ABSTRACT BOOK

1. MEBioSys CONFERENCE

9. – 10.9. 2025

OREA RESORT SANTON BRNO

Session 1:

Advanced metamaterials and their applications

Equilibrium and non-equilibrium transport in compositionally complex alloys and the role of short-range order

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3d transition-metal alloys, spanning from low-entropy alloys and conventional alloys such as austenitic stainless steel to high-entropy alloys, exhibit notably reduced transport parameters, including thermal and electrical conductivity, electron-phonon coupling, and optical properties.

In this study, we perform comprehensive ab initio calculations to investigate equilibrium transport properties, specifically optical conductivity and electrical resistivity, in the prototypical CrMnFeCoNi. By employing the Korringa-Kohn-Rostoker Green's function formalism extended with dynamical mean-field theory, we accurately capture the influence of electronic correlations. Additionally, we systematically examine the effect of short-range ordering on electrical resistivity, uncovering a counterintuitive increase in resistivity associated with short-range ordering, primarily attributed to modifications in the electronic density of states at the Fermi level.

Complementarily, we explore non-equilibrium transport under conditions typical of ultrashort pulse laser ablation, characterized by significant electron-phonon temperature imbalances and electron temperatures reaching several thousand Kelvin. Results are presented in context with experimental pump-probe and final-state measurements and benchmarked against state-of-the-art models.

Collectively, these insights significantly enhance the understanding of electronic and structural contributions to transport phenomena in modern, disordered 3d transition-metal alloys.

Keywords: biocompatible high-entropy alloys, ultrafast ablation, DFT calculations and predictions

In situ neutron diffraction measurements of additively manufactured metals

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Materials fabrication, post-treatment, or deformation behaviour are often complex processes that are challenging to understand just by the conventional characterization of the initial and final materials state. To get a deeper insight into the studied process already during its occurrence, various modern methods are pursued, such as in situ neutron diffraction measurements. This technique is based on the elastic scattering of neutrons and is especially useful for the investigation of crystal structures and their magnetic properties. By neutron diffraction, a wide range of studies is possible, such as structural changes within a material during mechanical loading, heating, chemical reaction, and many other conditions. Moreover, this non-destructive method enables obtaining unique representative data due to the ability of neutrons to penetrate deeply into a material. Recently, neutron diffraction has been extensively used in the materials science community dealing with additive manufacturing processes, offering the opportunity to follow the dynamic processes within a material during fabrication and investigating their consequences on the microstructure. These novel approaches in manufacturing and microstructural engineering can be thoroughly investigated in detail. Several case studies in the field of additively manufactured metals, carried out in collaboration with the Paul Scherrer Institute (Switzerland), will be presented to showcase the possible benefits.

Keywords: additive manufacturing, metals, neutron diffraction, neutron imaging

Pressureless Spark Plasma Sintering of barium titanate electroceramics

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Efficient densification of electroceramics without applied pressure is difficult to achieve without unwanted grain growth. This work investigates the potential of pressureless Spark Plasma Sintering of lead-free barium titanate electroceramics and compares it with conventional pressure-assisted Spark Plasma Sintering, Rapid Pressureless Sintering in an elevator furnace and conventional sintering. Fully dense (>99 %) bulk samples were produced using high heating rates of 100 °C/min and short dwell times of 5 min at sintering temperatures between 1325–1400 °C. Abnormal grain growth was observed at unusually high temperatures. compared to other methods, due to the nature of heat transfer in the selected sintering technique. Oxygen vacancies and some secondary barium titanate phases were present, particularly at the highest sintering temperature. The defects were characterised, and their influence on the structural, electrical, and thermal properties was discussed in detail. Additional annealing in an ambient atmosphere eliminated these defects and positively influenced the properties and performance. The study highlights pressureless Spark Plasma Sintering as a viable approach for the efficient and sustainable fabrication of advanced BaTiO3 electroceramics.

Keywords: Barium titanate; piezoceramics; pressureless spark plasma sintering; rapid pressureless sintering; microstructure

Towards High-Strength, Ductile, and Biocompatible Zn-Based Alloys for Resorbable Medical Devices

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The development of biodegradable metallic materials with high strength and suitable ductility remains a significant challenge in the field of temporary medical implants. Zinc-based alloys have emerged as promising candidates due to their moderate corrosion rates, favourable biocompatibility, and the absence of harmful degradation products. However, the inherent trade-off between strength and elongation limits their clinical deployment in load-bearing applications. In this study, we report an approach combining chemical modification of widely considered Zn-Mg system by silver with powder metallurgy including mechanical alloying (MA), spark plasma sintering (SPS) and extrusion to fabricate ultrafine-grained Zn-Mg and Zn-Mg-Ag alloys.

High-energy ball milling of pure Zn, Mg and Ag powders for 4 hours resulted in nanocrystalline powder precursors of Zn-1Mg and Zn-1Mg-1Ag compositions containing Mg_2Zn_{11} intermetallics and oxide dispersoids. These particles inhibit grain coarsening during consolidation, enabling the formation of bulk materials with average grain sizes around 700 nm. The consolidated alloys displayed exceptional mechanical performance, reaching ultimate tensile strengths up to 435 MPa and fracture elongation values near 12%. Comprehensive characterization using SEM, EBSD, TEM, and atom probe tomography (APT) revealed a refined and uniform microstructure, with intermetallic particles distributed both intra- and intergranularly. The presence of fine oxide particles, mainly MgO or mixed MgO with ZnO, contributed to grain boundary pinning and thermal stability. Addition of silver (1 wt.%) conferred strong antibacterial properties against *Staphylococcus epidermidis* while maintaining non-cytotoxic behaviour toward human osteoblasts in vitro, as validated by ISO-compliant extract tests. Corrosion

analyses in simulated physiological media confirmed low degradation rates and formation of stable protective layers.
This study demonstrates that mechanical alloying combined with tailored thermomechanical processing enables the production of Zn-based alloys exhibiting an excellent balance of high strength and acceptable ductility. The developed Zn-Mg and Zn-Mg-Ag materials exhibit structurally stable ultrafine-grained microstructures that remain resistant to coarsening during consolidation, thanks to the dispersion of nanoscale oxides and intermetallic particles. This stability underpins their reliable mechanical performance and positions them as highly promising candidates for next-generation biodegradable implants.

Keywords: Zinc; bioresorbable materials; powder metallurgy; microstructure; mechanical properties

Silver-enriched micro domain patterns as advanced bactericidal coatings

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Metal nanostructure-treated polymers are widely recognized as the key material responsible for a specific antibacterial response in medical-based applications. We have aimed our study on anchoring of silver nanoparticles (AgNPs) into polyetherether ketone (PEEK) with a tailored surface morphology that exhibits laser-induced periodic surface structures (LIPSS). Formation of hexagonal domains doped with AgNPs using a KrF excimer laser on the PEEK was also studied. We demonstrated that laser-induced forward transfer technology is a suitable tool, which, under specific conditions, enables uniform decoration of the PEEK surface with AgNPs, regardless of whether the surface is planar or LIPSS structured. The antibacterial test proved that AgNPs-decorated LIPSS represents a more effective bactericidal protection than their planar counterparts, even if they contain a lower concentration of immobilized particles. The hexagonal PEEK structures immobilized with silver nanoparticles (AgNPs) were prepared successfully. The antibacterial tests proved the antibacterial efficacy of Ag-doped PEEK composites against *Escherichia coli* and *Staphylococcus aureus* as the most common pathogens. The findings presented here contribute to the advancement of materials design in the biomedical field, offering a novel starting point for combating bacterial infections through the innovative integration of AgNPs into inert synthetic polymers.

Keywords: composite, polymer, noble metal, laser exposure, nanostructure, antibacterial properties

Session 2:

Surface treatment and tribology

Advancements in Synthesis of 2D MoS_2 Nanostructures

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Two-dimensional (2D) nanomaterials, such as graphene, Mxenes, hexagonal boron nitrides, transition metal dichalcogenides (TMDCs), etc., represent a very important class of nanomaterials with continuously increasing importance. Due to their intrinsic features, unique properties and diversity of functionalities, they count among the most widely studied materials nowadays. While considerable research efforts have been spent to synthesize them in different forms (e.g. nanosheets, nanoflakes) and compositions limited efforts have been devoted to surface modification and property tailoring of these materials.

The focus of this presentation is the demonstration of the most advanced gas-phase and wet-chemical approaches for the synthesis of MoS_2 nanostructures [1-3], and other TMDC nanostructures [4,5], towards more chemically and mechanically stable surfaces. These materials have prospects also for effective performance in tribological applications, which is the main target of our materials in project MeBioSys.

The presentation will introduce and describe the synthesis of MoS_2 nanosheets by Atomic Layer Deposition and MoS_2 nanoparticles by hydrothermal synthesis [6]. It will also include the corresponding chemico-physical characterization and encouraging results obtained in tribological applications.

Keywords: Nanostructures, Molybednum Sulfide, 2D, Atomic Layer Deposition

[1] M. Motola et al. *Nanoscale*, **11** (2019) 23126

[2] H. Sopha et al., *FlatChem* **17** (2019**)** 100130.

