

CEITEC VUT – CEIPEX research topics

1	CEIPEX RESEARCH TOPIC LEVEL2: advanced biomaterials
2	RESEARCH GROUP: Advanced Biomaterials (L. Vojtová)
3	TOPICS/FOCUS: Radical-free photocrosslinkable hydrogels for 3D bioprinting of advanced cartilage constructs
4	SUMMARY: 3D bioprinting is rapidly emerging as a transformative technology in regenerative medicine, enabling the fabrication of complex, patient-specific tissue constructs with unprecedented spatial precision. Among the strategies employed in this field, photocrosslinking has gained particular attention due to its ability to provide spatiotemporal control over the biochemical and mechanical properties of biomaterials. Hydrogels represent the principal class of bioinks for such applications; however, conventional photocrosslinking methods often rely on photoinitiators that generate free radicals, which may compromise cell viability and hinder clinical translation. This project seeks to advance the field by developing a new generation of radical-free, photocrosslinkable hydrogels specifically designed for 3D bioprinting applications. The research will focus on engineering dynamic polymeric networks that can be rapidly stabilized under cytocompatible light conditions, thereby ensuring precise spatiotemporal gelation without the limitations of radical-mediated chemistry. The resulting materials are expected to combine high printability, mechanical robustness, and biocompatibility, establishing an advanced platform for biofabrication and regenerative medicine of cartilage tissue.
5	RG WEBPAGE: https://biomaterials.ceitec.cz/

1	CEIPEX RESEARCH TOPIC LEVEL2: advanced instrumentation and methods for materials characterization
2	RESEARCH GROUP: Advanced Instrumentation and Methods for Materials Characterization (J. Kaiser)
3	TOPICS/FOCUS A) Unravelling microplastic fate and transport using combined advanced imaging and chemical characterization methods B) Advancing coral biomineralization studies: Real-time imaging of coral skeletogenesis using 4D X-ray microcomputed tomography
4	SUMMARY A) This project aims to driving forward microplastic research by developing a novel, multi-instrumental approach that combines high-resolution X-ray computed tomography (CT) with SEM, FTIR, Raman spectroscopy and LIBS. Using a dynamic, environmentally realistic model system, simulating natural processes such as UV degradation, organisms' activity, and biofilm formation, we will track microplastic movement and transformation in complex matrices like soil and sediment. This multi-modal methodology will expand detection capabilities and provide new insights into microplastic fate, informing improved environmental monitoring and mitigation strategies.

	B) The project will advance our understanding of coral biomineralization by developing a novel, non-invasive method for real-time imaging of skeletal formation in live reef-building corals using 4D X-ray microcomputed tomography. By capturing high-resolution structural changes over time, we seek to uncover the dynamic processes behind coral skeletogenesis and how they are influenced by environmental stressors such as ocean acidification. The methodology developed will provide a powerful platform for interdisciplinary research at the intersection of marine biology, imaging science, and environmental change.
5	RG WEBPAGE: https://www.ceitec.eu/advanced-instrumentation-and-methods-for-materials-characterization/rg6

1	CEIPEX RESEARCH TOPIC LEVEL2: future energy
2	RESEARCH GROUP: Future Energy and Innovation Lab (M. Pumera)
3	TOPICS/FOCUS Topic A: Nanorobots for Biomedical and Environmental Applications Topic B: Next Generation Materials for Flexible Wearable Sensors and Energy Storage Topic C: Atomically Engineered Materials for Sustainable Carbon-Free Fuels
4	SUMMARY A) Microrobots are at the forefront of next-generation solutions in healthcare and environmental technologies. They are designed to: • Remove nanoplastics from aquatic environments • Eradicate biofilms that obstruct medical treatments and device performance Our group explores the innovative designs and mechanisms of nano- and microrobots, with emphasis on: • Targeted biomedical therapies and improved antibiotic efficacy • Environmental remediation through micro- and nanoplastic adsorption • Advanced single atom engineering strategies for precise functionality We seek motivated candidates interested in pioneering microrobotics research, contributing to sustainable technologies, and addressing pressing biomedical and environmental challenges. Key References: • Urso, Ussia & Pumera, Smart micro- and nanorobots for water purification, Nat. Rev. Bioeng. 2023. • Mayorga-Martinez, Zhang & Pumera, Chemical multiscale robotics for bacterial biofilm treatment, Chem. Soc. Rev. 2024. • Urso, Ussia, Novotný & Pumera, Trapping and detecting nanoplastics by MXene-derived oxide microrobots, Nat. Commun. 2022. • Pumera et al., Technology Roadmap of Micro/Nanorobots, ACS Nano 2025. B) The transition to flexible and wearable electronics demands advanced energy storage and sensing materials. Our group pioneers the development of next-generation systems that integrate: • Flexible and stretchable batteries and supercapacitors with high energy density • Wearable sensors for real-time health and environmental monitoring

