-polymersome interactions.

[1] Y. Zhu, et al. *Chem. Sci.* 14, 7411–7437 (2023)

[2] O. Rifaie-Graham, et al. *J. Am. Chem. Soc.* 140, 8027–8036 (2018)

[3] B. Webb, et al. *Nat. Rev. Cancer* 11, 671–677 (2011)

[4] X. Peng, et al. *Adv. Sci*. (accepted 2025, preprint: bioRxiv 2024-08)

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Comparative Adsorption Performance of Regionally Derived Bacterial Nanocellulose (BNC) in Wastewater Remediation

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Abstract:

Heavy metal contamination in wastewater poses severe environmental and health risks, necessitating efficient and sustainable treatment methods that are cost-effective and utilize readily available materials in our environment. Bacterial nanocellulose (BNC) has emerged as a promising sorbent due to its unique structural features, high surface area, biocompatibility, and modifiability. This paper explores the synthesis and production of BNC using bacteria from Antarctic (*Brevundimonas EF1*) and non-Antarctic sources (*Lysinibacillus spp*). The BNCs from the bacteria were harvested by washing thoroughly with distilled water, dried, and used in treating simulated water containing heavy metallic ions (Copper, cadmium, manganese, lead, and iron) at equal concentrations. Scanning electron microscopy was used to compare the morphology of the BNC before and after placing them in solutions of the metallic ions with a concentration of 100 ppm. Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES) was used to determine the concentration of specific chemical elements in samples of the simulated heavy metal solutions before and after the interaction with the BNCs. The efficiency of adsorption was calculated for all the metallic ions. The efficiency percentages of adsorption for the ions: Cu^{2+} Mn^{2+} Pb^{2+} Fe^{3+} Cd^{2+} are (29.23, 81.00, 26.90, 51.81, 43.66) and (0.00, 0.00, 94.02, 62.48, 14.80) for *Brevundimonas* and the *Lysinibacillus*, respectively. The Antarctic BNCs showed more adsorption and affinity for the metallic ions than the non-Antarctic BNCs. BNC-based sorbents can be applied in industrial wastewater treatment due to their environmental and economic advantages. The findings suggest that BNCs are highly effective and eco-friendly, with significant potential for largescale application and future development into multifunctional smart materials for water purification.

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Advanced Materials

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Advanced Materials and AI to Answer Sustainable Society Demands

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Abstract:

In the current digital era, as the world is growing up with smart technology, at the same time our planet is drowning with materials scarcity, a huge number of unrecycled waste and environmental pollution. The world is facing challenges against rapid climate changes and continuous ecological disturbances, caused by the revolutionary growth in socio-economic developments with the fastest growing trend in smart electronics, plastic-based products, and the continuous dependence on non-recyclable raw materials, besides exhausting our natural resources. On the other hand, a huge significant progress in IoT and wearable smart electronics systems is demanding very high-resolution displays of the communication interface and the use of green technologies, exploiting emerging devices beyond silicon, most of them at a nanoscale basis. Moreover, energy is required to foster and power all these demands. For festering progress, the use of AI is a demand to which supercomputers are connected and so, energy demands must be considered as a target for developing novel devices with ultra-low power consuming. As far as energy is concerned, the way to exploit green power sources and ways to storage energy is a clear demand for our progress, as a way forward to minimize the electronic waste (e-waste) caused by the ever-increasing number of disposable electronic devices. The present talk aims to show pathways able to answer to two above identified demands, to which we must add the ones related to minimize the electronic waste (e-waste) caused by the ever-increasing number of disposable electronic devices. By doing so, we aim to contribute to future green products, green powered, and make social awareness of green and sustainable technology, which could revolutionize the industry and society both with new business approaches with smart sustainable lifestyles.

Figure 1. Eco-strategies for next generation materials engineering and applications

[1] D. Nunes, et al *Metal Oxide Series* (ed. G. Korotcenkov) (2025) ISBN 044321656897804432165 65; [2] G. Ferreira, et al *J. Energy Chem.* 102, 230–242 (2024) [3] B. He, et al *Adv. Funct. Mater.* 34, 2316375 (2024); [4] G. Fagas, et al *Nat. Rev. Electr. Eng.* 1, 354–355 (2024)

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IAM4EU –
The co-Programmed Public Private Partnership for Advanced Materials under Horizon Europe

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Abstract:

IAM4EU, the Innovative Advanced Materials for the European Union co-programmed public private partnership for funding under Horizon Europe will be presented.
The partnership took up its work in March 2025 and has a 250m € budget out of the Horizon Europe budget earmarked for the topics developed under it from 2025-2027. The current state and the Strategic Research & Innovation Agenda (SRIA) of IAM4EU and how interested higher education institutions, research organisations, SMEs and larger industries can participate in the multidisciplinary network on innovative advanced materials of IAM-I will be discussed.

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The Molecular Approach to Multifunctional 2D electronics: From High-Performance Pressure Sensors to Neuromorphic Logics

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Abstract:

The exceptional properties of 2D materials can be enhanced, broadened, and optimized through their integration with custom-designed molecules, using the principles of supramolecular chemistry. By harnessing the vast variety of molecules that can be engineered and synthesized with targeted functionalities, it becomes feasible to design 2D materials with tunable physical and chemical properties. This strategy facilitates the development of new functionalities and the creation of multifunctional hybrid systems tailored for electronic applications beyond traditional CMOS technologies, aligning with the "more than Moore" approach focused on functional diversification.[1]

In my lecture I will present our recent findings on the use of chemical approaches to develop flexible pressure sensors with enhanced characteristics and complex multi-responsive opto-electronic devices capable to emulate brain-like logic operations.

On the one hand, by tuning of the employed materials, structural design, and functionality, we have realized graphene-based pressure sensors displaying high sensitivity (742.3 kPa^{-1}) with a linear response extended over a widest window exceeding 800 kPa. Such pressure sensors are endowed with a voltage-controlled highly precise inherent correction of thermal drifts to ultimately enable reliable sensing applications across varying environmental conditions. [2]

On the other hand, we demonstrate that the asymmetric interfacing of 2D semiconductors with stimuli responsive molecules and (bio)polymers enabling dipole modulation at the interface with the semiconductor or acting as reservoir of ion that are controllably released offers a precise tool to achieve high control over the dynamic doping. When such organic-inorganic hybrid van der Waals heterostructures are integrated in field-effect transistors, synaptic plasticity including sensory, short-term, and long-term memory operation can be emulated, paving the way for environmental-friendly neuromorphic computing and energy-efficient 2D optoelectronics.

By combining the best of two worlds, the interfacing of 2D materials with the infinite arsenal of functional molecules available on our planet represents a versatile strategy to harness multifunctionality and boost performance in 2D material-based hybrid devices, towards disruptive technologies addressing global challenges in electronics, sensing, and energy-related applications.[3]

[1] *Chem. Rev.* 122, 50 (2022)
[2] *Adv. Mater.* (in press, 2025, DOI: 10.1002/adma.202503867)
[3a] *Adv. Mater.* 36, 2307359 (2024)
[3b] *Adv. Funct. Mater.* (in press, 2025, DOI: 10.1002/adfm.202509607)

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2D Material Inks Enabled by Supramolecular Chemistry: From Synthesis to Applications

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Abstract:

This talk delves into the role of supramolecular chemistry in achieving in one-pot approach both liquid-phase exfoliation of 2D materials in water and their non-covalent functionalization, hence enabling to produce a wide range of biocompatible 2D materials that retain their intrinsic electronic properties but have specific surface chemistry, determined by the selected supramolecular receptor. [1-2] I will provide examples of applications of such water-based inks in printed transistors and photodetectors, as well as in wearable sensors for breath monitoring. [3]

[1] K. Parvez, et al. *Acc. Chem. Res.* 58, 343 (2025)

[2] J. McManus, et al. *Nat. Nanotechnol.* 12, 343–350 (2017)

[3] L. Chen, et al. *Adv. Mater*. 36, 2312621 (2024)

NanoBio
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Thursday 11th September

Micro-nano Fabrication

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Laser-Surface Processing for Green Hydrogen Energy Storage

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Abstract:

In this presentation a review of our recent work on the application of laser-surface processing in the fabrication of nanostructured metallic electrodes will be presented. These electrodes have been found to exhibit enhanced electrochemical properties and they have been used in water-splitting electrochemical cells where we have found that they produce almost 5 times as much Hydrogen gas when compared with flat metallic electrodes. The enhanced Hydrogen evolution reactivity and electrochemical properties are attributed to the concomitant enlargement of the electrode's electrocatalytic area due to the nanostructured surface and to possible contribution of field enhancement effects arising from the presence of nanoparticle formation during the laser-surface interaction. The details of the experiments as well as the impact of applications of lasers in the energy and environmental sectors will be discussed.

[1] Poimenidis, et al., *Int. J. Hydrog. Energy* 46, 37162 (2021)

[2] Poimenidis, et al., Int. *J. Hydrog. Energy* 47, 9527 (2022)

[3] Poimenidis et al., *Material Sci. Eng. B* 299, 116922 (2024)

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Micro and Nanofabricated, Functional Surfaces and Devices

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Abstract:

Leveraging micro- and nanoengineering, functional surfaces revolutionize interactions between materials and their environment, leading to a new era of advanced materials. Functional surfaces are capable of providing a wide range of applications, i.e., selfcleaning [1], anti-fogging [2], antibacterial action [1] as well as anti-reflection, atmospheric water collection [3] and friction control [4]. These surfaces if incorporated inside devices can significantly improve the performance of microfluidic devices, sensors, and MEMS [5]. In this lecture, the micro-nanofabrication approaches that enable precise control of surface morphology and chemistry, which have been developed in the Laboratory of Advanced Functional Materials and Nanotechnology at the Department of Food Science and Nutrition (DFSN) of the University of the Aegean will be presented together with some state of art applications of these functional surfaces.