[3] A. Teklit et al, *Nanomaterials* **10** (2020**)** 953

[4] R. Zazpe et al. *FlatChem* **21** (2020) 100166

[5] R. Zazpe et al. *Applied Materials Today* **23** (2021) 101017

[6] I. Saldan et al., Ms in preparation.

pHEMA Hydrogels as a Model for Studying the Superlubricity of Articular Cartilage

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Articular cartilage (AC) is a complex connective tissue that plays a vital role in facilitating low-friction movement and ensuring the long lifetime of human joints. Hydrogels, have been investigated as model materials for AC replacement in tribological studies, or as materials that could potentially replace worn AC in the human body. This study investigates transparent poly(hydroxyethyl methacrylate) (pHEMA) hydrogels as biomimetic AC materials in tribological experiments focusing on the investigation of AC superlubricity mechanisms through a combination of frictional measurements and *in-situ* observation of contact area using fluorescent microscopy.

The pHEMA hydrogels synthesized using free-radical polymerization with blue light under two different atmospheres (nitrogen N2 and air) were compared with bovine AC. Samples prepared in an air atmosphere were further modified using sodium hyaluronate (HA) and 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) in order to mimic the AC uppermost superficial layer. The hydrogels were characterized by swelling tests using gravimetric analysis and surface topography analysis by surface roughness measurements via an optical scanning microscope. The frictional performance of the pHEMA hydrogels under fully lubricated conditions with a model synovial fluid (SF) was assessed with a pin-on-plate tribometers, while the contact area was also observed with a fluorescence microscope to analyse the behaviour of the individual SF constituents.

Synthesis under a nitrogen atmosphere resulted in the formation of smooth-surfaced hydrogels (S_a = 1.17 µm and S_z = 20.82 µm), whereas synthesis under a laboratory atmosphere resulted in the formation of wrinkled surface with substantially higher surface roughness (S_a = 8.96 µm and S_z = 106.31 µm). pHEMA hydrogels synthesised under a laboratory atmosphere also exhibited a coefficient of friction (COF) that closely resembled that of AC (Fig. 1). At the end of the frictional measurements, a COF value of 0.0173±0.0006 was measured for the cartilage-on-cartilage contact, whereas a COF value of 0.0320±0.0037 was measured for pHEMA air-on-cartilage contact under the same conditions. Adding HA and DPPC to the surface layer of the hydrogel resulted in a further decrease in COF to 0.0163±0.0019. *In-situ* observations revealed an interaction between HA and phospholipids dissolved in SF and AC/pHEMA surfaces, leading to the formation of lubricating layers that are essential for further research into AC superlubricity mechanisms.

The presented results demonstrate that pHEMA hydrogels, particularly those modified with HA and DPPC, can effectively mimic the tribological behaviour of natural articular cartilage under SF lubricated conditions. The observed reduction in COF, along with in-situ evidence of boundary layer formation, highlights the potential of these hydrogels as biomimetic materials for studying AC superlubricity. This work provides a valuable foundation for further exploration of the molecular interactions within synovial fluid and AC, and their role in maintaining ultralow friction at joint interfaces.

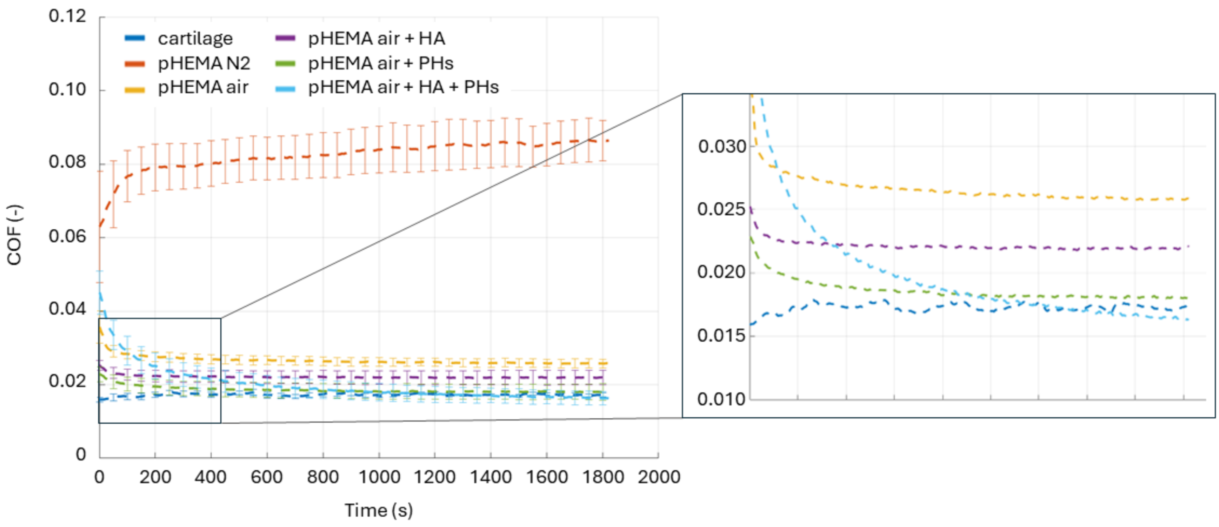

Fig. 1 Friction of pHEMA hydrogels

Keywords: Articular cartilage, pHEMA hydrogels, fluorescent microscopy, friction, synovial fluid

Thermo-electron accumulation in light and heavy water during MHz-burst laser ablation

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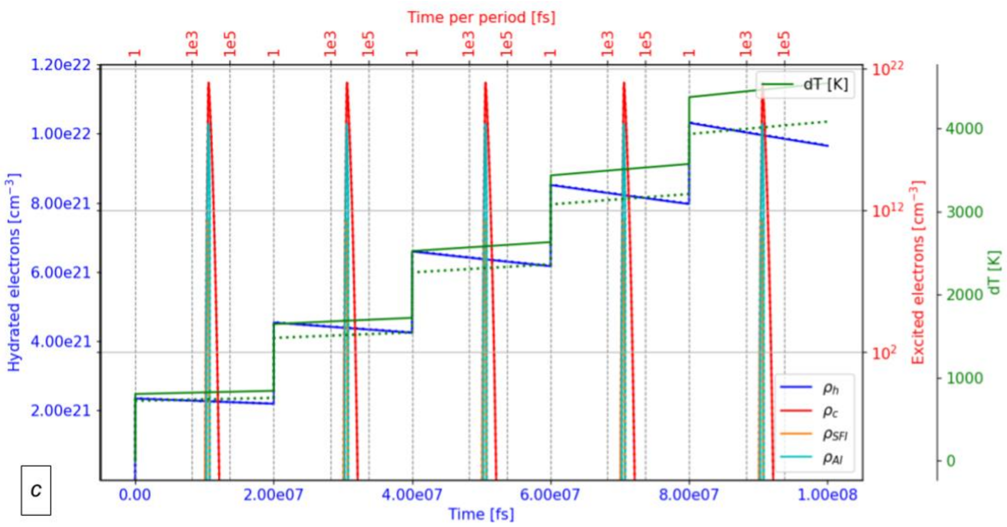
Laser ablation under water is one of the ways for forming heterostructures on solids, like Ti, stainless steel, Al alloys and others [1]. This study aims to compare the ablation plasma glow and thermal effects in light and heavy water under both single-pulse and burst-mode ultrashort laser irradiation. Notably, this research introduces the novel application of burst laser ablation in heavy water for the first time. The ablation was conducted beneath the water surface along a circular, laser-scanned trajectory, with two distinct ablation regimes: burst mode and single-pulse mode, utilizing lenses with varying focal lengths and different pulse durations. Absorption processes and plasma glow were monitored using visible and infrared detectors, a fast silicon detector, and a thermocouple.

The study revealed that the burst regime in heavy water produced the most intense plasma glow when 1 ps laser pulses were used, with shorter pulses yielding less intense glow and the longest pulses yielding the least (Fig. 1. a and b). Surprisingly, plasma glow at a lower initial power density was four times higher than at a higher power density. These findings were compared with existing theories on plasma formation in water by ultrashort laser pulses. The observed increase in pulse-to-pulse plasma glow in burst mode was attributed to thermo-electron accumulation effects (Fig. 1, c). The density of excited and hydrated electrons, and temperature changes of ablated water were calculated using both strong-field ionization and avalanche ionization models [2]. The results of thermocouple measurements were compared with thermal balance calculation. Additionally, the influence of pulse parity on burst ablation glow in heavy water was discussed.