	• 2D and MXene-based nanomaterials, conductive polymers, and hybrid architectures • 3D printing for batteries and sensors This research bridges materials science, nanotechnology, and device engineering, addressing key challenges in: • Mechanical flexibility and stability of energy storage devices • Biocompatibility and integration into wearable platforms • High sensitivity, selectivity, and durability of flexible sensors We seek motivated postdoctoral researchers eager to shape the future of smart energy and sensing technologies through materials innovation and device engineering. C) This project focuses on the design and development of next-generation electrocatalysts for the sustainable production of carbon-free fuels such as hydrogen and ammonia. By applying single-atom engineering and atomic-scale tailoring of catalyst surfaces, we aim to significantly enhance catalytic efficiency, selectivity, and stability. The electrocatalytic processes will be ultimately powered by renewable green energy sources, ensuring a closed, environmentally friendly fuel cycle. The research will establish a fundamental understanding of structure–property relationships at the atomic level, enabling breakthroughs in scalable, sustainable fuel generation technologies crucial for the energy transition.
5	RG WEBPAGE: https://www.ceitec.eu/future-energy-and-innovation/rg322

1	CEIPEX RESEARCH TOPIC LEVEL2: advanced ceramic materials, polymers & composites
2	RESEARCH GROUP: Advanced Ceramic Materials (M. Trunec)
3	TOPICS/FOCUS Development of multimaterial 3D printing using the digital light processing method
4	SUMMARY The project aims to develop innovative 3D-printing technology for ceramic/ceramic or ceramic/metal composite components using the digital light processing (DLP) method. The developed method will be demonstrated by preparing prototype composite components designed in collaboration with research and industrial partners. The project will focus on developing novel materials and manufacturing processes as well as establishing a long-term research platform for technology transfer. This platform will provide interested institutes and companies with opportunities for sustainable collaboration and access to advanced 3D printing technologies under development. Leading CEITEC Institution and PI: CEITEC BUT, Prof. Martin Trunec, RG201 Cooperating CEITEC Institution and PI: CEITEC IPM, Dr. Zdenek Chlup
5	RG WEBPAGE: https://www.ceitec.eu/advanced-ceramic-materials/rg12

1	CEIPEX RESEARCH TOPIC LEVEL2: nanomagnetism & spintronics
2	RESEARCH GROUP: Nanomagnetism and Spintronics (V. Uhlíř)
3	TOPICS/FOCUS A) In situ magneto-ionic control of antiferromagnetic/ferromagnetic interfaces B) Magnetic actuation platforms for biological environments

4	SUMMARY A) Study how electric fields or ion migration reshape magnetic order in thin films, using advanced electron microscopy. The goal is to directly watch magnetic domain walls and/or phase changes as they happen, linking atomic-scale mechanisms to device-scale functionality. B) Design magnetic micro- and nanostructures that can be remotely controlled by external magnetic fields to actively influence biological systems. These platforms would deliver mechanical forces or trigger local electrical responses inside cells or tissues, enabling new modes of stimulation and therapeutic intervention.
5	RG WEBPAGE: https://www.ceitec.eu/nanomagnetism-and-spintronics/rg261