[1] G.S. Watson, et al *Acta Biomater.* 21, 109–122 (2015)

[2] I.F. Wahab, et al *J. Mater. Res. Technol.* 23, 687–714 (2023)

[3] D. Nioras, et al *Ind. Eng. Chem. Res.* 63, 20872–20882 (2024)

[4] K. Ellinas, et al *Micro Nano Eng.* 14 (2022)

[5] V. Tselepi, et al *Appl. Therm. Eng.* 272, 126419 (2025)

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Ultrafast Laser Nanostructuring of Molybdenum Thin Films: Thickness Effects on High-Spatial Frequency LIPSS Formation

Stella Maragkaki [1*], Matina Vlahou[1,2], George Perrakis[1], George D. Tsibidis[1] and Emmanuel Stratakis[1,3]

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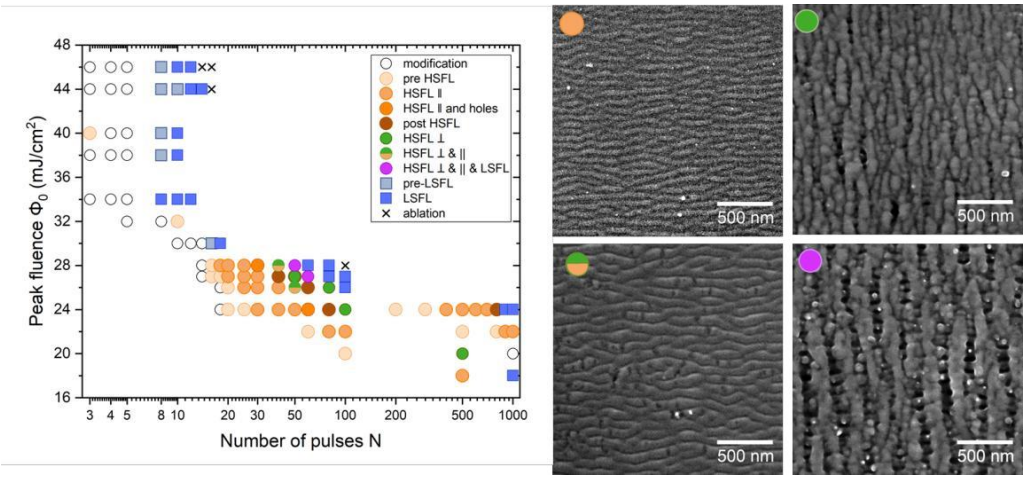
Abstract:

Ultrafast laser nanostructuring offers a versatile route for tailoring surface properties at the nanoscale, with potential applications in photonics, sensing, and bio-interfaces. Here, we investigate how the thickness of molybdenum (Mo) thin films influences the formation of high-spatial frequency laser-induced periodic surface structures (HSFL) under ultraviolet femtosecond irradiation. By systematically varying film thickness and laser parameters, we observe pronounced shifts in ripple periodicity, orientation, and the transition to low-spatial frequency LIPSS (LSFL). Thinner films tend toward more complex nanoscale morphologies. Electromagnetic simulations of near-field distributions corroborate the experimental results, providing insight into the physical mechanisms driving these changes. This study highlights strategies for controlled nanoscale patterning of metallic films for functional surface applications.



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Double-Pulse Femtosecond Laser Fabrication of Highly Ordered Periodic Structures on Au Thin Films Enabling Low-Cost Plasmonic Applications

Fotis Fraggelakis [1], Panagiotis Lingos [1], George D. Tsibidis [1*], Emma Cusworth [2], Nicholas Kay [2], Laura Fumagalli [2], Vasyl G. Kravets [2], Alexander N. Grigorenko [2], Andrei V. Kabashin [3], and Emmanuel Stratakis [1,5]

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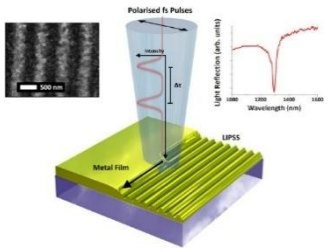
Abstract:

Periodic plasmonic arrays, making possible excitations of surface lattice resonances (SLRs) or quasi-resonant features, are of great importance for biosensing and other applications. Fabrication of such arrays over a large area is typically very costly and time-consuming when performed using conventional electron beam lithography and other methods, which reduce application prospects. Here, we propose a technique of double femtosecond pulse (~170 fs) laser-assisted structuring of thin (~32 nm) Au films deposited on a glass substrate and report a single-step fabrication of homogeneous and highly ordered Au-based laser-induced periodic surface structures (LIPSS) over a large area (Fig. below). Our experimental results unveil the key importance of the interpulse delay as the determining factor rendering possible the homogeneity of laser-induced structures and confirm that highly ordered, functional LIPSS occurs solely upon double pulse irradiation under a specific interpulse delay range. A theoretical investigation complements experimental results, providing significant insights into the structure formation mechanism. Ellipsometric measurements show that such LIPSS structures can exhibit highly valuable plasmonic features in light reflection (Fig. below). In particular, we observed ultranarrow resonances associated with diffraction-coupled SLRs, which are of paramount importance for biosensing and other applications. The presented data suggest that femtosecond double pulse structuring of thin metal films can serve as a valuable and low-cost tool for large-scale fabrication of highly ordered functional elements and structures.

[1] F. Fraggelakis et al, *ACS Nano* 19, 2358 (2025)

Acknowledgement: This work has partially funded from Horizon Europe, the European Union's Framework Programme for Research and Innovation, under Grant Agreement No. 101057457 (*METAMORPHA*).



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Laser Printing of Luminescent YAG:Ce 3D Microstructures

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Abstract:

Yttrium aluminum garnet (YAG) has served as a laser gain medium for over six decades [1]. Traditionally, YAG monocrystals have been synthesized using the Czochralski method [2]. Although various synthesis approaches exist for producing polycrystalline YAG [3,4], none are suitable for fabricating complex three-dimensional (3D) microstructures. This study demonstrates that two-photon polymerization (TPP) laser 3D printing [5], followed by a post-processing calcination step [6,7], enables the fabrication of polycrystalline, luminescent YAG:Ce 3D microstructures. YAG and YAG:Ce precursor 3D objects were produced by a Laser Nanofactory (UAB Femtika) femtosecond laser lithography workstation and using two-photon polymerization 3D printing method for enhanced resolution. 517 nm irradiation wavelength laser of 144 fs pulses was used for the fabrication of 3D microstructures. To study and determine the most optimal production parameters for these materials, 3D arrays of woodpile structures were printed by changing exposure power (intensity) and fabrication time (scanning velocity). After the fabrication, polymerized YAG/YAG:Ce precursor samples were immersed in ethanol to dissolve unpolymerized resin. Afterward, samples were heated first at 800 °C to remove all of the organic matter and later at 1600 °C to produce pure YAG/YAG:Ce. The temperature necessary for the first heating step was determined using the thermogravimetric analysis method. The purity of the calcinated YAG/YAG:Ce samples was also estimated using the single crystal X-ray diffraction analysis method. This was done by obtaining X-ray diffraction data - Debye Scherrer rings, and integrating that data using Bruker Apex 3 software. Finally, luminescence measurements of YAG:Ce were carried out, showing the dependence of Ce concentration on luminescence intensity.

Acknowledgements: This research has been carried out in the framework of the "Universities Excellence Initiative" program by the Ministry of Education, Science and Sports of the Republic of Lithuania under the agreement with the Research Council of Lithuania (project No. S-A-UEI-23-6) and was funded by Vilnius University Research Promotion Fund (project No. MSF-JM-10/2024)

[1] Zac, et al Laserresell (2022); [2] A. Ikesue, et al *Ceramic Lasers* Cambridge University Press (2013)
[3] B. Bettes, et al *Mater. Res. Lett.* 11, 1–20 (2023)
[4] A. Towata, et al *Compos. A* 32, 1127–1131 (2001)
[5] G. Zyla, et al *Laser Photon. Rev.* 18, 2301312 (2024)
[6] G. Merkininkaitė, et al *Opto-Electron. Adv.* 5, 210077 (2022)
[7] A. Harnik, et al *Appl. Mater. Today* in review (2025)

NanoBio
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Thursday 11th September

Nanotechnology in Healthcare I

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Self-Assembled Conductive Fibres in Live Cells

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Abstract:

Self-assembly of molecular components is a naturally occurring process in cells (e.g., cytoskeletal dynamics, organelle formation). Here, we report on the intentional design and harnessing of such processes for therapeutic and technological applications. A small hydrophobic thiophene derivative, DTTO, can bio-generate nanofibers through intracellular self-assembly. We investigated the electronic structure of these fibers using steady-state and time-resolved photoluminescence, as well as transmission spectroscopy [1]. Our results indicate that DTTO monomers within fibers exhibit weak J-type intermolecular coupling. The observation of stimulated emission suggests the possibility of achieving optical gain in these systems. Biological assays on *Escherichia coli* exposed to DTTO provide insights into the stability and biocompatibility of the material. Electrical characterization further demonstrates that these nanofibers display p-type conductivity on the order of 10^{-5} S/cm. Such properties highlight potential applications that will be discussed. Overall, our findings support the emerging concept of self-assembled nanodevices—functional structures generated in situ through the simple injection of monomers into living cells, tissues, or organisms.

[1] F. Monti et al. *Small Sci.* 2500241(2025)

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Ionic Liquid-Assisted Assembly of Human Platelet Lysate-Based Nanoparticles for Antibody Encapsulation

Julián Fuentes[1, 2], Cátia F. Monteiro[1], Ana Beloqui[2], Catarina A. Custódio[1*], João F. Mano[1*]

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Abstract:

Protein-based nanomaterials are increasingly attractive for biomedical applications due to their intrinsic biocompatibility and functional versatility. In this work, a nanocarrier based on methacrylated human platelet lysate (hPLMA), a complex mixture of proteins with therapeutic potential, was developed. Nanoparticle formation was achieved under mild, aqueous conditions through the addition of the biocompatible ionic liquid choline tosylate, which triggered the supramolecular assembly of hPLMA. Circular dichroism spectroscopy confirmed conformational changes in hPLMA proteins upon interaction with the ionic liquid, supporting this mechanism of assembly.

A design of experiments (DOE) approach was used to optimize key parameters, including hPLMA concentration, pH and volume of the ionic liquid, and the rate of its addition to the protein solution. The resulting nanoparticles exhibited narrow size distributions, robust colloidal stability, and a uniform spherical morphology, as confirmed by scanning transmission electron microscopy (STEM).

Immunoglobulin G (IgG) was successfully encapsulated, and *in vitro* release studies demonstrated its sustained release over time. Additionally, cytotoxicity assays performed on DK-MG glioblastoma cells confirmed the excellent biocompatibility of the nanoparticles.

These results support the potential of this platform as a mild and tunable strategy for the development of hPLMA-based nanoparticles with potential in drug delivery applications.

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Bio-Reconfigurable Impedance Based Electronic Platform for Multiplexing Virus Diagnostic

Arianna Adelaide Maurina[1*], Cainã De Oliveira Figares[1], Francesco Damin[2], Chiara Capelli[2], Laura Sola[2], Elena Criscuolo[3], Nicola Clementi[3], Giorgio Ferrari[1], Marco Sampietro[1]

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[2] *SCITEC-CNR, Milan, Italy*

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Abstract:

We present a modular, miniaturized and reconfigurable bioelectronic platform for multiplexed virus diagnostics, based on Differential Impedance Sensing (DIS). This technology enables detection of nucleic acid and protein targets through impedance variations at the electrode–electrolyte interface. The current change is amplified through streptavidinated polymeric beads which bind to the biological complex at the chip interface [1]. The platform integrates seven gold interdigitated microelectrodes (IDEs) on a single chip, each capable of spatially selective biofunctionalization for simultaneous multi-target analysis.

The IDEs are fabricated via maskless photolithography and optimized to achieve high sensitivity (~5 mΩ per bead). A patterned SU8 layer minimizes parasitic coupling, while Lock-In amplification at 6 MHz ensures low-noise, drift-free measurements. The impedance spectrum exhibits a stable resistive plateau, making this frequency region ideal for quantitative sensing.