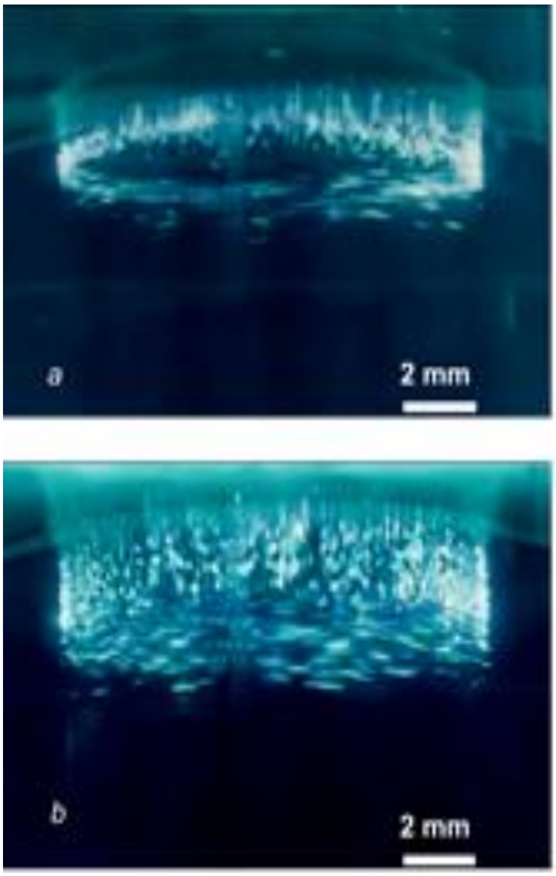


Fig. 1. Single pulses and burst water ablation ($\tau_p = 1$ ps, $F = 255$ mm): *a* - ablation ring in single distant pulses regime; *b* - ablation ring in burst regime with 5x pulses; *c* - theoretical evaluation of excited electron density dynamic, accumulation of hydrated electrons and temperature (solid lines - H_2O, dotted lines - D_2O).

[1] Zhang D, Ranjan B, Tanaka T and Sugioka K (2020) Multiscale hierarchical micro/nanostructures created by femtosecond laser ablation in liquids for polarization-dependent broadband antireflection *Nanomaterials* **10** 1–15

[2] Noack J and Vogel A (1999) Laser-induced plasma formation in water at nanosecond to femtosecond time scales: calculation of thresholds, absorption coefficients, and energy density *IEEE J. Quantum Electron.* **35** 1156–67

Keywords: Burst water ablation, thermo-electron accumulation, heavy water, ultrashort pulses, plasma glow

Enrichment of a micro/nanotextured titanium surface with laser-induced nanoparticles exhibiting biocompatible, antibacterial and non-cytotoxic capabilities: synthesis and immobilization

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Materials used or designed for dental and bone prostheses should have suitable bulk properties and optimal biological performance, addressing two main concerns in implant therapy: implant-associated infections and effective bone tissue integration. Enhancing biocompatibility and antibacterial activity while minimizing cytotoxicity has emerged as one of the primary goals in developing new advanced implants and restorative materials [1]. Our approach for reaching these criteria consisits in the synergy between two disciplines: a) laser texturing of in order to achieve appropriate micro/nanotopography of Ti surface and b) pulsed laser ablation in liquid used for synthesis of colloidal nanoparticles which are subsequently electrostatically immobilized onto Ti surface for the purpose of tuning the biological response. Current studies suggest that suitable phases that exhibit the necessary balance between biocompatibility, antibacteriality and non-cytotoxicity are intermetallic compounds such as e.g. Ti_2Cu, MnSi, Cu_2Si which were so far achieved only under the conditions of elevated temperatures and/or high vacuum. Here we exploit our recent revealing [2] of possible colloidal reactivity between laser-induced metastable metal oxides sols which allows formation of these phases at room temperature. In summary, our concept involves laser-assisted synthesis of nanoparticles with the desired biological response and their subsequent immobilization onto a laser-textured surface (simplistic scheme is given in Fig. 1).

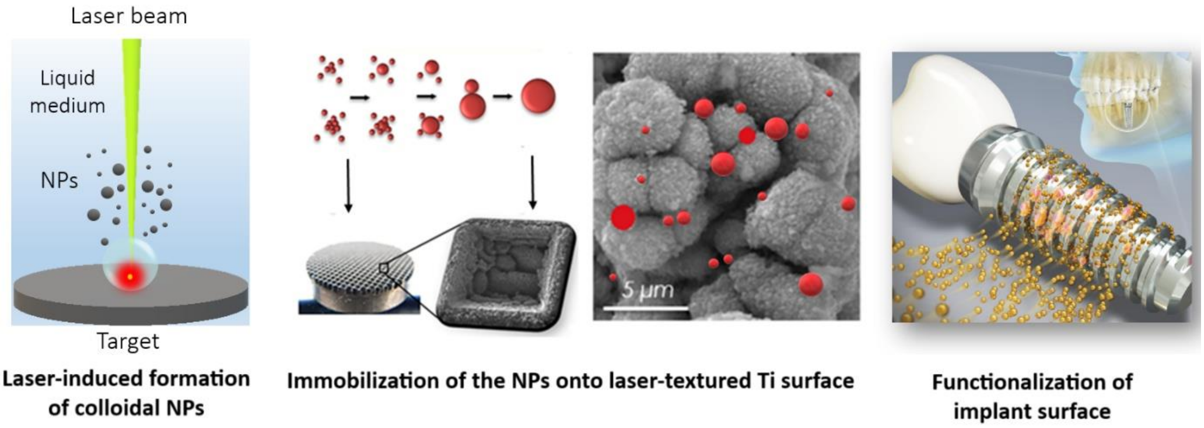

Fig. 1 Scheme of laser-induced functionalization of Ti medical implant surfaces

[1] K. G. Neoh, X. Hu, D. Zheng, E.T Kang, Balancing osteoblast functions and bacterial adhesion on functionalized titanium surfaces. Biomater. 33 (2012) 2813-2822.

[2] T. Křenek, L. Vála,a R. Medlín, J. Pola, V. Jandová, V. Vavruňková, P. Mikysek, P. Bělský, M. Koštejn, Dalton Trans., 2022, 51, 13831–13847

Keywords: Surface modification; nanostructures; implants; laser ablation; titanium; bioactivity; antibacterial effect; silicides

work-package B.2.2 - Bioactive functionalization and surface characterization

Session 3: International Mobilities

In-situ observation of persistent slip markings in the early fatigue of LPBF 316L stainless steel

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Laser powder bed fusion (LPBF) is a widely used additive manufacturing (AM) technique that enables the production of complex geometries by selectively melting metal powders layer by layer using a focused laser beam. This process is characterized by highly localized heating, rapid solidification, and extreme thermal gradients, which results in a unique and often anisotropic hierarchical microstructure. These microstructural features differ significantly from those found in conventionally manufactured materials and can have a pronounced impact on the material's mechanical behavior, particularly under cyclic loading conditions.

Given the growing adoption of LPBF for structural applications, especially in the aerospace, biomedical, and energy sectors, understanding the fatigue performance of LPBF-fabricated materials is of critical importance. In this study, we investigate the early fatigue damage mechanisms in additively manufactured 316L austenitic stainless steel, with a particular focus on the formation and evolution of persistent slip markings (PSMs). These localized surface features serve as precursors to crack initiation and can provide valuable insight into the deformation behavior of the material under cyclic loading.

To observe the development of PSMs in real time, we employed an in-situ cyclic loading module integrated within a scanning electron microscope (SEM), enabling direct visualization of surface changes during fatigue testing. The surface evolution of PSMs was monitored from the virgin (unloaded) state up to 75 load cycles. In addition, specimens pre-cycled for 50 and 500 cycles were examined to capture the progression of slip activity over extended fatigue exposure. Advanced characterization techniques, including electron back-scattered diffraction (EBSD), electron channeling contrast imaging (ECCI), and atomic force microscopy (AFM), were used to measure the size, morphology, and distribution of the PSMs with high spatial resolution.

The results were compared with existing literature on conventionally manufactured 316L stainless steel to assess the influence of the LPBF process on early-stage fatigue behavior. This comparison highlights the impact of additive manufacturing-induced microstructures on slip activity.

Keywords: LPBF, 316L steel, persistent slip band, slip activity, slip reversibility, half-cycle deformation

Advancing analysis of 3D printed materials: Mobility at Paul Scherrer Institute enhances TEM expertise and optimisation of in-situ straining

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The mobility took place at Paul Scherrer Institute (PSI), Switzerland. From 9th September to 13th December 2024. Markéta Gálíková joined Electron Microscopy Facility led by Dr. Elisabeth Agnes Müller Gaubler. The group uses advanced electron microscopy techniques for the characterisation of microstructural features of various materials. The goal of the Mrs. Gálíková mobility was to broa den her experience in the field of transmission electron microscopy (TEM) and to gain hands-on experience with probe-corrected TEM equipped with fast and sensitive camera, suitable for 4D-STEM and to strengthen the relationship between PSI and IPM.

Mrs. Gálíková was trained on various electron microscopes – TEM: JEOL JEM 2010, probe-corrected JEOL JEM ARM200F and SEM Zeiss Nvision equipped with Focused Ion Beam (FIB) at the very beginning of the mobility. She took part in research activities of Electron Microscopy Facility. In collaboration with Dr. Anja Weber, she participated on sample preparation of omni-probes for X-ray tomography, with Dr. Emiliya Poghosyan she learned about operating probe-corrected TEM system and how to obtain HRTEM and HRSTEM data. In addition, Dr. Radim Skoupý introduced his research of Ptychography and 4D-STEM data processing scripts, which contributed to better understanding of 4D-STEM strain mapping via Python py4DSTEM package. This matches the goals of WP A.1.2. of MeBioSys project, as it is beneficial for analysis of internal stresses introduced to the material during 3D printing and analysis of residual stress distribution, which is essential for tuning processing parameters and further development of 3D printed materials.