1	CEIPEX RESEARCH TOPIC LEVEL2: Experimental biophotonics
2	RESEARCH GROUP: Experimental Biophotonics (R. Chmelik)
3	TOPICS/FOCUS: FAST-4D hiQPI : Fast, Accurate, Scalable Time-lapse 4D Holographic Incoherent-light-source Quantitative Phase Imaging.
4	SUMMARY The goal of this project is to optimise and accelerate algorithms for reconstructing 3D refractive index distributions from hiQPI data, thereby enabling time-resolved (4D) high-fidelity hiQPI imaging of both weakly and strongly scattering samples. The main outcome will be software with a user-friendly graphical interface, capable of rapidly reconstructing large-scale hiQPI time-lapse z-stacks, taken under various light propagation conditions. To achieve this, different reconstruction strategies will be explored and compared, including physics-driven algorithms, AI-based approaches, and hybrid methods. In parallel, the experimental parameters required to acquire hiQPI z-stacks with sufficient information content will be systematically explored and optimized. The resulting 4D reconstruction pipeline will be applied to biological samples such as organoids and highly motile cells (e.g., sperm) and may be complemented by segmentation and cell-tracking algorithms to extend its applicability in biological research.
5	RG WEBPAGE: https://biophotonics.ceitec.cz/

1	CEIPEX RESEARCH TOPIC LEVEL2: bioelectronics materials and devices
2	RESEARCH GROUP: Bioelectronics Materials and Devices (E. Glowacki)
3	TOPICS/FOCUS Exploring High-Frequency Electrical Neurostimulation Beyond Classical Mechanisms
4	SUMMARY We are seeking a motivated postdoctoral researcher to join our interdisciplinary team at the Bioelectronics Materials and Devices Laboratory, Brno University of Technology. Our research focuses on high-frequency electrical neurostimulation, specifically using unconventional waveforms in the kilohertz-to-megahertz (kHz–MHz) range. The central goal is to investigate how these atypical frequencies can influence neuronal function through non-classical biophysical mechanisms, potentially operating beyond

	standard membrane depolarization. This is a fundamental scientific question with significant implications for future bioelectronic therapies and neural interfacing technologies. We offer a flexible and multidisciplinary research environment, with opportunities to work across several experimental and theoretical platforms: Computational modeling of neuronal responses to high-frequency fields; In vitro electrophysiology, including patch clamp and multielectrode arrays; Experiments on model organisms (e.g. invertebrate nervous systems); Noninvasive human studies, with access to stimulation and recording equipment. The project benefits from strong collaborative ties with neuroscience groups at the CEITEC campus of Masaryk University (MUNI), enabling joint experiments and access to complementary infrastructure across Brno's leading research institutions. A successful fellowship project may thus span both campuses.
5	RG WEBPAGE: https://www.ceitec.eu/bioelectronics-materials-and-devices/rg375

1	CEIPEX RESEARCH TOPIC LEVEL2: advanced ceramic materials, polymers & composites
2	RESEARCH GROUP: Advanced Multifunctional Ceramics (K. Maca)
3	TOPICS/FOCUS Upcycling of ceramic waste to produce carbide-based ceramics
4	SUMMARY Grinding sludges from machining of advanced ceramics accumulate worldwide as costly and often hazardous waste streams that are rich in valuable materials (e.g., B₄C, SiC and synthetic diamonds), but contaminated by coolants, binders, and fines that hinder straightforward reuse. Landfilling or incineration of these sludges forfeits critical raw materials, carries long-term environmental liabilities, and exposes producers to tightening regulations and disposal fees. Meanwhile, demand for hard, wear- and corrosion-resistant non-oxide ceramics continues to rise, yet primary powders remain expensive and energy-intensive to produce. The objective of this project is to find the most effective processing route to upcycle industrial waste ceramic grinding sludges into a clean, formable feedstock and then into high-performance, non-oxide (carbide) ceramics for various applications. Upcycling sludges into high-quality powder feedstocks addresses three converging pressures — resource efficiency, compliance and risk reduction, and decarbonization — by closing material loops, reducing embodied energy and CO₂, and creating a reliable, lower-cost route to produce advanced ceramic components without compromising their performance. This project delivers technological innovation and environmental benefits by valorising industrial waste and introducing a novel class of materials. The outcomes will be validated from laboratory to pilot scale, with attention to input variability, quality control, and readiness for industrial adoption.
5	RG WEBPAGE: https://www.ceitec.eu/advanced-multifunctional-ceramics/rg388