Validation was conducted with biotinylated oligonucleotides and heat-inactivated SARS-CoV-2 samples. Streptavidinated polymeric beads bind selectively to the probes, generating a measurable and reproducible differential impedance response. For SARSCoV-2, antibodies targeting distinct epitopes of the spike protein enable bead-based amplification via sandwich assays. Functional copolymer chemistry (MCP-4) and high precision spotting support robust probe immobilization and multiplexing capability.

This platform combines long-term electrical stability, high sensitivity, and flexible biofunctionalization design, offering a promising solution for point-of-care diagnostics.

[1] P. Piedimonte, et al. *Biosens. Bioelectron*. 202, 113996 (2022)

NanoBio
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Thursday 11th September

Nanotechnology in Healthcare II

NanoBio
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Conformable Electronics for Biomedical Applications

Gianluca Fiori[1*]

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Abstract:

Conformable and ultrathin electronic systems are a compelling need in biomedical applications, especially in scenarios where intimate contact with soft, curvilinear, or even internal organs is required. Unlike traditional rigid electronics, these systems must be mechanically flexible, minimally invasive, and able to maintain high-performance electrical behavior. Two-dimensional (2D) materials offer an ideal platform thanks to their nanometric thickness, excellent mechanical properties, and promising electronic characteristics [1].
In this talk, we will present a recent hybrid technology platform which integrates semiconducting MoS_2 with inkjet-printed PEDOT:PSS electrodes and a soft organic gate dielectric (polyvinyl formal), all assembled on micrometers-thick polyimide substrates. This approach enables the fabrication of fully conformable transistors and analog/digital circuits with nanoscale thicknesses, offering high flexibility and electrical performance tailored for biomedical use cases [2].
Crucial to the scalability and prototyping of such devices is the development of precision additive manufacturing tools capable of handling 2D materials. Recent advances in high-resolution materials printers enable fast and versatile integration of these materials into functional electronic architectures, dramatically accelerating the development cycle of conformable systems [3].
These innovations pave the way toward next-generation biomedical electronics with unprecedented adaptability and patient comfort.

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Advanced GO-Based Hydrogels for Controlled Hyaluronic Acid Release in Knee Osteoarthritis Treatment

Roya Binaymotlagh[*1], Laura Chronopoulou[1,2], Damiano Petrilli[1], Francesca Sciandra[3], Francesco Amato[1], Andrea Giacomo Marrani[1], Cleofe Palocci[1,2*]

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Abstract:

Osteoarthritis (OA) is a prevalent chronic pain syndrome and a leading cause of disability worldwide, characterized by progressive deterioration of articular cartilage. This degradation leads to pain, swelling, inflammation, and eventual stiffness as the cartilage wears down, causing boneon-bone friction. Current medical treatments primarily aim at pain relief; however, many interventions, especially invasive or surgical ones, carry risks of adverse outcomes. Consequently, intra-articular (IA) therapy, particularly hyaluronic acid (HA) injections, is widely adopted as a conservative treatment option. HA plays a crucial role in maintaining joint homeostasis by supporting proteoglycan synthesis and scaffolding, restoring optimal HA concentrations in synovial fluid, and providing chondroprotective and anti-inflammatory effects. In recent years, hydrogels composed of natural and synthetic materials have emerged as promising candidates for OA treatment. Our research focuses on the biosynthesis and characterization of novel hydrogel composites combining short peptide hydrogelators with graphene oxide (GO) nanosheets functionalized with HA (patent pending). These GO@HA@Hydrogel nanocomposites are designed to facilitate the controlled release of HA into the extracellular matrix, aiming to promote cartilage regeneration and mitigate inflammation. This project harnesses the oxygen-containing functional groups of GO nanosheets to enable covalent coupling or physical adsorption of HA molecules through various chemical approaches. The resulting GO-bioconjugates are incorporated within hydrogel matrices to achieve sustained and controlled HA release. We will systematically study how GO nanofillers influence the native hydrogel structure and its viscoelastic properties, which are critical for mimicking the mechanical environment of native cartilage tissue. Through this multidisciplinary approach combining advanced materials science and cellular biology, this work aims to develop innovative nanocomposite hydrogels capable of delivering HA in a controlled manner, enhancing cartilage repair and providing a potential therapeutic strategy for OA management.

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Instrument-on-a-Chip for Attoampere Detection

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Abstract:

Current measurement is fundamental in most research fields, spanning from biological applications to material science, from nanotechnology devices to molecular systems, to mention only a few. As devices shrink to the nanoscale and increasingly more subtle physical phenomena are investigated, requirements on current resolution are pushed to extremely high levels.

In this work, we present an integrated current front-end capable of resolving attoamperes (1 aA ≈ 6 electrons/s) in a few seconds. The key component that allows this sensitivity is a reset network based on tunneling and/or hot-electron injection that introduces virtually no leakage (< 1 aA) and no noise (< 20 aA/√Hz) when not activated, unlocking the full potential of a capacitive transimpedance amplifier as a current frontend.

Implemented in standard Complementary Metal-Oxide-Semiconductor (CMOS) technology, the proposed solution shows the characteristic advantages of miniature scale of the overall system (3.5 mm x 3.5 mm) and the potential for multichannel operation. The system can be operated with diverse settings, offering a trade-off between speed and resolution: for 100 ms of averaging time (Tavg), the current resolution is of 1.3 fArms, whereas for Tavg = 10 s a resolution of 13 aArms is achieved.

We highlight the challenges related to preserving the high resolution of the system when interfacing it with a device. Namely, leakage currents, may overwhelm the attoampere currents of interest. We show the operation of the system in a dry and wet environment when interfaced with a gold electrode post-processed on the surface of the chip.

For a dry environment, leakage current is on the order of 10's of femtoamperes and are due to the surface conductivity of the chip, which is associated to ionic contamination and the presence of adsorbed water. By appropriate cleaning and rendering the surface hydrophobic, we show a reduction on the leakage current by 3 orders of magnitude, down to a few attoamperes. In liquid, leakage current is dominated by charge exchange at the electrode-electrolyte interface, which can be mitigated by passivation with a Self-Assembled Monolayer (SAM) such as 6-mercapto-1-hexanol. The unprecedented attoampere resolution places the proposed system at the core of any advanced application where extremely small levels of current should be detected.

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Unraveling the Mechanisms of Complexation and Thermal Stabilization of a Model Protein/Polyelectrolyte system

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Abstract:

Studying protein-polymer complexes at the molecular level is crucial for understanding how polymers interact with proteins, affecting their stability and function. The complexation process of Lysozyme (LYZ) and poly(acrylic acid) (PAA) is highly dependent on pH and temperature, affecting both the stability and binding dynamics of the interaction network. Using atomistic molecular dynamics simulations, we explored how these environmental factors shape the binding strength, molecular rearrangements and conformational adaptability of the [LYZ-PAA] complexes. The energetic results reveal that pH has a pronounced effect on the resulting complexes, where higher pH disrupts protein-polymer interactions due to increased electrostatic repulsion, weakening complex formation. At the same time, increase in temperature and thus in molecular mobility, lead to more transient and fluctuating interactions while maintaining overall binding stability. Furthermore, atomistic simulations reveal a partially reversible effect upon thermal treatment. With temperature change distinct amino acids are found to exhibit the closest proximity to PAA, resulting into different PAA/Lysozyme interactions and consequently, a different complexation pathway is followed. These findings support corresponding experimental observations regarding the stabilization of thermally treated samples.

[1] M. Arnittali, et al *Polymers* 16, 2565 (2024)

[2] A. Papagiannopoulos, et al *Carbohydr. Polym.* 218, 218–225 (2019)

[3] S. Ektirici, et al *ACS Omega* (2025) under review

NanoBio
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Thursday 11th September

Bio-nanomaterials III

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Engineering Neuromorphic Biomaterials for Neuroelectronic Applications

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Abstract:

The design of neuromorphic interfaces that integrate seamlessly with biological systems remains a pivotal challenge in neuroelectronics. Here conductive polymers offer unique opportunities to bridge synthetic and biological realms by emulating the structure, function, and adaptability of neural tissue. We focus on the development of bioinspired neuromorphic devices using organic electrochemical transistors (OECTs) based on PEDOT:PSS, engineered with nanoscale dimensionality and tailored for ionic-electronic signal transduction. These devices exhibit synaptic functionalities such as short-term facilitation and long-term potentiation, governed by neurotransmitter-mediated mechanisms.
We further investigate how dimensionality, from planar to pseudo-3D and 3D nanostructured surfaces, modulates cellular adhesion, membrane deformation, and signal transduction efficiency. Employing conductive scaffolds and microstructures, we demonstrate how topographical cues direct neuronal outgrowth and enhance cell material coupling. The incorporation of native and synthetic lipid bilayers at the bio-interface introduces a biomimetic layer that facilitates selective ion transport and enables more physiologically relevant communication with neuronal cells.
This research underscores the role of biomaterials in the construction of adaptive, dynamic interfaces capable of real-time interaction with biological tissues. Our approach opens new avenues for implantable neuromorphic systems, brain-machine interfaces, and next-generation biohybrid computing platforms.

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Living Electrical Cables

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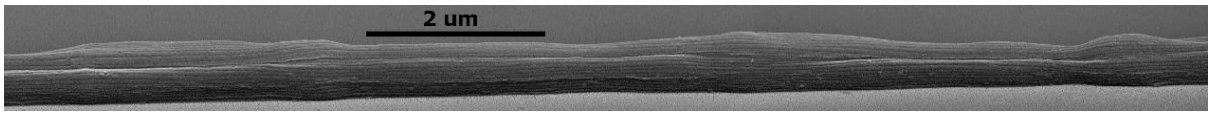
Abstract:

Being able to transport electrical charges is essential for living organisms, which have developed conducting structures to support their life-sustaining pathways [1,2]. Such transport traditionally occurs on nanometer to micron scales [3,4], and with conductivity values that are orders of magnitude lower than those for organic conductors. One organism stands out from all the others, being able to conduct electricity over centimeter distances and more efficiently than any pristine conductive polymer [5]: cable bacteria. These multicellular organisms form centimeter-long filaments, and possess conductive fibers that run uninterrupted along the surface of the whole chain [6]. Traditional transport models for biological conduction fail when applied to cable bacteria [7] and the metal-organic framework that allows for such high conductivities is only partially understood [8,9].
We perform electrical characterization on short segments of the conductive fiber structure, with the aim to unveil its charge transport mechanism. By studying how conduction changes as a function of temperature, we identify the relevant energy scales at play and identify different transport regimes. We notice significant similarities with transport experiments on other organic and inorganic systems, hinting at 1D conduction mechanisms that have never been previously observed in biological systems.