Towards the end of the mobility Mrs. Gálíková and Dr- Müller successfully established a method of sample preparation for in-situ TEM straining tests via FIB-SEM preparation and even performed proof-of-concept experiment with Single Tilt Liquid Nitrogen Cooled Straining Holder, model 671 with material studied within the Mebiosys project. Since there was no previous knowledge of in-situ straining tests at Dr. Müller's group and no in-situ equipment at IPM, this experiment promises future collaboration between PSI and IPM on future international projects, which will broaden knowledge about plasticity of (not only) 3D printed materials even at the atomic level.

Keywords: TEM in-situ staining, 4D-STEM, PSI-IPM collaboration, AM materials, sample preparation

Tribocorrosion Study of Additively Manufactured Ti6Al4V with Surface Structure and UHMWPE Interfaces Under Synovial Fluid Degradation: Insights from a Scientific Mobility at EPFL

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As part of a three-month scientific mobility, I had the opportunity to conduct research at the prestigious École polytechnique fédérale de Lausanne (EPFL) in Switzerland. EPFL consistently ranks among the top technical universities worldwide—in the field of Engineering, it is regularly listed in the global top 10 according to the QS World University Rankings. My work was carried out within the Tribology and Interfacial Chemistry research group, which focuses on modern aspects of tribology and chemical interactions at liquid–solid interfaces. The laboratory is led by Professor Stefano Mischler (H-index 48), and my direct scientific advisor during the internship was Dr. Anna Neus Igual Muñoz (H-index 30), a specialist in biotribology and tribocorrosion. Their expertise and mentorship greatly contributed to the direction and quality of the research.

During my stay, I focused on the study of tribocorrosion between additively manufactured Ti6Al4V with a defined surface structure created directly during the process of 3D printing and UHMWPE. The main goal was to understand the changes in the chemical and physical behaviour of synovial fluid after various stages of long-term tribological experiments. Synovial fluid samples obtained after 100,000; 200,000; and 300,000 wear cycles were analysed and compared with fresh fluid. The study aims to determine whether degradation or transformation processes occur in SF during mechanical loading, which could influence wear, lubrication behaviour, or corrosion processes at the implant interface.

This research is directly aligned with the broader goals of the MEBioSys project, particularly in exploring the lubrication behaviour and long-term performance of artificial joint interfaces under biologically relevant conditions. By investigating the evolution of synovial fluid properties during extended tribological testing, the study contributes to a deeper understanding of contact mechanisms in biosystems and supports the development of experimental approaches that reflect real physiological environments. Additive manufacturing, used in the preparation of friction surfaces, is one of the innovative technologies considered within the project for translating biological lubrication principles to engineered systems. In this context, the concept of *superlubricity* is a long-term aspiration that guides the investigation of advanced surface designs and lubrication regimes inspired by natural joint systems. The mobility allowed me to consult the methodology with experts across disciplines, to access advanced analytical equipment, and to gain experience that significantly broadens the competencies of our research group and strengthens the scientific output of the project.

Moreover, this internship significantly enhanced my know-how in the field of tribocorrosion, which is increasingly recognized in the current scientific literature as a critical factor affecting the long-term performance of biomedical implants. The collaboration with EPFL opens up opportunities for future joint projects, and the data collected during this research stay will serve as the basis for a planned scientific publication.

Keywords: additive manufacturing, Ti6Al4V, implant, tribocorrosion, wear

work-package A.2.1 - Mechanisms of superlubricity in biosystems

Effect of substrate temperature on the nanodiamond coatings prepared by spray deposition

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Substrate temperature is one of the key parameters influencing the final structure of thin material layers prepared by spray coating. It affects both the distribution of nanoparticles within individual droplets and the overall morphology of the resulting coating. During a research stay at the Budapest University of Technology and Economics (BME), in the Combustion Research Group laboratory, the influence of substrate temperature on nanodiamond layer formation was investigated using a nebulizer-based spray coating device. The laboratory is equipped with a heated chamber that allows precise temperature control and stable deposition conditions. Aqueous nanodiamond suspensions with concentrations of 1 and 10 mg/mL were used to coat silicon wafers. The droplet impact velocity was varied by adjusting the gas overpressure in three regimes: 25, 50, and 75 kPa. Substrate temperatures ranged from 50 to 200 °C in 25 °C increments. Deposition times of 2, 5, and 10 seconds were used for comparison. The coated samples were evaluated using optical microscopy with a focus on surface coverage, uniformity, and deposition morphology. The results demonstrate a significant influence of temperature on coating uniformity and quality. At lower temperatures, a continuous film was formed followed by solvent evaporation, which led to coarser and less homogeneous structures with reduced surface coverage. In contrast, substrate temperatures of 75–100 °C produced more uniform and finer layers with improved coverage. At temperatures above 150 °C, a decrease in deposited material was observed due to droplet evaporation before impact and altered airflow behaviour around the heated substrate. These findings contribute to the optimization of spray-coating parameters for the fabrication of thin films with tailored properties.

Keywords: Spray coating, Nanodiamonds, Surface morphology, Substrate heating

Influence of supersampling on mechanical properties of human bone samples

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Information about bone microarchitecture can be useful not only for diagnosing different kinds of bone diseases, such as osteoporosis, but also for monitoring the effectiveness of treatments. For imaging bone tissue, different biomedical devices can be used. In cases where only samples of bone are available, micro-computed tomography (micro-CT) is a useful device for high resolution imaging. Such devices allow for the study of the microarchitecture of bone samples. However, the restricted sample size and the high radiation exposure make it unsuitable for clinical applications. In clinical settings, medical CT, high-resolution peripheral quantitative computed tomography (HR-pQCT), or magnetic resonance imaging (MRI) are typically used. These techniques have limited resolution, which may obscure information about the microarchitecture of bone tissue. Supersampling is a method that could potentially address this issue. It is a post-processing step, and it can potentially enhance the resolution of images, however, it requires validation. Two datasets of human mandibular bone specimens with different voxel sizes were created: the first had a resolution of 30 µm, and the second had a resolution of 60 µm. The 30 µm correspond to the resolution achieved through micro-CT, while 60 µm correspond to the resolution obtained from HR-pQCT. Supersampled images of micro-CT data were created to investigate the influence of supersampling on the bone morphometry and mechanical properties. Images obtained from micro-CT with resolution 60 µm were supersampled to resolution 30 µm by using trilinear interpolation. A bone morphometry analysis was conducted on the micro-CT data and also supersampled images, with the objective of detecting any potential differences caused by supersampling. Subsequently, the finite element analysis was used to estimate apparent Young's modulus and investigate the influence of supersampling on mechanical properties. The results indicate that the quantity of bone tissue present in the specimen is not affected by the supersampling ($p>0.05$). However, analysis of other bone morphometry parameters revealed statistically significant differences.

Keywords: micro-computed tomography, bone, human mandible, supersampling, image processing

Intelligent Morphing Structures: Evolutionary Design and Sensing Integration in Gradient Metamaterials

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The design of gradient metamaterial structures offers a promising pathway for achieving adaptable mechanical behaviour in advanced engineering applications. This work presents a comprehensive methodology for the structural design and optimization of a flexible metamaterial system with gradient bending stiffness, aimed at enabling controlled shape transformations. A simplified spring-based model is employed to represent the mechanical behaviour of the structure, significantly reducing computational demands compared to traditional finite element methods. A differential evolution (DE) algorithm is used to optimize geometric parameters, minimizing the deviation between the deformed and target shapes under applied loads. The optimization process is explored at three levels of complexity, from basic algorithm tuning to multi-shape morphing under varying conditions.

In addition to structural optimization, the integration of sensing capabilities into the metamaterial system is investigated. Piezoelectric PVDF (polyvinylidene fluoride) film sensors are embedded within the structure to enable real-time shape monitoring and feedback control. Two experimental setups validate the sensing concept: one under cyclic tensile loading and another within a morphing demonstrator. The sensors successfully captured deformation patterns and distinguished between morphing states, demonstrating their potential for closed-loop control in adaptive structures.

Part of this research was conducted during an internship at Imperial College London, where the proposed approach was discussed and refined in collaboration with faculty members. Several experimental components, including the sensing integration and validation tests, were carried out in the laboratories at Imperial, contributing valuable insights and technical feedback to the overall development of the system.

Keywords: Mechanical metamaterials, Gradient structures, Structural optimization, Embedded sensing, Adaptive structures

Atomistic Insights Into High-Pressure Twinning Pathways ans Twin-disclocation Interactions in BCC Nanocrystal

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Plastic deformation in body-centered cubic (BCC) nanocrystals is traditionally attributed to shear-driven twinning processes along well-defined twin boundary planes, typically initiated under high stresses and accompanied by twin-dislocation interactions. Through systematic molecular dynamics simulations with advanced interatomic potentials in conjunction with density functional theory simulations, we uncover novel pressure-driven mechanisms for twin nucleation, growth, and annihilation at the intersection of crystal plasticity and structural phase transitions. We show that as the compressive stress increases, the classic twinning route is progressively suppressed, giving rise to two distinct atomic-scale pathways: (i) a dual-shuffle mechanism distinguished by the formation of transitional HCP phases without the classic, invariant twin boundary planes, essentially driven by the applied pressure, and (ii) a process mediated by the formation of transient FCC-like platelets under the synergistic effect of ultra-high pressure and shear. These routes produce characteristic wedge- and platelet-shaped twins that evolve into distinctive defect networks through pervasive twin annihilation mechanisms that emit dislocations, enabling plastic strain accommodation through the formation of mixed twin/dislocation networks. The simulation reveals specific twin-dislocation interactions as a function of the active twinning pathway, providing fundamental insights to the onset of distinct defect networks. A detailed insight into the initiation of twin-mediated plasticity also emerges through the analysis of the energy landscapes of the competing twinning pathways, enabling fundamental assessments of twin nucleation under high compressive, tensile, and shear stresses. Our simulations provide a novel pressure-driven framework to the assessment of plasticity in small-scale components and nanostructured metals subjected to extreme mechanical solicitations, including shock and contact loading conditions.