1	CEIPEX RESEARCH TOPIC LEVEL2: plasma technologies
2	RESEARCH GROUP: Plasma Technologies (L. Zajíčková)

3	TOPICS/FOCUS A) Pushing thin-film deposition techniques beyond their conformality limits or towards strong gradients B) Tuning the bioactivity of carbon-based coatings and nanoparticles
4	SUMMARY A) Plasma enhanced chemical vapor deposition (PECVD) is gaining momentum in many areas, spanning from microelectronics (thin films in integrated circuits and memories) to biomedical applications (surface finishes for biosensors or implants). Higher integration in the case of microelectronics and sensing devices, as well as complex porous structures of implanted materials, pushes the technologies towards higher deposition conformality, enabling uniform coatings on 3D microstructures. PECVD cannot offer as high deposition uniformity as atomic layer deposition (ALD), but understanding the deposition mechanisms and using precursors that produce depositing species with low sticking coefficients can push the process towards high conformality. On the contrary, the knowledge gained about the processes can tune the deposition towards defined gradients in the film properties, an attractive approach for bottom-up structuring. The project will involve dedicated experiments with well-defined 3D microstructures to obtain information about the sticking coefficient of deposition species and the role of ions, as well as parallel tests of ALD conformality. The experiments should be supported by calculations, e.g., Monte Carlo or molecular dynamics simulations. B) Inspired by covalent bonds in proteins, in which the carboxyl group (-COOH) of one amino acid links with the amino group (-NH₂) of another amino acid, surfaces aimed at the immobilization of biomolecules, as well as adhesive surfaces in general, are prepared with these functional groups. Besides through covalent bonds, immobilization can also proceed through electrostatic interactions, which can be strong for micro- and nanostructured surfaces. The polarity of amino and carboxyl groups plays opposite roles in this process. In another approach, the radicals trapped in thin films prepared by plasma processing methods are efficiently utilized for the covalent immobilization of biomolecules. The presence of unsaturated bonds, reactive in aqueous environments, raises questions about their significance. Thus, the multifunctionality of plasma-prepared materials can be leveraged to advantage by tuning their surface bioactivity. Moreover, understanding the role of various functionalities in plasma-prepared films can serve as an inspiration for understanding the bioactivity of carbon dots, which are prepared by plasma or wet chemical processes, and whose structures can contain molecular fluorophores.
5	RG WEBPAGE: https://www.ceitec.eu/plasma-technologies/rg386

1	CEIPEX RESEARCH TOPIC LEVEL2: Experimental biophotonics
2	RESEARCH GROUP: Experimental Biophotonics (R. Chmelik)
3	TOPICS/FOCUS: Advanced software for batch processing of correlative imaging with quantitative phase and fluorescence

4	SUMMARY Design and develop software for batch processing of correlative imaging, dealing with responses of live tissue culture cells, where quantitative phase and fluorescence micrographs are stored in directories corresponding to individual experiments, which include time-lapse, multi-field, and multi-channel sequences. The software should perform relevant pipelines of image-processing steps on individual time-lapse sequences, appreciating the natural hierarchy of the experimental design and feeding the cell-relevant segmentation results into data analysis based on analysis of variance. The project should allow flexibility in the experimental design hierarchy and utilize the extensive experience and development in the field achieved by our research group. The software should be multi-platform, including Windows and Unix, and utilize Mathematica, C, and potentially Python.
5	RG WEBPAGE: https://biophotonics.ceitec.cz/