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Friday 12th September

DYNASTY Workshop and Summer School in 2D Materials

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(Tutorial Lecture)
Exciton Formation in 2D Semiconductors

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Abstract:

Robust excitons dominate the optical properties of atomically thin semiconductors based on transition-metal dichalcogenides (TMDs). The use of fully encapsulated hexagonal boron nitride (hBN) and charge-tunable (CT) TMD monolayers (MLs) allow the electrostatic doping of the MLs, thereby substantially improving the control of exciton complexes. Exciton relaxation and formation dynamics in TMDs have been extensively studied by time-resolved optical spectroscopies. Nonetheless, a crucial question persists: What is the exciton formation mechanism, and how does this process occur in two-dimensional semiconductor systems? This study addresses this fundamental problem through polarization-dependent micro-photoluminescence (PL) studies performed at cryogenic temperatures (4K) on fully hBN-encapsulated and CT TMD monolayers close to the neutrality point. The results of our experiments performed on both WSe_2 and MoS_2 MLs clarify the role played by the two potential formation mechanisms: a) geminate and b) bimolecular. The geminate exciton formation process corresponds to the monomolecular annihilation of the photogenerated correlated electron-hole pair. In contrast the non-geminate formation results from the random bimolecular binding of two free charges, losing all correlation between the excitation photon and the electron-hole pair of the exciton.
For a laser excitation energy below the band gap, we show that the geminate mechanism prevails as expected, whereas above the band gap, both geminate and bimolecular phenomena coexist. These results bring precious information on the exciton formation mechanism in 2D semiconductors, which is crucial for the optoelectronic applications of these materials.

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Elastic Screening of Pseudogauge Fields in Graphene

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Abstract:

Lattice deformations in graphene couple to the low-energy electronic degrees of freedom as effective scalar and gauge fields. Using molecular dynamics simulations, we show that the optical component of the displacement field, i.e., the relative motion of different sublattices, contributes at equal order as the acoustic component and effectively screens the pseudogauge fields. In particular, we illustrate this effect for twisted bilayer graphene and corrugated monolayer graphene [1]. In both cases, optical lattice displacements significantly reduce the overall magnitude of the pseudomagnetic fields. For corrugated graphene, optical contributions also reshape the pseudomagnetic field and significantly modify the electronic bands near charge neutrality. Previous studies based on continuum elasticity, which ignores this effect, have therefore systematically overestimated the strength of the strain-induced pseudomagnetic field. Our results have important consequences for the interpretation of experiments and design of straintronic applications. Furthermore, similar considerations must be considered for other two-dimensional materials where both acoustic and optical lattice displacements are expected to contribute significantly to the optoelectronic properties of these materials.

[1] C. De Beule, et al. *Phys. Rev. Lett.* 134, 046404 (2025)

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Topochemical Reactions from Monoelemental Xenes to MXenes

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Abstract:

The Xenes represent a rapidly developing family of monoelemental two-dimensional (2D) materials. The chemistry of monoelemental materials from the tetrel group will be presented, with a detailed discussion of various synthesis strategies and chemical exfoliation techniques based on topochemical deintercalation and exfoliation. The differences between the exfoliation of pnictogens and tetrels will be highlighted, comparing chemical and mechanical exfoliation approaches [1]. In addition, methods for synthesizing 2D compounds across all main group elements, as well as techniques for crystal growth, will be discussed. MXene synthesis is closely related to approaches used for tetrel-based Xenes, involving selective etching of elements from parent layered carbides through topochemical deintercalation and exfoliation. The surface chemistry of MXenes and their functionalization strategies will be presented. In particular, siloxane chemistry enables the effective introduction of various organic groups onto the MXene surface, expanding their range of applications. Furthermore, direct reactions with chalcogens enable modification of surface functional groups and, at elevated temperatures, the formation of composite systems through the direct synthesis of transition metal dichalcogenides. Such direct topochemical conversion of MXenes yields composite materials and chalcogen-terminated MXene surfaces.

[1] T. Hartman, et al., *ACS Nano*, 14, 7319 (2020)

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Alloy-Driven Tuning of Bandgap, Spin-Orbit Splitting and Phonon Energy in 2D Mo-Based TMDs

Panayiotis Spiliotakis[1,2], Eirini Katsipoulaki[1,3], Danae Katrisioti[1,2], Konstantinos Mourzidis[4], Takashi Taniguchi[5], Kenji Watanabe[6], Georgios Kopidakis[1,2], Emmanuel Stratakis[1,3], Xavier Marie[4,7], George Kioseoglou[1,2] and Ioannis Paradisanos[1*]

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Abstract:

Two-dimensional transition metal dichalcogenides (TMDs) provide a highly tunable platform for exploring excitonic and vibrational phenomena in the atomically thin limit[1]. This work presents a systematic investigation of the evolution of optical properties in a series of Mo-based TMD monolayers with varying chalcogen composition, in the alloy system $MoS_2xSe_2(1-x)$, where x ranges from 0 to 1.

The optical bandgap is found to decrease continuously from 1.9 eV in MoS_2 to 1.55 eV in $MoSe_2$, tracking the substitution of sulfur with selenium. At the same time, the A-B exciton splitting increases from 150 meV to 200 meV, reflecting the influence of chalcogen composition on spin–orbit coupling. Additionally, the average phonon energy varies from approximately 24 meV (MoS_2) to 19 meV ($MoSe_2$), indicating systematic modifications in lattice vibrational properties across the alloy series.

These findings demonstrate that chalcogen composition offers an effective means to tune the optical response of Mo-based TMD monolayers. The observed trends provide valuable insights into the excitonic and vibrational behavior of 2D alloys, with direct implications for the development of tunable photonic, optoelectronic, and valleytronic devices.

[1] S. Shree, I. Paradisanos et al. *Nat Rev Phys* 3, 39–54 (2021)

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(Tutorial Lecture)
Tuning the Optoelectronic Properties of 2D-TMDs via Dielectric Engineering

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Abstract:

Nanoscale-engineered surfaces induce regulated strain in atomic layers of 2-dimensional (2D) materials that could be useful for unprecedented photonics applications and for storing and processing quantum information. This work presents textured induced strain distribution in single layers of WS_2 (1L-WS_2) transferred over Si/SiO_2 (285nm) substrates [1]. The detailed nanoscale landscapes and their optical detection are carried out through AFM, SEM and optical spectroscopy. Remarkable differences have been observed in the WS_2 sheet localized in the confined well and at the periphery of the cylindrical geometry of the capped engineered surface. Raman spectroscopy independently maps the whole landscape of the samples. Temperature dependent helicity-resolved Photoluminescence (PL) experiments (off-resonance excitation), show that suspended areas sustain circular polarization from 150 K up to 300 K, in contrast to supported (on un-patterned area of Si/SiO_2) and strained 1L-WS_2.
These findings highlight the impact of dielectric environment on the optical properties of 2D materials, providing valuable insights into the selection of appropriate substrates for implementing atomically thin materials in advanced optoelectronic devices.

Acknowledgement: This work was supported by the EU-funded DYNANSTY project, ID:101079179, under the Horizon Europe framework programme

[1] G. Kourmoulakis, et al., *Nanomaterials* 14, 1437 (2024)

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(Tutorial Lecture)

Low Dose Electron Microscopy Imaging, One Electron at a Time

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Abstract:

Transmission electron microscopy is an indispensable tool providing a direct image of matter down to its atomic structure. Nanotechnology relies entirely on it and in life science imaging, it is responsible for most of what we know about the structure of proteins, viruses and cell constituents. Imaging with electrons however also has the drawback that the strong interaction can cause damage through structural changes. In this talk, we will look into how modern detectors and computational methods are reshaping this field. We now can build up images literally one electron at a time allowing to strike the most optimal balance between information gained and damage created.

[1] A. Annys, et al. *Preprint* (2025), https://arxiv.org/abs/2505.06602

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Twist-angle Tuned Second Harmonic Generation in 2D Transition Metal Dichalcogenide Homo- and Heterobilayers

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Abstract:

Two-dimensional (2D) transition metal dichalcogenide (TMD) monolayers (MLs) exhibit second harmonic generation (SHG) due to their non-centrosymmetric crystal structure along their armchair direction [1]. The 2D TMDs can be vertically stacked via van der Waals forces, enabling interlayer coupling between the MLs [2]. Such coupling gives rise to emergent physical phenomena that are highly sensitive to the twist-angle between the MLs [3]. Furthermore, the stacked MLs generate interference SHG, which is also strongly dependent on their twist-angle [4-6].

Here, we show that tuning the twist-angle in 2D TMD homo- and hetero-bilayers allows accurate control over both the intensity and the polarization of the SHG signals. Moreover, we demonstrate that these SHG signals can be used to precisely determine the twist-angle between the stacked MLs.

The ability to tailor the intensity and the polarization of SHG signals by adjusting the twist-angle between MLs, represents a significant advancement for next-generation 2D nonlinear optical materials. Additionally, the produced SHG signals enable rapid, non-invasive and large-area mapping of the twist-angle, which is invaluable for the characterization of twisted 2D devices.

Acknowledgements: This work has been supported by the EU-funded project DYNASTY under the Horizon Europe framework programme (Grant Agreement number: GA 101079179]). SP acknowledges DemosAxia project under the Horizon Europe framework programme (Grant Agreement number: GA 101160387)

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[3] L. Mouchliadis, et al. *npj 2D Mater. Appl* 5, 6, (2021)

[4] S. Psilodimitrakopoulos, et al. *2D Mater* 8, 015015, (2021)

[5] S. Psilodimitrakopoulos et al. *npj 2D Mater Appl* 5, 77, (2021)

[6] S. Psilodimitrakopoulos et al. *Nanophotonics* 13, 3181, (2024)

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Exploring 2D materials with Theory and Simulation

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Abstract:

Two-dimensional (2D) materials of atomic thickness exhibit interesting physics and show great promise in electronics, optoelectronics, quantum technologies, catalysis, clean energy and environment applications. Beyond graphene, many 2D materials with diverse electronic properties are being intensively explored. Layer by layer stacking of monolayers gives rise to van der Waals heterostructures of nanometer thickness and clean interfaces. Electronic properties are strongly affected by strain, nanostructuring, structural and chemical defects, disorder, generating a wide range of 2D nanostructures with novel features, possibilities and challenges. Theory and simulation play a crucial role in answering emerging fundamental questions and identifying candidate materials with properties tailored for specific applications. First-principles calculations for the solution of the quantum mechanical problem are the main tool for atomic-scale understanding of these materials but face serious challenges in non-periodic and multi-component systems. We will present theoretical and computational approaches used by our research group for overcoming such challenges, with results that often explain observations and make useful predictions, thus assisting and, sometimes, guiding experiments. Finally, we will briefly discuss efforts to combine theory, multi-scale modeling/simulation, and machine learning to accelerate progress in fundamental and applied aspects of 2D materials research.

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Silicon Nanoantennas for Tailoring the Optical Properties of MoS_2 Monolayers

Danae Katrisioti[1,2*], Peter R. Wiecha[3], Aurélien Cuche[4], Sotiris Psilodimitrakopoulos[1], Guilhem Larrieu[3], Jonas Müller[3], Vincent Larrey[5], Bernhard Urbaszek[6], Xavier Marie[7,8], Emmanuel Stratakis[1], George Kioseoglou[1,2], Vincent Paillard[4], Jean-Marie Poumirol[4] and Ioannis Paradisanos[1],

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Abstract:

Silicon-based dielectric nanoantennas provide an effective platform for engineering light-matter interactions in van der Waals semiconductors [1]. We demonstrate nearfield coupling between monolayer MoS_2 and silicon-based dielectric nanoantennas arranged in hexagonal lattices with tunable geometries. This interaction leads to a three-fold enhancement in photoluminescence and excitation-wavelength-dependent emission aligned with Mie-resonant modes. Raman spectroscopy reveals up to an 8- fold enhancement in the vibrational modes of MoS_2, while second-harmonic generation exhibits a 20–30-fold increase in efficiency, tightly correlated with the nanoantenna resonances.
Through a combination of photoluminescence excitation (PLE) spectroscopy, polarization-resolved photoluminescence, atomic force microscopy, and numerical simulations, we decouple the roles of strain, thin-film interference, and Purcell enhancement in modifying the optical response. These results highlight the tunable nature of near-field interactions in 2D materials and establish dielectric Mie-resonant structures as a scalable, CMOS-compatible platform for engineering both linear and nonlinear optical properties at the nanoscale.