Keywords: Pressure-driven twinning, BCC nanocrystals, Plastic deformation, Twin-dislocation interactions, Molecular dynamics simulations

work-package – A.1.1 - Theory-driven development of new alloys / A.1.2 - Bio-inspired additively manufactured metal materials / A.1.3 - Preparation of functional (multi)materials based on ceramics

Process–Structure Relationships in LPBF of Ti-25Nb-4Ta-8Sn

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During my five-month research internship at the Institute of Metals and Technology in Slovenia, I focused on the development of the advanced Ti-25Nb-4Ta-8Sn alloy using Laser Powder Bed Fusion (LPBF) technology. The main experimental work involved optimizing key LPBF parameters such as laser power, scan speed, hatch spacing, layer thickness, and scan strategy. A unique aspect of the study was the investigation of argon gas flow over the powder bed which proved to have a significant effect on part quality and process stability. Particularly the increased flow had significant effect on the grain size, morphology and orientation supressing the formation of preferential grain orientation in the <001> direction along the building direction.

Throughout the internship, I gained hands-on experience with the LPBF process and became proficient in operating the Aconity Mini machine, which provides a high degree of flexibility for parameter variation and in-situ observation. In the field of microstructural characterization, I expanded my expertise in scanning electron microscopy and data analysis by working with two state-of-the-art commercial software platforms: AZtec Crystal (Oxford Instruments) and OIM Analysis (EDAX). Both tools include advanced features such as dictionary-based indexing and, particularly spherical indexing in OIM, allowing for high-precision analysis of grain size, crystallographic texture, and residual stress.

The studied material is part of ongoing research conducted within the MeBioSys project. The knowledge and practical skills gained during this internship are directly transferable to the upcoming implementation of the EOS M290 LPBF system with unique combination of operational parameters acquired by UCT Prague as part of the project solution.

Keywords: titanium; biomaterials; LPBF; microstructure

Session 4: Poster session

The Critical Role of Low-Amplitude Cycles in Oxide-Induced Crack Closure and Fatigue Life

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Since in engineering practice, fatigue experiments applying the full load spectrum may last for several weeks or even months, it is common to omit so-called "non-damaging" cycles, the cycles bellow the threshold value for crack propagation, typically threshold maximal stress intensity factor $K_{\max}$, in order to reduce testing time. This simplification is widely accepted based on the assumption that such low-amplitude cycles have no meaningful effect on crack growth. However, this study demonstrates that the omission of these cycles can lead to paradoxical and potentially dangerous consequences for fatigue life predictions, especially in humid environments where oxide-induced crack closure mechanism (OICC) is active.

The effect of OICC under full and partial discretized variable amplitude loading representing actual train service conditions was demonstrated on compact tension specimens (CT) made of railway axle steel EA4T. While the omission had negligible impact on crack propagation under dry air conditions, the results in humid air revealed an acceleration of crack growth when these cycles were excluded. This led to a reduction in residual fatigue life compared to specimens subjected to the full spectrum in the same environment which is contrary to the general assumption that higher number of cycles leads to a shorter residual fatigue life.

Formation of oxide layer was observed using optical and electron microscopes. Images of fracture surfaces revealed that ferrous oxide debris accumulation was significant under full loading spectrum in humid air, it was mild under full loading spectrum in dry air, and it was negligible under partial loading spectrum regardless of humidity. These results were confirmed by cycle-by-cycle simulations enabling separation of different crack closure mechanisms.

These findings challenge the traditional assumption that low-amplitude cycles are irrelevant to fatigue damage and highlight the importance of accounting for all load cycles in fatigue testing, as their omission can result in inaccurate predictions of residual fatigue life, especially in humid conditions. The interplay between environmental conditions and loading spectrum cannot be ignored without risking substantial underestimation of damage. A more comprehensive approach that considers the mechanical and environmental contributions of all load cycles is essential for ensuring structural integrity in demanding applications such as railway transportation and nuclear power plants.

Keywords: Fatigue crack growth, oxide-induced crack closure, steel, variable amplitude loading, residual fatigue life, non-damaging cycles, threshold level.

Low Cycle Fatigue of High Manganese Steel with Variable Microstructure Processed by Laser Powder Bed Fusion

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In this study, the low cycle fatigue behaviour of a high manganese steel X30Mn22 was investigated in several microstructural variants featuring different predominant crystallographic orientations. Metastable austenitic solidification structure of studied material underwent strain-induced martensitic transformation which is crystallographic orientation-dependent. Therefore, the studied types of structures, {011}- and {111}-textured, and without predominant texture, showed different cyclic behaviour characterized by various magnitude of cyclic hardening. Notable variations in fatigue lifetime were found also with respect to the type of microstructure. To explain underlying deformation mechanisms a detailed SEM characterization was carried out on initial microstructures, surface relief after cyclic loading, and internal deformation structures. Localization of cyclic plastic deformation resulted in martensitic transformation via γ (FCC) → ε (HCP) → α´(BCC) sequence, which was identified in all microstructural variants. These processes created a distinct surface relief which induced fatigue crack initiation and promoted fatigue crack propagation.

Keywords: Low cycle fatigue, high manganese steel, laser powder bed fusion, microstructure, crystallographic texture, martensitic transformation, cyclic deformation, fatigue crack initiation, Microstructure characterization.

Repeated liquid impact induced martensitic transformation in austenitic steel

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Erosion by repeated water droplet impacts is a degrading phenomenon leading to the loss of effectiveness or even failure of many engineering parts, including turbine blades. Recent development in the field of water jetting has led to the creation of several types of pulsed water jets (PWJ). These devices employ erosion beneficially by shattering a continuous water jet into individual water elements, effectively generating repeated water droplet impacts on the targeted surface. This can be utilised for surface modification based on impact parameters to harden the subsurface, modify the subsurface stress, or for controlled surface roughening.

This technique draws scientific interest due to two key advantages concerning surface modification. Firstly, it is considered a cold method that does not produce heat in the adjacent material. Secondly, the working medium is pure water, minimizing the risk of embedding the surface with foreign particles, which is a common problem in surfaces roughened by solid impacts. The PWJ used for experiments was equipped with a 40kHz sonotrode, generating 40,000 water impacts per second. The Hydraulic pressure was set to 70 MPa with a nozzle diameter of 0.8 mm, creating a flow rate of approximately 337 m/s. The surface was treaded employing two movement patterns. First, the linear trajectory with feedrates 5, 4, 3, 2, 1 mm/s, and secondly perpendicular interlaced trajectory with feedrates 10, 8, 6, 4, 2 mm/s. Feedrates were selected to reach an equivalent number of droplet impacts per surface area.

Modified surfaces were scanned using a MicroProf FRT optical profilometer. The profile surface parameters were defined in accordance with ISO21920-2 standard. The selection of both R-profile parameters and S-area parameters was used to sufficiently describe the created surface. Surface morphology was observed using a scanning electron microscope, Lyra 3 XMH FEG/SEMxFIB from Tescan. The modified surfaces were measured using X-ray diffraction devices, a Bruker D8 Advance diffractometer with Cu anode, and an Empyrean (Malvern Panalytical) with Co anode, which were used for phase identification and quantification.

The results confirm that repeated droplet impact leads to deformation-induced martensitic transformation. An increase in the droplets impacting a unit area leads to a higher content of the martensitic phase. The phase transformation explains the deeper hardness profile of PWJ exposed AISI 304L, commonly reported in literature in comparison to other materials. Employing the gained knowledge PWJ technique can be employed as a surface roughening method with the additional benefit of controlled subsurface hardening.