[1] R. Won, *Nat. Photonics* 13, 585–587 (2019)

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Atomic-Scale Imaging of Moiré Superlattices in Twisted Transition Metal Oxide Membranes

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Abstract:

Heterostructures composed of dissimilar materials have been pivotal in advancing nanoscale science, particularly through the study of two-dimensional (2D) materials and van der Waals interfaces. Recent breakthroughs in fabrication now allow the creation of freestanding complex oxide films approaching monolayer thickness [1] — opening new directions to explore the rich functional landscape of transition metal oxides (TMOs).

A key feature of these systems is the formation of Moiré superlattices, emerging from twisted bilayer configurations. These nanoscale interference patterns can induce unprecedented electronic, optical, magnetic, and mechanical properties—absent in the untwisted or bulk forms of the same materials. [2]

In this study, we apply advanced Scanning Transmission Electron Microscopy (STEM), including annular dark field (ADF) imaging and four-dimensional STEM (4DSTEM), to directly visualize the local atomic structure of twisted TMO membranes. While such techniques are well-established in the 2D materials field [3], this marks their first application to freestanding oxide heterostructures.

Complemented by simulations and Density Functional Theory (DFT) calculations, our findings reveal chiral lattice distortions and structural modulations directly linked to the twist angle.

[1] S. Choo, et al *Sci. Adv.* 10, eadq8561 (2024); F.M. Chiabrera, et al *Ann. Phys. (Berl.)* 534, 2200084 (2022)

[2] E.Y. Andrey, et al *Nat. Rev. Mater.* 6, 201–206 (2021); N. Pryds, et al *APL Mater.* 12, 010901 (2024)

[3] N.P. Kazmierczak, et al *Nat. Mater.* 20, 956–963 (2021); I.M. Craig, et al *Nat. Mater.* 23, 323–330 (2024)

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Engineering Carrier Density and Exciton Polarization in WSe_2 Monolayers via Photochlorination

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Abstract:

Transition Metal Dichalcogenides (TMDs) of the form MX_2 (M = Mo, W and X=S, Se, Te) represent a special class of 2D van der Waals materials. Unlike their 3D-counterparts, which are indirect gap semiconductors, MX_2 monolayers exhibit a direct bandgap, leading to a significant enhancement in photoluminescence quantum yield. Moreover, TMDs feature valley dependent optical selection rules, establishing them as promising candidates for atomically thin optoelectronic devices and spin-valley memory applications. A key factor influencing the performance of TMDs in these applications is the carrier density. To address this, we demonstrate the modulation of the Fermi level in WSe_2 monolayers using an ultraviolet-assisted photochlorination method. Systematic shifts and relative intensities between charged and neutral excitons indicate a progressive and controllable decrease of the electron density and switch WSe_2 from n- to a p-type semiconductor. Density functional theory predicts Cl_2 adsorption at Se vacancies drives p-type doping, while X-ray photoelectron spectroscopy confirms the incorporation of chlorine [1]. Furthermore, this method can strongly impact the circular polarization degree of excitons, demonstrating its potential to control exciton-carrier scattering processes [2]. These findings indicate that photochemical techniques can be utilized to tailor nanopatterned lateral p-n junctions, while also highlighting their potential for engineering valley relaxation phenomena.

[1] E. Katsipoulaki, et al. *2D Mater* 10, 045008 (2023); [2] E. Katsipoulaki, et al. *Adv. Optical Mater.* e00575 (2025)

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POSTER SESSION: Bio-Nanomaterials

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Surface modification approaches for obtaining multifunctional surfaces in dentistry applications

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Abstract:

Dental implantology's material requirements include a lack of potential for inducing allergic disorders and providing both functional and esthetic features for the patient's benefit. In the last years, laser-based surface modification techniques have emerged as transformative tools for enhancing the interface of dental materials and implants. This work presents approaches in surface modification involving laser texturing, structuring, and functionalization of key dental substrates (e.g. titanium, zirconia ceramics). For example, Zirconia ceramics have become a candidate of interest to be used as an alternative to titanium dental implants, implying the need for endowing the surface with biologically instructive properties by changing basic parameters such as surface texture or chemistry. Within this context, we propose anisotropic and isotropic patterns (linear microgroove arrays, and superimposed crossline microgroove arrays, respectively) textured in zirconia substrates, as bioinstructive interfaces to be used for future cellular guidance. The designed textured micronano interfaces with either steep ridges and microgratings or curved edges, and nanoroughened walls obtained by direct femtosecond laser texturing were analyzed by Scanning Electron Microscopy, Atomic Force Microscopy, contact angle and surface energy measurements. Our results show that femtosecond laser texturing was shown to provide precise control over surface topography (microgrooves, nanopores, hierarchical textures) as well as maintaining surface chemistry without thermal damage or contamination. In addition, Matrix Assisted Pulsed Laser evaporation was shown to have the ability to create complex bioinspired morphologies as hybrid or composite coatings based on PCL and HA on top of the textured surfaces. Therefore, combining laser structuring with bioactive coatings multifunctional surfaces can hold exceptional promise for next-generation dental restorations, implants.

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miR-1-3p Enhances VEGF Secretion and Fibroblast Function in Diabetic Wound Healing

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Abstract:

Diabetes mellitus (DM) is a chronic metabolic disease characterized by hyperglycemia and insulin resistance, which impairs wound healing. Diabetic foot ulcers remain difficult to treat due to reduced angiogenesis, chronic inflammation, and fibroblast dysfunction—key barriers to effective tissue repair. MicroRNAs (miRNAs), which regulate gene expression post-transcriptionally, offer promising therapeutic potential for restoring regenerative capacity.

We identified a specific miRNA, miR-1-3p, as significantly downregulated in dermal fibroblasts from type 2 diabetic donors compared to non-diabetic controls (n=6/group, fold change < –2, adj. $p < 0.05$). We hypothesized that restoring miR-1-3p would enhance fibroblast-mediated healing through vascular endothelial growth factor (VEGF) secretion and insulin signaling modulation. Diabetic fibroblasts transfected with miR-1-3p mimics exhibited a 2.3-fold increase in migration and a 1.9-fold rise in basal VEGF secretion, which further increased 3–3.5-fold with insulin ($p < 0.01$). VEGF mRNA levels remained unchanged, suggesting post-transcriptional regulation. Western blotting revealed increased phosphorylation of AKT (2.8–3.9-fold) and IRS1, with reduced PI3KC2A protein levels despite stable mRNA expression.

In vivo, topical delivery of miR-1-3p via hydrogel accelerated wound closure in diabetic nude mice, surpassing non-diabetic controls by day 6. While sample size was limited, the results indicate that miR-1-3p enhances angiogenesis and insulin responsiveness via post-transcriptional control. These findings position miR-1-3p as a promising therapeutic candidate for diabetic wound healing and vascular regeneration.

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Transient absorption spectroscopy of the Fucoxanthin-Chlorophyll *a/c* (FCPs) Proteins of the Marine Diatoms *Fragilariopsis sp* and *P. Tricornutum*

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Abstract:

Marine Diatoms contribute to oxygenic photosynthesis and carbon fixation and handle large changes under variable light intensity on a regular basis. The unique lightharvesting apparatus of diatoms are the Fucoxanthin-Chlorophyll *a/c*-binding proteins (FCPs). Here, we show the enhancement of Chlorophyll *a/c* (Chl *a/c*), Fucoxanthin (Fx), and Diadinoxanthin (Dd) marker bands in the Raman spectra of the diatoms *Fragilariopsis sp* and *P. tricornutum* , which allows distinction of the pigment content in the cells grown under low-(LL) and high-light (HL) intensity at room temperature. Reversible LL-HL dependent conformations of Chl *c*, characteristic of a planar and nonplanar configuration of the porphyrin macrocycle, and the presence of five-and sixcoordinated Chl *a/c* with weak axial ligands are observed in the Raman data. Under HL the energy transfer from Chl *c* to Chl *a* is reduced and that from the red-shifted Fxs is minimum. Therefore, Chl *c* and the blue-shifted Fxs are the only contributors to the energy transfer pathways under HL and the blue- to red-shifted Fxs energy transfer pathway characteristic of the LL is inactive. We suggest that the light intensity dependent conformational changes of the pigments affect the excitonic coupling of the complexes involved in the emission. The excited state dynamics of Fx probed by time resolved fs absorption spectroscopy will also be presented.

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Tumoral cell identification by label-free machine learning spectroscopy

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Abstract:

According to the World Health Organization, cancer is the second leading cause of death worldwide, accounting for 9.6 million deaths annually. Several factors contribute to this high mortality rate, including limited access to diagnostic facilities, high costs of laboratory pathology, diagnostic errors, and late-stage disease detection. Therefore, it is crucial to develop diagnostic strategies that address these challenges. In this paper, we present a label-free spectroscopic approach that differentiates cultures of tumor cells from those of normal cells using machine learning (ML). Human cell lines squamous cell carcinoma (A431), tongue squamous cell carcinoma (SCC-4), pharynx carcinoma (FaDU), and human keratinocyte cells (HaCat) were analyzed. Cell cultures were measured by spectroscopic ellipsometry at a fixed 55 ° from 240 nm to 1700 nm. Our findings demonstrated elevated performance for two-class classification with accuracies above 92%, and for multi-class classification with an accuracy of 86%. Our results highlight the promising potential of this label-free approach for applications in oncology. The successful integration of spectroscopy and ML demonstrates the potential of this methodology as a practical, accessible, and cost-effective solution for cancer diagnosis and prognosis.

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Non-specific optical sensing for label-free diagnosis of the effects of COVID-19 in semen

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Abstract:

The male reproductive system can be affected by viral infections, which may impact reproductive function and fertility. Although seminal parameters generally return to normal after recovering from the illness, there may still be subtle changes that affect reproductive outcomes. These changes may not be detectable using standard protocols for semen analysis outlined by the World Health Organization (WHO). This study investigates the use of a novel intelligent optical sensing approach to diagnose the effect of COVID-19 in the semen of men. The study involved collecting semen samples from COVID-19-recovered men and a control group with no history of infection. The semen samples of both groups were considered within normality by the WHO criteria. The specular reflectivity spectra of the semen samples were recorded and processed by machine learning (ML) algorithms as an array of 674 non-specific optical sensors. The Support Vector Machine ML model demonstrated the best performance with an accuracy of 92%. The acquired data was also used to realistically simulate the performance of a low-cost optoelectronic sensor, utilizing a very small aliquot of ejaculate, a white LED, and a 6-channel multispectral sensor. The simulations demonstrate a good accuracy of 82%. Furthermore, an ML analysis of the spermogram data revealed clear differences between both groups of samples, supporting the results of both sensing approaches. These results indicate that the use of artificial intelligence to process information from arrays of non-specific sensors can be effective in the diagnosis of the prolonged effects of COVID-19 in the semen of men who have already recovered from the illness, and that traditional seminal analysis methods fail to reveal.

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Silver Nanostructures for Antimicrobial and Light-Activated Therapies

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Abstract:

The escalating prevalence of antibiotic-resistant bacterial infections represents a critical global health challenge. If this trend continues unchecked, such infections may become a leading cause of mortality worldwide. This alarming situation underscores the urgent need for novel antimicrobial agents and alternative therapeutic strategies that circumvent conventional antibiotic mechanisms. Among emerging candidates, silver nanoparticles (AgNPs) have demonstrated potent antibacterial activity at low concentrations while maintaining minimal toxicity toward mammalian cells. They can act as standalone antimicrobials or function synergistically with antibiotics that have lost efficacy against resistant strains, thereby restoring therapeutic effectiveness at significantly reduced doses [1, 2]. Importantly, the therapeutic potential of AgNPs extends beyond their antimicrobial properties. Through precise control of their size, shape, and localized surface plasmon resonance, these nanostructures exhibit tunable photothermal effects - converting light energy into heat, leading to localized hyperthermia and cellular damage. This property opens new avenues for light-activated therapies, including antibacterial and anticancer applications, as well as advanced strategies for disease treatment and mechanistic studies of pathophysiological processes [3]. Thus, silver nanostructures represent a versatile platform for both conventional and light-mediated therapies, offering a promising alternative in the fight against multidrugresistant infections and other biomedical challenges.

[1] L. Hochvaldová, et al. *Nanotechnology Reviews*, 11, 1115–1142 (2022)

[2] L. Hochvaldová, et al. *Scientific Reports*, 12, 1–9 (2022)

[3] M. Mistrik et al. *Nature Communications*, 12, 1-11 (2021)

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In vitro cytotoxicity of thin-film neural probes based on reduced graphene oxide

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Abstract:

Our research is part of the MINIGRAPH EIC Pathfinder project (https://minigraphproject.eu) in which the main goal is to develop a next-generation neuroelectronic therapy designed to meet critical needs in brain–computer interface technology. The Minigraph consorcium aims to engineer a highly miniaturized, biocompatible brain implant with closed-loop capabilities, integrating a skull-mounted flexible electronics unit and high-density arrays of graphene-based microelectrodes and thus achieve superior spatial resolution and long-term performance while maintaining optimal compatibility with brain tissue.

Our part of the project is to experimentally evaluate safety and clinical translatability of the new graphene based neural probes. We conducted in vitro cytotoxicity assessments of the graphene-based neural implants using the SH-SY5Y human neuroblastoma cell line. In the first phase of the study, we focused on measuring cytotoxicity without electrical stimulation. International standards for testing the cytotoxicity of new materials used in medicine recommend testing according to ISO 10993-5. This test is based on the extraction of the investigated material with a medium and the subsequent incubation of this extract with cells—an indirect material–cell contact approach. Secondly, we performed assessments using direct material–cell contact. In addition to measuring cytotoxicity using flow cytometry, we examined morphological changes, as well as the adhesion and proliferation of cells after exposure to reduced graphene oxide (rGO).

Our findings show that all tested graphene samples exhibit no cytotoxic effects after 24 hours of exposure. Furthermore, extended studies over 15 days confirmed their longterm biocompatibility, with no significant impact on cell viability or morphology observed. These results support the safety profile of graphene for neural applications and can contribute valuable insights toward regulatory approval and the development of safe neuroelectronic materials.

Acknowledgement: This work has been funded from the European Union's Horizon Europe research and innovation program under grant agreement number 101070865 (MINIGRAPH).

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Dual Optimization of Geometry and Bioactivity in Melt Electrowritten Scaffolds for Cardiac Tissue Engineering

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Abstract:

Melt Electrowriting (MEW) has emerged as a powerful tool for developing architecturally precise scaffolds tailored to cardiac tissue engineering. A key challenge in this domain is the simultaneous optimization of scaffold geometry for mechanical performance and enhancement of surface bioactivity to support cell adhesion. In this work, we addressed both limitations through a dual approach. First, we optimized scaffold design using a rhomboid geometry and a 20-layer configuration, which provided superior mechanical integrity and mimicked native cardiac anisotropy. Second, to overcome the hydrophobicity and limited cell-interactive properties of polycaprolactone (PCL), we functionalized the scaffold with RGD peptides using two methods: (1) chemical conjugation, and (2) electrospinning of a PCL-RGD blend— necessitated by RGD's poor electrospinnability in pure form. Surface characterization confirmed increased hydrophilicity and successful peptide integration. By addressing both geometric precision and surface bioactivity, this study advances the design of MEW-based cardiac patches for regenerative medicine.

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Investigating Surfactant–Alginate Interactions: Towards the Design of Nanostructured Bio-Based Hydrogels

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Abstract:

My research focuses on investigating surfactant–alginate interactions asa foundation for the design of nanostructured bio-based hydrogels, with an emphasis on natural polysaccharides as key biopolymeric matrices. Preliminary studies with cationic (CTAB), anionic (SDS), and non-ionic (Tween 80) surfactants have revealed distinct interaction behaviours with alginate. On the basis of these findings, gels will be prepared and characterized using advanced techniques: Dynamic Light Scattering (DLS) for size distribution, Small-Angle X-ray Scattering (SAXS) and Small-Angle Neutron Scattering (SANS) for nanoscale structural organization, and resonancebased methods such as Electron Paramagnetic Resonance (EPR) and Nuclear Magnetic Resonance (NMR) for molecular-level insight into composition and dynamics. Structure–property relationships derived from these analyses will provide the design of hydrogels with tailored mechanical, optical, and transport properties by addition of metal and semiconductor nanoparticles. Furthermore, extended applications will be pursued by integrating enzymes, pharmaceuticals, tissue engineering components, and other bioactive agents to enhance the functionality and versatility of the developed hydrogels. The ultimate goal is to develop sustainable, functional polysaccharide-based hydrogels for optoelectronic and biosensing applications.

Acknowledgments: Professor Luigi Paduano and Professor Gerardino D'Errico

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Dose-dependent effects of ZnO nanoparticles on freshwater microalgae under salinity stress

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Abstract:

Our evaluation of the effects of spherical 30-70 nm commercial zinc oxide nanoparticles (ZnO NPs, Sigma-Aldrich, St. Louis, USA) on the freshwater microalga *Lobosphaera* sp. revealed pronounced dose-dependent responses, with salinity levels showing minimal influence on this pattern.

At the lowest concentration tested (0.75 mg L-1), where ZnO NPs formed smaller aggregates (<100 nm) in freshwater conditions, they exhibited protective effects, increasing cell density by over 15% and improving photosynthetic parameters. Interestingly, in saline media (2-4 mg L-1 NaCl), these same low-concentration ZnO NPs showed a six-fold size reduction after 7 days compared to freshwater controls, yet maintained their protective effects. As ZnO NPs concentrations increased to 7.5 mg L- 1 and further to 75 mg L-1, NPs aggregation became more pronounced, correlating with progressively stronger toxic effects - moderate growth inhibition at intermediate concentration and near-halving of cell counts at the highest dose. The greater toxicity observed at higher concentrations appeared directly related to both the increased NPs dose and consequent enhanced Zn^{2+} ion release, with aggregate size playing a secondary role. This concentration-dependent response was consistently supported by photosynthetic measurements, biochemical analyses, and zinc bioaccumulation data.

These findings demonstrate ZnO NPs' dual role as either stress protectors or potent growth inhibitors depending on concentration, providing critical insights for environmental risk assessment in increasingly salinized freshwater ecosystems and potential biotechnological applications.

This work was supported by the [Project Name (Разработка кормовых добавок на основе макро- и микроводорослей для снижения генерации метана в животноводстве), тема № FEMG-2024-0005, Рег. № 1023110200100-7-4.4.1] from [Министерство науки и высшего образования Российской Федерации].

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A smart drug delivery against drug resistant cancer cells using super-functionalized carbon nanotubes

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Abstract:

The development of drug resistance and enhanced survival capacity in cancer cells is a hallmark of therapeutic failure, typically arising from prolonged or repeated exposure to chemotherapeutic agent [1]. Resistance mechanisms frequently involve aberrant drug metabolism, impaired cellular uptake, and dysregulation of apoptosis. These alterations collectively contribute to the emergence of drug-resistant phenotypes, which pose a significant obstacle to effective cancer treatment. Consequently, there is a compelling need to develop advanced, targeted drug delivery platforms that are capable of circumventing the intrinsic limitations of standard chemotherapy and overcoming resistance in malignant cells.

Nanocarrier systems can be designed to overcome multidrug resistance by boosting drug accumulation within resistant cancer cells. Their unique physicochemical properties enable selective tumor targeting through both passive and active mechanisms. Additionally, they allow co-delivery of multiple therapeutic agents or ligands aimed at specific molecular targets, creating synergistic effects that enhance anticancer activity and help bypass resistance-related treatment barriers [2].

Herein, we have demonstrated the formulation of a smart combination of super-functionalization of MWCNTs with Fe_3O_4 and gold nanoparticles (NPs) followed by Doxorubicin (DOX) loading. The physicochemical studies have established the successful functionalization and development of the formulation. Moreover, the cell viability assays demonstrated that the treatment effectively inhibited both D2F2 and D2F2-DOX resistant cancer cells, highlighting its potential as a strategy for targeting drug-resistant tumors.

Acknowledgement: Prachi Ghoderao acknowledges support from project No. 2022/45/P/NZ7/03645 co-funded by the National Science Centre and the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska–Curie grant agreement no. 945339.

[1] S.U. Khan, et al *Cell Commun. Signal.* 22, 1–26 (2024)

[2] H. Wang, et al *J. Control. Release* 330, 173–184 (2021)

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Fibroblast, macrophage modulation and bacteria hindering through surface modification strategies

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Abstract:

Dental implantology's material requirements include a lack of potential for inducing allergic disorders and providing both functional and aesthetic features for the patient's benefit. In the last years, laser-based surface modification techniques have emerged as transformative tools for enhancing the interface of dental materials and implants. This work presents approaches in surface modification involving laser texturing, structuring, and functionalization of key dental substrates(e.g. titanium, zirconia ceramics). For example, Zirconia ceramics have become a candidate of interest to be used as an alternative to titanium dental implants, implying the need for endowing the surface with biologically instructive properties by changing basic parameters such as surface texture or chemistry. Within this context, we propose anisotropic and isotropic patterns (linear microgroove arrays, and superimposed crossline microgroove arrays, respectively) textured in zirconia substrates, as bioinstructive interfaces to be used for future cellular guidance. The designed textured micronano interfaces with either steep ridges and microgratings or curved edges, and nano-roughened walls obtained by direct femtosecond laser texturing were analysed by Scanning Electron Microscopy, Atomic Force Microscopy, contact angle and surface energy measurements. Our results show that femtosecond laser texturing was shown to provide precise control over surface topography (microgrooves, nanopores, hierarchical textures) as well as maintaining surface chemistry without thermal damage or contamination. In addition, Matrix Assisted Pulsed Laser evaporation was shown to have the ability to create complex bioinspired morphologies as hybrid or composite coatings based on PCL and HA on top of the textured surfaces. Therefore, combining laser structuring with bioactive coatings multifunctional surfaces can hold exceptional promise for next-generation dental restorations, implants.