Keywords: pulsating water jet, droplet impact, phase transformation, austenitic steel

Biomedically inspired Neural Network Segmentation of Dislocation Structures in L-PBF Austenitic Steel

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Bioinert austenitic stainless 316L steel produced by laser-powder bed fusion (L-PBF) develops a fine cellular microstructure composed of dislocation-rich walls. These cells, often near-hexagonal in shape, contribute significantly to the alloy strength by impeding dislocation motion. However, this structure is sensitive to thermal exposure, which can partially dissolve or coarsen dislocation network, reducing its strengthening effect. Reliable and efficient analysis of structural changes is important for understanding the mechanical behavior of the material after heat treatment or under service conditions. We present a deep learning-based segmentation framework tailored to identify and quantify these cellular dislocation structures across various material states of L-PBF 316L stainless steel, including the as-built condition as well as samples subjected to stress-relief and recrystallization annealing. The framework combines image preprocessing with a U-Net architecture, employing a ResNet encoder pretrained on ImageNet. Training masks were prepared semi-automatically, reducing the manual effort while preserving accuracy. This approach allowed us to achieve high segmentation performance even with a limited number of training images. Microscopy data were obtained using both scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM). While SEM provided an overview of the etched substructure and cell morphology, STEM offered higher-resolution insight into the dislocation arrangement within the cell walls. By applying the segmentation model to these datasets, we extracted geometric parameters such as cell diameter and shape, and examined how they correlate with local dislocation density in the as-built and heat-treated (stress-relieved and recrystallized) states. This correlation helps clarify how microstructural refinement and recovery processes develop at the submicron scale. Although developed for metallic systems, the segmentation strategy is based on convolutional neural networks originally designed for biomedical image analysis. The cellular microstructure in L-PBF 316L, with its near hexagonal dislocation cell networks, shares geometric similarities with natural hierarchical systems found in biological tissues. This analogy, along with the method ability to resolve fine scale structural features, makes it suitable for broader applications such as the analysis of engineered scaffolds, porous implants, or bioinspired materials. By adapting tools from biomedical imaging, this work demonstrates how cross disciplinary approaches can advance materials characterization, offering a more scalable and quantitative pathway for evaluating complex microstructure features.

Keywords: Deep Learning, Additive Manufacturing, Hierarchical Structures, Image Analysis

Investigation of Transparent pHEMA Hydrogels as Tribological Models of Articular Cartilage

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As living standards rise and life expectancy increases, the demand for joint health in aging populations has also grown. Currently, several medical approaches exist to support joint and cartilage health, however they remain insufficiently effective, and the prevalence of joint diseases continues to rise. To develop improved methods for treating and preventing joint disorders such as osteoarthritis, it is crucial to understand the chemical and mechanical processes that enable joints to move with minimal friction. A deeper understanding of joint lubrication requires the development of a transparent tribological model that mimics cartilage and allows these processes to be studied in detail directly using optical methods such as fluorescence microscopy.

This study investigates the use of transparent, modified pHEMA-based hydrogels, developed at CEITEC BUT, as a tribological model that approximates the chemical and mechanical properties of native cartilage. Hydrogels with added hyaluronic acid (pHEMA + HA), pHEMA with both HA and phospholipid vesicles (pHEMA + LIP + HA), and pure pHEMA hydrogel were compared using a unique methodology that combines fluorescence microscopy with tribological measurements. The tribological tests were conducted using a model synovial fluid in a pin-on-plate setup, where the pin was derived from bovine hip cartilage and the plate was the pHEMA hydrogel.

The study comprises two experimental sections, utilizing fluorescently labeled components of synovial fluid to confirm the involvement of the hydration lubrication mode. The first experimental section was conducted with rhodamine B labeled phospholipid (16:0 Liss Rhod PE), and the second with fluorescein isothiocyanate labeled HA (1.6 MDa FITC HA). Each experiment involved two distinct phases: first establishing the fluorescent background, observing the development of fluorescence in the contact region without a lubricating film, and second, performing a tribological experiment, while simultaneously monitoring fluorescence. Each experiment on the hydrogel was repeated three times with the same cartilage.

Fluorescence data were analyzed by subtracting the background signal, revealing the development of the labeled substance in the lubricating film relative to the coefficient of friction (CoF). The results demonstrate that the lowest CoF was achieved by the pHEMA + LIP + HA hydrogel than, the second lowest CoF had pHEMA + HA and pure pHEMA had the highest friction. Fluorescence analysis confirmed the formation of a lubricating film, which is consistent with J. Klein's model of hydration lubrication in joints. The results suggest that pHEMA + LIP + HA hydrogel is the most reliable transparent model of articular cartilage in terms of CoF and lubricant film formation. It will be used in the following research to investigate the molecular mechanisms of lubricant film formation.

Keywords: superlubricity, biotribology, lubrication mechanism, articular cartilage model, hydrogel

Synthetic Liposome-loaded Hydrogels as Cartilage Models for Biotribological Testing

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Articular cartilage (AC) reduces friction and absorbs pressure in the joints. Mimicking its complex structure and tribological behavior is essential for developing artificial joint materials. Synthetic hydrogels, such as poly(hydroxyethyl methacrylate) (pHEMA) offer a promising model material for the evaluation of superlubricity in tribological testing. pHEMA hydrogels are known for their flexibility, optical clarity, and biocompatibility, and their mechanical and surface properties can be tuned by adjusting the chemical formulation. In this study, pHEMA hydrogels were synthesized via free-radical polymerisation using hydroxyethyl methacrylate monomer, a crosslinker, and a photoinitiator. To mimic the behavior of a natural AC, the hydrogels were enriched with hyaluronic acid and liposomes.

Liposomes were prepared via a thin film hydration method and characterised using a ZetaSizer Ultra (Malvern Instruments, UK). Surface morphology was examined via scanning electron microscopy (MIRA3-XMU, TESCAN, CZ), swelling behavior was evaluated using gravimetric analysis, and tribological properties were assessed using a pin-on-plate tribometer (UMT Tribolab, Bruker, USA) under artificial synovial fluid.

Surface morphology of pure and hyaluronic acid-enriched pHEMA hydrogels was examined via scanning electron microscopy, revealing wrinkled structures similar to natural AC. The samples of pure pHEMA showed a swelling ratio of ~50% for pHEMA samples and >200% for bovine AC. The coefficient of friction (COF) for AC was 0.0159, while pHEMA showed a slightly higher COF of 0.0299. The wrinkled surface of pHEMA may enhance fluid retention, contributing to its frictional performance. Following these experiments, liposomes based on dipalmitoyl phosphatidylcholine (DPPC) with diameters of 144.7±0.4 nm and a zeta potential of -23.2±0.8 mV with a narrow dispersity (0.084±0.013) were incorporated into pHEMA hydrogels together with HA as a component of the water phase. Samples with a liposome concentration ranging from 0.25–5.05% v/v were prepared and tested. Based on the transparency of the hydrogels, the most suitable pHEMA hydrogels were also tested for the superlubricity experiments using fluorescence microscopy.

Our findings indicated that pHEMA hydrogels can mimic the surface and tribological characteristics of a model AC, making them suitable model systems for *in vitro* joint studies.

Keywords: pHEMA, liposomes, articular cartilage, hyaluronic acid, superlubricity

Deposition of radon progeny in the upper respiratory airways and trachea

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After the radon decay, its progeny in ambient air either remain unattached, forming clusters smaller than 4 nm or attach (in the range from 100 to 400 nm) to existing aerosol particles suspended in the air. According to the study by Kreuzer et al. (2014)*, the relative risk associated with exposure to radon progeny was slightly higher for pharyngeal cancer than for laryngeal cancer. The internship was conducted at HUN-REN institution in Budapest under the supervision of Dr. Árpád Farkas, who has extensive experience in lung simulation studies. The work focused on the post-processing of the simulations in ANSYS Fluent, the task was to analyse the deposition of radon progeny particles, especially in the larynx and pharynx regions. Particle tracking was conducted under two different breathing regimes; mouth breathing and nasal breathing and, for two particle sizes; 1 nm (representing unattached radon progeny) and 200 nm (representing attached radon progeny). The simulation geometry included the nasal cavity, mouth cavity, larynx, pharynx and trachea. A user-defined function was used for more accurate particle tracking. A user-defined function in C was developed to analyse progeny deposition in greater detail within each computational cell. The local deposition density in each cell, relative to the average deposition density in a given region, was defined as the cell enhancement factor. This factor is commonly used to quantify inhomogeneities in the predicted deposition patterns. Although a higher cell enhancement factor was observed in the pharynx during nasal breathing and in the larynx during mouth breathing, the differences between regions were relatively small. Specific deposition sites can be used to compare with actual cancer occurrence locations.

Keywords: radon progeny, laryngeal cancer, pharyngeal cancer, airway, in silico

**Kreuzer, M., Dufey, F., Marsh, J. W., Nowak, D., Schnelzer, M., & Walsh, L. (2014). Mortality from cancers of the extra-thoracic airways in relation to radon progeny in the Wismut cohort, 1946-2008. INTERNATIONAL JOURNAL OF RADIATION BIOLOGY, 90(11), 1030–1035. https://doi.org/10.3109/09553002.2014.909074*

Phase-Shifted SSDV for Enhanced Vibration Damping

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Vibration control in flexible mechanical structures is a long-standing challenge in engineering design. While passive shunt damping using piezoelectric elements has been extensively explored, recent research has increasingly focused on semi-passive or semi-active techniques that enable greater adaptability without requiring continuous power input. One of the most promising approaches in this domain is the Synchronized Switch Damping on Voltage source (SSDV) method, which has undergone various enhancements, such as adaptive control or asymmetrical switching strategies.

In this work, we introduce a novel variant of the SSDV method—**Phase-Shifted SSDV**—that utilizes precise phase manipulation in the switching process to enhance the energy dissipation performance. The approach is based on the premise that, when the system's resonance frequency is known, a specific phase shift applied during the switching events can significantly improve damping behavior compared to conventional SSDV. We developed a dedicated switching circuit capable of implementing controlled phase delays and tested the system on a single-degree-of-freedom piezoelectric beam setup.

Experimental results show that applying optimal phase shifts leads to a notable increase in vibration attenuation. Compared to the standard SSDV technique, the proposed phase-shifted variant achieves better performance in terms of both the peak amplitude reduction and overall vibrational energy dissipation, especially near the resonance frequency. A parametric study reveals the sensitivity of the damping effect to the phase value and voltage amplitude, highlighting the importance of synchronization accuracy.

The proposed Phase-Shifted SSDV method demonstrates clear potential for applications where the natural frequency of the system is known or can be estimated. It represents a low-power, tunable alternative to more complex active control systems, while preserving the simplicity and robustness of semi-passive shunt strategies. Future work will focus on integrating adaptive algorithms for real-time tuning of phase and voltage, and on extending the method to multi-mode systems.

Keywords: vibration, damping, piezo, control electronics, vibration control

Development of IoT device for metamaterial sensing applications

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The task of an IoT device is to measure physical quantities from the real world, process the resulting signal, and transmit the information to a higher-level application. Data transmission can be implemented via wired buses such as Ethernet, USB, or UART, as well as through wireless protocols like LTE-M, BLE, or LoRa.

When applying the Internet of Things concept to smart materials, a common challenge is the acquisition of signals from many sensors. In the case of a metamaterial containing piezoceramic elements, it is necessary to monitor each individual ceramic island. There are several approaches to handle multi-sensor data acquisition. One option is multiplexing the ADC combined with signal conditioning; however, this method does not support synchronous sampling. Multi-channel ADCs enable synchronous data acquisition but are typically more expensive and often lack tailoring for specific task.

ADC modules implemented in FPGA can be used for signal acquisition, offering advantages such as on-chip data processing and a flexible number of channels. By connecting an RC circuit to a Low Voltage Differential Signal (LVDS) input, a successive-approximation (SAR) ADC can be created. The resulting ADC can be further optimized for low power consumption or enhanced precision, depending on the application requirements.

Keywords: IoT, metamaterial, sensing, AD converter, FPGA

Computational modelling of small-scale domain switching near sharp piezoelectric bimaterial notches and cracks

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Piezoelectric materials exhibit domain switching when structural or electric loads exceed certain limits, which affect their designed functionality. In addition, this effect occurs easily in the vicinity of singular stress concentrators, e.g. cracks or notches. Assuming a scenario of small-scale domain switching, the size and shape of the domain switching region—located just ahead of a clearly defined, primarily monoclinic piezoelectric bi-material notch—are determined using the energetic switching principle and the micromechanical domain switching introduced earlier in the literature. This analysis is specific to a given combination of materials, notch geometry, structural setup, and polarization orientation. The piezoelectric bi-material notch consists of the piezoelectric ceramics PZT-5H and $BaTiO_3$. The asymptotic in-plane fields around the sharp bi-material notch are examined using the extended Lekhnitskii–Eshelby–Stroh formalism. Subsequently, a boundary value problem is solved, incorporating the spontaneous strain and polarization within the switching domain. Their effects on the in-plane singularity intensity at the crack tip along the interface are then calculated. Finally, the influence of the initial poling direction on variations in energy release rates is explored.

Keywords: Small-scale domain switching, Bi-material piezoelectric sharp notch, Expanded

Lekhnitskii–Eshelby-Stroh formalism, Two-state H-integral

Enabling Distributed, Multifunctional SHM through Integrated Metamaterials and Piezoelectrics

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Pursuing robust and resilient infrastructure demands advancements in Structural Health Monitoring (SHM) methodologies. Traditional SHM techniques often rely on periodic inspections using non-destructive testing methods, such as acoustic emission or electro-mechanical impedance analysis; however, these approaches are inherently limited by the potential for undetected damage between assessments. This research investigates a novel paradigm shift towards continuous, distributed SHM by integrating mechanically engineered metamaterials and embedded piezoelectric sensors within structural support systems.

The core concept revolves around leveraging the unique properties of re-entrant mechanical metamaterials – artificially designed structures exhibiting unconventional mechanical behaviour – to provide both load-bearing capacity and a platform for distributed sensing. Piezoelectric materials, known for their ability to convert mechanical strain into electrical signals and vice versa, are strategically embedded within this metamaterial framework. This synergistic combination enables the creation of smart supports capable of continuously monitoring vibration patterns, strain distributions, and potentially even impact loads experienced by the supported structure.

Experimental validation is underway using an aluminium beam supported by pin-and-roller configurations incorporating prototype smart supports. Initial results indicate promising performance in vibration assessment, demonstrating the ability to differentiate between healthy and unhealthy beam conditions based on subtle shifts in piezoelectric signal characteristics. Future work will focus on refining the metamaterial design to optimise sensor coupling efficiency, developing advanced signal processing algorithms for damage classification, and exploring the potential for active control strategies utilising the embedded piezoelectric to mitigate structural vibrations or reinforce weakened areas.

Keywords: Mechanical Metamaterials, Embedded Sensors, Smart Structures, Distributed Sensing, Load-Bearing Structures

Lightweight high-performance lattice structures

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Lattice structures produced by metal additive manufacturing offer a promising pathway toward lightweight, high-performance components for demanding technical applications. Their periodic architecture enables tailored mechanical behavior while significantly reducing material consumption. This conference poster addresses two complementary approaches to improve the performance of lattice structures: optimization of laser processing strategies and geometric refinement by hollow strut design. The first approach investigates the influence of laser scanning strategies on the quality of BCC lattice structures fabricated from WE43 magnesium alloy by Laser Beam Powder Bed Fusion (PBF-LB). Among the tested strategies, hatch strategy with skywriting achieved the most favorable results. It resulted in a relative density of over 99.5%, minimized subsurface porosity and promoted a fine microstructure. These improvements resulted in an effective elastic modulus of 136 MPa and a material Young's modulus of 40 GPa, which is only 12% below the bulk value. This demonstrates the potential of process optimization to maintain mechanical integrity in complex geometries. The second approach investigates the mechanical benefits of replacing solid struts with hollow struts in AlSi10Mg BCC lattice structures. Hollow struts demonstrated up to 70% higher stiffness at equivalent cross-sectional area, which can be attributed to improved bending resistance and efficient material distribution. However, surface roughness and joint quality were found to be critical factors limiting performance, especially under compressive loading. Together, these studies demonstrate that both optimization of process parameters and geometric design are essential to maximizing the mechanical efficiency of lattice structures. The findings provide a foundation for the development of next-generation lightweight components for applications in the aerospace, biomedical and automotive industries.

Keywords: Lattice Structures; Additive Manufacturing; Laser Beam Powder Bed Fusion (PBF-LB); Hollow Struts; Mechanical Performance; Lightweight Design

Superelastic metamaterials with controlled anisotropy (inspired by Karel Brulík's diploma thesis)

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The use of shape memory alloys in combination with the complex geometry of additively manufactured metamaterials enables the design of morphable segments that are capable of continuously changing their shape while maintaining their structural integrity. These can be used in aviation, for example, as a more efficient replacement for conventional flaps, contributing to greater flight efficiency and lower environmental impact. The advantage of these solutions is not only the high degree of reversible deformation, which exceeds the possibilities of conventional materials many times over, but also the possibility of targeted control of directional stiffness by optimizing the internal geometry. In this work, the influence of the internal geometry of a superelastic 2D metamaterial made of a NiTi alloy on the extent of pseudoelastic deformation and the anisotropy of the mechanical response was analyzed. The results obtained made it possible to identify the main influence of the deformation mode and stress distribution on the magnitude of the pseudoelastic deformations. The key elements were found to be the size of the filet radius and the tapered walls, which could be optimized to increase the magnitude by up to 183%. In terms of anisotropic response, the filet radius size and the tapered walls again proved to be key elements that allowed to control the deformation modes under the different loading conditions and thus the degree of anisotropy in the range A = 1-7.74, as well as the position of the joints, which determines the overall load transfer.

Keywords: Metamaterial, NiTi, pseudoelastic deformation, anisotropy, Laser Powder Bed Fusion

Heat Treatment and Stress-Relief Optimization of L-PBF Inconel 939 for High-Temperature Applications

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Additively manufactured Inconel 939 (IN939) is a promising material for critical components in the aviation and space industries due to its excellent retention of mechanical properties at elevated temperatures. Such components can benefit from the design freedom and near-net-shape fabrication offered by laser powder bed fusion (L-PBF), enabling topology-optimized or organic bio-inspired shapes that enhance performance while reducing material waste. However, the aerospace sector demands high part quality and process stability, requiring well-defined fabrication and post-processing to avoid defects and ensure consistent results. This study investigates the L-PBF fabrication of IN939 and compares the effects of different stress-relief annealing and heat treatment conditions. Stress-relief annealing was performed at 760°C, 860°C, and 960°C; the optimal temperature minimized cantilever deformation, and the associated microstructural evolution was analysed. Furthermore, three distinct heat treatment routes were applied, resulting in notable differences in microstructure, tensile strength, and creep resistance. The maximum tensile strength achieved was 1439 MPa with 13.7% elongation, while creep rupture tests at 870°C and 100 MPa yielded lifetimes up to 48.33 hours. These findings provide quantitative insights into the relationship between heat treatment conditions and the performance of additively manufactured IN939, supporting the development of optimized post-processing strategies for advanced, bio-inspired high-temperature components.