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Electrospun Nanofiber Oral Films of Buckwheat Rutin: Overcoming Solubility Limitations and Enhancing Biological Performance

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Abstract:

Fagopyrum esculentum Moench (buckwheat) is a pseudocereal widely valued for its rich content of bioactive compounds, including flavonoids, phenolic acids, and dietary fiber. Among these, rutin is one of the most abundant and biologically active constituents, contributing to the pronounced antioxidant, anti-inflammatory, antimicrobial, and neuroprotective properties of buckwheat. Promising biological profile is offset by challenges in nutraceutical use, primarily its low solubility in water and restricted oral bioavailability. Electrospun polymeric nanofibers have emerged as a promising strategy to overcome these challenges by enhancing dissolution and bioavailability of rutin, thereby broadening its potential application as a nutraceutical ingredient with relevance for longevity and healthy aging.

In this study, a lyophilized buckwheat extract was standardized for rutin content using HPLC, with rutin identity further confirmed through FTIR derivative analysis. The lyophilizate was incorporated into electrospun oral films composed of polyvinylpyrrolidone K30 (PVP K30) and polyvinyl alcohol (PVA) at varying polymer ratios. The resulting nanofibers underwent comprehensive physicochemical characterization and in vitro evaluation of release. FTIR analysis revealed intermolecular interactions between rutin and the polymeric carriers, confirming successful encapsulation. Scanning electron microscopy (SEM) verified the nanofibrous morphology of the oral films, while X-ray powder diffraction demonstrated that rutin was present in an amorphous state. Dissolution studies in simulated saliva showed a significant enhancement in rutin release, highlighting the potential of electrospun oral films as a promising delivery system for rutin.

These findings suggest that electrospun PVP K30/PVA nanofibrous oral films represent an effective delivery platform for rutin present in buckwheat, ensuring enhanced dissolution and supporting its potential application in nutraceuticals.

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Magnetic Nanoclusters for Alzheimer's Disease Theranostics

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Abstract:

Alzheimer's disease (AD) remains the most prevalent neurodegenerative disorder worldwide. N-methyl-D-aspartate receptors (NMDARs) are a subclass of glutamate receptors, which play an essential role in excitatory neurotransmission. Nevertheless, their excessive overactivation leads to excitotoxicity and promotes cell death, underlying a potential mechanism of neurodegeneration occurred in AD. Because of this, NMDAR modulators are an important therapeutic avenue, but the high impenetrability of the blood brain barrier (BBB) limits their effective delivery to the brain. Superparamagnetic Iron Oxide Nanoparticles (SPIONs) have emerged as promising tools in the diagnosis and treatment of AD, offering multifunctional capabilities, such as drug delivery, contrast agents for early detection and BBB permeability properties, that address key challenges in neurodegeneration [1]. In the present work we explore and optimize SPIONs nanoclusters for the delivery of the experimental NMDAR modulator 7-FEOTA [2]. Magnetic nanoclusters of SPIONs were successfully synthesized and functionalized with PEG, promoting its stability in biologically relevant media. The evaluation of MagAlg-PEG SPIONs as a drug delivery system for the 7-FEOTA compound was monitored through the loading and release profiles in phosphate buffer, while its cytotoxicity was tested against the L929 cell line. Preliminary results indicate its biocompatibility, and its potential as a drug delivery system of 7-FEOTA for AD.

Acknowledgement: This work has been funded from European Regional Development Fund – Project Excellence in Regenerative Medicine" (No. CZ.02.01.01/00/22_008/0004562).

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Myricetin-Loaded Electrospun Nanofibers: Amorphization Strategy to Enhance Antioxidant Properties

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Abstract:

Polyphenols such as myricetin (MYR) exhibit a wide range of beneficial biological activities, including antioxidant, anti-inflammatory, and neuroprotective effects. However, their pharmaceutical and nutraceutical application is limited by poor aqueous solubility and low oral bioavailability. One of the promising approaches to overcome these limitations is the use of electrospun polymeric nanofibers, which can promote amorphization, enhance dissolution, and improve biological performance.
Based on our previously developed and optimized electrospinning protocol for MYR and polyvinylpyrrolidone (PVP), MYR-loaded nanofibers were prepared for in vitro studies aimed at evaluating their release behavior, physical stability, and biological activity.
In vitro dissolution testing in water was conducted to assess the release profile and monitor potential recrystallization. Structural analyses using X-ray Powder Diffraction (XRPD) confirmed the maintenance of the amorphous state after exposure to aqueous conditions. Antioxidant assays demonstrated enhancement in biological activity compared to crystalline MYR. The release profile displayed a characteristic "spring and parachute" effect, indicating rapid initial supersaturation followed by sustained solubility - typical of stable amorphous solid dispersions. These findings confirm that MYR-loaded electrospun nanofibers not only improve solubility but also preserve enhanced biological properties, supporting their potential as an effective delivery system for poorly soluble polyphenols.

Acknowledgements: This work was supported by the grant OPUS from the National Science Centre Poland UMO-2020/37/B/NZ7/03975.

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Auxetic Scaffolds via Multiphoton Lithography for Neuroregeneration

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Abstract:

The nervous system exhibits limited innate regenerative capacity. Tissue engineering strategies, including 3D printing, offer promising avenues for neural repair [1]. In this context, Multiphoton Lithography (MPL) enables high-resolution fabrication of micro-scale 3D architectures, such as auxetic scaffolds, which possess a negative Poisson's ratio. These structures mimic the mechanical behavior of certain biological tissues and may enhance mass transport [2]. This study investigates how scaffold mechanics influence neural stem cell (NSC) differentiation. It involves a comparative analysis of three distinct porous scaffolds - auxetic elastic, non-auxetic elastic and stiff. Scaffolds were fabricated via MPL using SZ2080™ photoresin and mechanically tested. NE-4C neural stem cells were cultured on scaffolds and analyzed through scanning electron microscopy (SEM), immunocytochemistry and confocal microscopy using markers such as Ki-67, Nestin, Tuj- 1 and GFAP.
SEM confirmed a distinctive response of the auxetic scaffolds, which exhibited uniform contraction around proliferating cells, highlighting their unique mechanical characteristics. Immunocytochemical analysis revealed scaffold-specific variations. For example, neural differentiation began more rapidly and was more extensive in auxetic scaffolds.
The auxetic scaffolds have shown encouraging indications for enhancing the biological performance of NSCs, inducing faster their neuronal differentiation, and also for their use as models to study neuroregeneration as well as future implants.

Acknowledgments: The research project was co-funded by the Stavros Niarchos Foundation (SNF) and the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the 5th Call of "Science and Society" Action – "Always Strive for Excellence – Theodore Papazoglou" (Project Number: 9578).

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Iron Carbide Nanoparticles for Enhancing CAR-T Cell Therapy in Metastatic Melanoma: Dual Hyperthermia and Surface Engineering

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Abstract:

Metastatic melanoma is an aggressive cancer with limited long-term survival despite advances in conventional treatments [1]. Immunotherapy, particularly chimeric antigen receptor (CAR) T-cell therapy, has shown promise; however, its efficacy in solid tumors is restricted by poor infiltration due to the immunosuppressive tumor microenvironment (TME) [2]. Nanoparticle-mediated hyperthermia has emerged as a strategy to remodel the TME and enhance CAR-T cell penetration.

Iron carbide nanoparticles (IC-NPs) are attractive for this approach, combining magnetic properties with photothermal conversion efficiency, they enable dual hyperthermia under magnetic fields and near-infrared (NIR) irradiation. Simultaneous magnetic and photothermal heating may reduce the required nanoparticle dose while achieving therapeutic temperatures [3]. The crystallographic structure of Fe_5C_2 and Fe_7C_3 nanoparticles was verified by X-ray diffraction (XRD), and morphology examined by high-resolution transmission electron microscopy (HRTEM). The magnetic behavior was assessed with superconducting quantum interference device (SQUID).

Surface modifications were applied to enhance stability and functionality. Fe_5C_2 nanoparticles were decorated with gold, to improve photothermal efficiency and enabling further functionalization for dispersibility and biocompatibility [4]. Fe_7C_3 nanoparticles carried a graphite-like carbon coating with near-graphite interlayer spacing, offering core protection.

Preliminary results show Fe_5C_2 nanoparticles have good photothermal and magnetothermal performance, while Fe_7C_3 provides excellent photothermal but limited magnetothermal efficiency. These complementary features suggest iron carbide nanoparticles could serve as multifunctional platforms to support CAR-T therapy in metastatic melanoma.

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Bridging Synthetic Biology and Bioelectronics via Chemical Reactions

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Abstract:

Living organisms are inherently complex, distributed systems with integrated sensing, processing, and actuation capabilities. Creating interfaces between such biological systems and electronic devices offers powerful opportunities for advancing both fundamental biological research and environmental and clinical applications, including diagnostics, bioremediation, and therapeutics. Traditionally, electronic interfaces rely on converting cellular signals into physical or electrical outputs—such as photons, ions, or electrons—often requiring an external power source like a battery. In contrast, we propose a novel platform that leverages engineered bacterial cells capable of sensing, computing, and storing information. These cells interact with nanoelectronic memristive devices, programming them directly through biochemical reactions, thereby eliminating the need for external electrical power.

In this talk fist, I will describe our new platform presenting the main components: 1. Synthetic Biology Module: Engineering biosensors-based bacteria utilizing biochemical energy to detect specific biomarkers such as blood. 2. Nanoelectronics Component: Memristive elements that undergo resistance changes in response to chemical cues, allowing for information storage without external power. 3. Biochip: A small (1.25 mm outer diameter, 8 mm length) hollow CNC-fabricated capsule with a semipermeable membrane, allowing selective molecular exchange while containing the biological system.

In the end, I will present a compact, energy-efficient micro-hybrid ingestible biochip for autonomous detection and monitoring of health disorders in the Gastrointestinal tract. It is an integration of biological systems and nanoelectronic memory devices in a powerless, safe and compatible capsule.

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Chitosan Nanofibers with *Centella asiatica* Extract as an Innovative Platform for Controlled Release of Bioactive Compounds in Wound Healing Applications

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Abstract:

Wound healing is a complex process that requires advanced biomaterials capable of supporting tissue regeneration while simultaneously delivering bioactive compounds [1]. In this work, electrospun nanofibers composed of chitosan (CS) and polyethylene oxide (PEO) were developed and functionalized with *Centella asiatica* extract, a natural source of asiaticosides and other triterpenoids known to accelerate collagen synthesis, reduce inflammation, and promote wound closure.

The nanofibers were fabricated via electrospinning and thoroughly characterized using scanning electron microscopy (SEM) to assess morphology, uniformity, and diameter distribution. Among the tested formulations, CS:PEO systems at a 1:2 weight ratio combined with 1% *Centella asiatica* extract exhibited optimal structural homogeneity and stability. Antioxidant potential, evaluated with the DPPH radical scavenging assay, demonstrated a significant increase in activity (70.6%) compared to the polymer base alone. Furthermore, in vitro anti-inflammatory analysis confirmed the ability of the nanofibers to inhibit hyaluronidase, while release studies revealed a gradual and sustained liberation of asiaticosides, reaching nearly complete release over a period of 7 days. Importantly, cell-based assays showed enhanced fibroblast viability and migration, directly supporting the wound-healing properties of the developed nanofiber system.

These results highlight the synergistic effect of combining chitosan with *Centella asiatica* extract, leading to multifunctional nanofiber dressings that not only provide a physical scaffold for tissue regeneration but also deliver bioactive compounds in a controlled manner. The presented approach offers a promising strategy for next-generation wound dressings with both protective and therapeutic functions.

Funding: This research was funded by the National Science Center (Poland), under the Sonata grant (number 2020/39/D/NZ7/01824).

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NanoBio
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Wednesday 10th September

POSTER SESSION: Nanomaterials

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Hybrid Energy Harvesting System: Integrating Teng and Solar for Electricity Generation

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Abstract:

Given the rising energy demands and the urgent need to transition to sustainable sources, this study proposes an innovative approach to ongoing electricity production using a hybrid system. This system combines a Triboelectric Nanogenerator (TENG) with a traditional solar panel to maintain a steady power supply in fluctuating weather. Operating at 11 volts, the TENG captures mechanical energy from natural movements like wind or vibrations, while the solar panel harnesses solar radiation. combining these technologies increases energy output, offering a reliable solution for both sunny and rainy days. In daylight, the solar panel primarily generates power, with the TENG contributing to maximize efficiency. Conversely, during the nights or rainy weather when solar energy is reduced, the TENG continues to harvest mechanical energy from vibrations, ensuring a consistent power supply. This hybrid system was designed and tested using digital measuring instruments such as frequency meter and voltmeters. The system provides a sustainable and adaptable solution suitable for various applications, including off-grid power generation, wearable electronics, and IoT devices. Through experimentation and performance analysis, this research confirms the viability and effectiveness of combining TENG with solar panels to fulfil the energy requirements of diverse environments, irrespective of the prevailing weather conditions.

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Precision Micromachining with Tailored Laser Beams in Amplitude and Phase

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Abstract:

The METAMORPHA concept introduces a single, agile USP laser micromachining platform designed to replace multiple conventional manufacturing chains, eliminating thousands of environmentally damaging processes. This all-electric, digital system produces no chemical waste and enables novel rework and repair capabilities. Its core is a versatile, all-in-one module combining one or two cascaded spatial light modulators (SLMs) with a galvo scanner, allowing unprecedented beam shaping and steering to perform polishing, milling, drilling, and cutting at any wall angle. Each workpiece undergoes high-resolution 3D scanning, with machine learning algorithms tailoring laser processes for maximum efficiency and first-time accuracy. Theoretical modelling simulates energy absorption from SLM-shaped beams to optimize parameters, eliminate unwanted features, and build material-specific databases. Experiments will validate this model by correlating tailored beam parameters with morphological results, supporting lab-scale optimization. The final system will adapt to various industrial setups, demonstrated by use cases including small, complex metal parts, large embossing rollers, and hard carbide refurbishment. METAMORPHA's integrated approach delivers scalable, precise, and sustainable manufacturing solutions that align with circular economy principles.

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METAMORPHA website: https://metamorpha.eu/

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Precision Laser-Engineered Aesthetic Photo-Rechargeable Storage Cell

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Abstract:

The PHOTO-GREEN project develops advanced laser-based fabrication methods to create cost-effective, aesthetically appealing, and environmentally sustainable interior photo-storage devices that integrate perovskite solar cells (PSCs) with carbon supercapacitors (SCs) for continuous power supply. It focuses on producing highperformance PSC modules that retain efficiency despite aesthetic patterning and enable efficient energy storage through optimized interconnections. By monolithically integrating energy generation (perovskite modules) and storage (carbon SCs) on a common electrode substrate, an ultrathin photo-storage device is realized, supported by optimized power management for sustainable energy autonomy.
To preserve conductivity, the laser-reduced graphene oxide (LrGO) electrode avoided plasma treatment and limited annealing to 100°C. PEDOT:PSS was chosen as the hole transport layer for its compatibility with low-temperature processing, yielding highquality films without conductivity loss. Three perovskite formulations with band gaps of 1.55 eV, 2.0 eV, and 2.25 eV were synthesized. Inverted PSCs using this composition achieved a peak efficiency of 3.91% following PEDOT:PSS optimization. Laser ablation with femtosecond and nanosecond lasers enabled precise patterning of device layers, confirmed by SEM and EDS analyses. Optical and theoretical modelling clarified multilayer optical behavior and laser-induced modifications, advancing photostorage device development.

Acknowledgement: This work was supported by: Greece 2.0 NATIONAL RECOVERY AND RESILIENCE PLAN "BASIC RESEARCH FINANCING" (Horizontal support for all Sciences) ID 16618 – Subproject 1 (MIS: 5163923) Project Title: Aesthetic PHOTO-recharGeable stoRage cEll Fabricated via prEcision laser manufacturing, Project Acronym: PHOTO-GREEN, Project ID: 014791

PHOTO-GREEN website: https://www.photogreen.gr/

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Aesthetically Patterned Semitransparent Perovskite Photovoltaics for Ambient Applications

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Abstract:

This work presents the development of semitransparent perovskite solar cells with tailored optical and electronic properties, achieved by combining bandgap engineering with advanced laser manufacturing techniques. A nonthermal laser ablation process is employed to directly write micromesh structures and customized aesthetic patterns across the photovoltaic stack. This approach enables selective material removal with micrometer precision while minimizing thermal damage, thus preserving the integrity and performance of the underlying layers. Bandgap tuning through halide and cation substitution allows the creation of perovskite absorbers with a range of colors, enhancing their aesthetic versatility without compromising stability or efficiency. The resulting solar cells combine photovoltaic performance with architectural integration, making them ideal for use in modern interiors and building-integrated applications. By uniting aesthetic appeal, color tunability, and energy functionality, this platform enables the realization of elegant, self-powered systems designed for ambient indoor environments.

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Electronic transport in Te nanorolls

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Abstract:

In this work, the electronic transport properties of Te roll-like nanostructures were investigated in a broad temperature range by fabricating single-nanostructure backgated field-effect transistors via photolithography. These one-dimensional nanostructures, with a unique roll-like morphology, were produced by a facile synthesis and extensively studied by scanning and transmission electron microscopy and electrical transport techniques. The nanostructures are made of pure and crystalline Tellurium with a trigonal structure (t-Te), and exhibit p-type conductivity with enhanced field-effect hole mobility between 273 cm2/Vs at 320 K and 881 cm2/Vs at 5 K. The thermal ionization of shallow acceptors, with small ionization energies between 2 and 4 meV, leads to free-hole conduction at high temperatures. The free-hole mobility follows a negative power-law temperature behavior, with an exponent between -1.28 and -1.42, indicating strong phonon scattering in this temperature range. At lower temperatures, the electronic conduction is dominated by nearest-neighbor hopping (NNH) conduction in the acceptor band, with a small activation energy $E_{NNH} \approx 0.6$ meV and an acceptor concentration of $N_A \approx 1 \times 10_{16}$ cm$_{-3}$. These results demonstrate the enhanced electrical properties of these nanostructures, with small disorder and superior quality for nanodevice applications.

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Structural, thermal, and conductive properties of sol-gel derived lanthanide-based ormolytes for electrochromic devices

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Abstract:

Electrochromic devices (ECDs) represent a promising solution for smart window applications, which aim to improve energy efficiency and thermal and visual comfort in buildings.

In this study, we report the synthesis and characterization of sol-gel-derived electrolytes based on acrylate/ionosilica (AC/IS) hybrid matrices doped with trivalent lanthanide ions (AC/IS-EuTbEr). XRD, SEM-EDS, FTIR, TGA, AFM, and contact angle measurements were used to analyze the resulting highly transparent, homogeneous, and luminescent monolithic films. The materials exhibited an amorphous structure and uniform distribution of the three ions. Photophysical analysis revealed strong emission in the visible (red (Eu^{3+}) and green (Tb^{3+}) and near-infrared (Er^{3+}) regions). The presence of the latter ions improved photothermal conversion under 1 Sun irradiation. The materials demonstrated high thermal stability (up to ~350 ºC). Lanthanide doping slightly increased the surface roughness compared to the non-doped sample (AC/IS). At room temperature, AC/IS and AC/IS-EuTbEr exhibited an ionic conductivity of 1.58×10^{-7} and 2.30×10^{-7} S cm^{-1}, respectively.

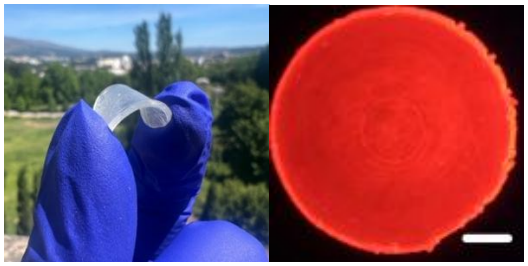

Fig. 1. Physical appearance of AC/IS-EuTbEr monolith under daylight (left) and UV radiation (365 nm) (right). The scale bar is 1.0 cm.

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Laser Synthesis of Nanostructures for Electrochemical Analytical Systems

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Abstract:

Laser synthesis of nanomaterials, particularly through pulsed laser ablation (PLA), offers significant advantages for developing advanced electrochemical analytical systems, especially electrochemiluminescent (ECL) sensors [1]. This method produces high-purity nanoparticles (NPs) with tailored properties, eliminating the need for toxic chemical stabilizers, enhancing biocompatibility, and enabling precise control over size, structure, and composition [2]. These attributes make lasergenerated NPs ideal for modifying electrodes to improve ECL sensor stability and sensitivity, critical for applications in medical diagnostics, environmental monitoring, and food safety [3].

Our work focuses on synthesizing luminescent and noble metal NPs, such as CsPbBr3 perovskite nanocrystals (PeNCs), via PLA, and studying their electrochemical and ECL properties. Results demonstrate that CsPbBr3 PeNCs, when incorporated into polymer films on glassy carbon electrodes, exhibit stable ECL signals after UV photoactivation, enhancing sensitivity for analyte detection [4]. The NPs' high surface area and purity improve electron transfer and luminescence efficiency, outperforming traditional organic phosphors like Ru(bpy)32+. Ongoing work explores the impact of laser parameters on NP properties to optimize ECL performance.

Future research aims to expand the material base, including lead-free perovskites, and refine laser synthesis techniques to develop cost-effective, reusable ECL sensors with broader analyte detection capabilities, promising significant advancements in analytical chemistry.

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