Keywords: Laser Powder Bed Fusion, Additive manufacturing, Inconel 939, heat treatment

Process Development for Thin-Walled AZ61 Components Produced by WA-DED

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This study presents a comprehensive approach to the optimization of Wire-Arc Directed Energy Deposition (WADED) for AZ61 magnesium alloy using Cold Metal Transfer (CMT). The aim was to enable the production of high-quality thin-walled components suitable for lightweight structural applications, particularly in sectors where material efficiency and sustainability are essential.

An experimental investigation was carried out to determine the influence of selected CMT parameters on weld geometry, arc stability, and energy input. The analysis identified the most critical variables, including the boost and burn phase currents, their durations, and the electrode travel speed. Using an optimized parameter set, a thin-walled component was successfully fabricated. Mechanical testing confirmed an ultimate tensile strength of up to 239 MPa and a yield strength of 115 MPa in the welding direction. However, notable anisotropy was observed, particularly in ultimate strength and elongation, indicating directional dependence. Microstructural evaluation revealed refined grain morphology and uniformly distributed intermetallic phases.

In addition to parameter optimization, thermal management of the process was addressed through preheating of the base material. Preheating the substrate to temperatures between 200 °C and 250 °C led to more consistent layer geometry, a reduction in internal stresses by up to 50 percent, and a significant decrease in interlayer porosity. These effects were attributed to improved thermal conditions during deposition, which promote more stable solidification and allow trapped gases to escape more effectively.

The combined strategy of precise parameter control and controlled thermal input proved effective in improving the reliability, structural integrity, and reproducibility of the WADED process for magnesium alloys. The results highlight the potential of this method as a sustainable manufacturing route for large-scale, lightweight components in advanced engineering applications.

Keywords: Wire Arc Direct Energy Deposition (WADED), magnesium alloy, processing, mechanical properties, CMT, WAAM, AZ61

Interfacial characteristic of CuCr1Zr-Mar60 horizontal interface processed by LPBF

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Multi-material (MM) 3D printing using Laser Powder Bed Fusion (LPBF) is an advanced manufacturing approach that enables the combination of dissimilar metals within a single component. This allows to design structures with specific properties, which is highly advantageous for applications requiring a balance between mechanical strength, thermal conductivity, and wear resistance. Combining copper alloys and steels is particularly attractive in aerospace, tooling, and electronics industries, where high-performance parts must manage both heat and mechanical loads effectively.

This study investigates the fabrication and characterization of a horizontal multi-material interface between CuCr1Zr copper alloy and Mar60 maraging steel using LPBF. To achieve optimal density and interfacial bonding, two different scanning strategies were employed, customized for each material.

Microstructural analysis was performed using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS). Results revealed that the quality and morphology of the interface were highly dependent on the order of materials in build direction. In samples where Mar60 was printed on top of CuCr1Zr (CS configuration), a relatively sharp and thin (~150 µm), defect-free interface was observed, indicating effective metallurgical bonding via diffusion. In contrast, samples with CuCr1Zr printed over Mar60 (SC configuration) exhibited a wider (~350 µm) interface, with dynamic material mixing and the presence of cracks filled with Cu rich phase propagating from interface toward the steel region.

Mechanical testing showed that both CS and SC interfaces experienced a significant increase in strength after heat treatment. The CS configuration increased from 216,14 ± 1,63 MPa to 465,44 ± 22,91 MPa, while the SC configuration raised from 212,96 ± 0,76 MPa to 426,87 ± 13,16 MPa. However, this was accompanied by a notable loss in ductility, (from 0,33 to 0,05 mm/mm), indicating increased brittleness particularly in the CS samples.

These results confirm the feasibility of producing CuCr1Zr–Mar60 MM parts via LPBF. The interface integrity and mechanical performance are strongly influenced by material order and thermal history, underscoring the need for further process optimization in MM metal printing.

Keywords: Laser Powder Bed Fusion (LPBF), multi-material, interface, copper alloy, maraging steel

High-performance auxetic structure for energy absorption

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Additive technologies, such as Laser Powder Bed Fusion technology, allow the production of complex structures with high control over their geometric parameters. In the field of kinetic energy absorption, it is beneficial to use structured material, because it can safely absorb a large amount of energy compared to bulk material. For high-performance absorbers, it can be advantageous to use auxetic structures which, due to their unique internal geometry, provide for example better energy redistribution. Compared to conventional structures, however, they do not achieve such high values of absorbed energy. There is also no detailed description in the literature of the mechanism for increasing the energy absorption, based on which it would be possible to effectively modify the geometry of the auxetic structure. This work deals with the systematic design of the internal geometry of a 2D auxetic structure to increase the absorption performance. Unit-cells with reinforcements manufactured from stainless steel 316L were tested both numerically and experimentally. Compression tests showed a significant contribution of the reinforcements to the absorbed energy. Digital Image Correlation technology provided deformation maps of the structure, which led to the clarification of the mechanism of energy increase by implementing the reinforcements. The obtained results led to an auxetic structure design that was able to absorb up to 70% more energy per unit mass compared to the reference geometry.

Keywords: Auxetic structure, energy absorption, reinforcement, Laser Powder Bed Fusion (LPBF), stainless steel 316L

Analysis of Metamaterial-Enhanced Triboelectric Sensors

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Triboelectric sensors based on metamaterials represent a promising platform for the development of low-cost, environmentally sustainable sensing technologies with enhanced functional performance. This study investigates the behavior of dielectric–dielectric triboelectric interfaces operating in contact–separation mode through time-dependent finite element simulations. The dielectric components are designed for fabrication via additive manufacturing, enabling precise control over geometry and integration with metamaterial architectures. The analysis focuses on fundamental electrical parameters, including open-circuit voltage, short-circuit current, and the effect of external load resistance, with the objective of elucidating the underlying mechanisms that influence signal generation and dynamic charge transport. Particular attention is paid to the influence of material configuration and geometrical scaling on the transient electrostatic response. The presented laboratory results aim to contribute to a more comprehensive understanding of triboelectric interface behavior and provide design insights relevant to the development of next-generation metamaterial-enhanced triboelectric sensing systems.

Keywords: triboelectric sensors, metamaterials, modelling, 3D printing, contact–separation mode

Development of Pseudo-Harmonic Zn–Mg Composite with Improved Strength for Biodegradable Orthopaedic Implants

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Zinc alloys are recognised for their excellent biocompatibility and favourable corrosion rates, making them suitable for bioabsorbable implants. However, the mechanical properties required for the biomedical orthopaedic applications are not met by pure zinc. This has led to efforts in alloying, particularly with magnesium, copper, manganese and silver, and advanced processing techniques. While additions of alloying elements improve strength through the solid solution strengthening, and formation of intermetallic phases, higher concentrations often result in coarse, brittle phases that negatively affect toughness and ductility.

Materials within the Zn–Mg system processed by conventional casting methods exhibit enhanced mechanical performance. Although hot extrusion improves these properties even further, it still falls short of orthopaedic standards. Recent studies have explored severe plastic deformation and powder metallurgy, with hydrostatic extrusion showing promising results. Building upon these advancements, this work introduces the concept of a heterostructured, pseudo-harmonic zinc-based material composed of ductile zinc domains embedded in a continuous ultrafine-grained Zn–1Mg skeleton. This materiál design was achieved by blending pure zinc powder with mechanically alloyed Zn–1Mg powder, followed by spark plasma sintering (SPS) and hot extrusion.

The fabricated materials exhibited a microstructure with coarse-grained zinc regions encapsulated by nanostructured Zn–1Mg domains. However, SPS consolidation led to the formation of oxide shells at the interfaces, negatively impacting mechanical properties. These shells were successfully disrupted into fine oxide particles during extrusion, improving mechanical performance. Among the processed materials, the 50:50 mixture of Zn and Zn–1Mg domains exhibited the most favourable properties, with compressive strength of 437 ± 12 MPa, tensile strength of 333 ± 7 MPa, and elongation to fracture of 13 ± 2 %, with a total magnesium content of only 0.5 wt %.

This study demonstrates a viable method for tailoring the microstructure of zinc-based alloys using the heterostructure concept, significantly enhancing their mechanical properties and highlighting their potential for use in biodegradable orthopaedic implants.

Keywords: zinc alloys; heterostructured materials; bioresorbable materials; microstructure; mechanical properties

Selective laser melting of β-titanium Ti-25Nb-4Ta-8Sn alloy

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With the ongoing advancements in healthcare, new β-titanium alloys are being developed for bone replacement applications. The Ti-6Al-4V alloy has traditionally been the material of choice in biomedical engineering due to its favourable mechanical properties and excellent corrosion resistance. However, its long-term clinical use presents several challenges. One major concern is the presence of vanadium, which is associated with potential toxicity and allergenic effects. Furthermore, its relatively high elastic modulus compared to human bone results in stress shielding, leading to bone resorption and possible implant failure or loosening.

To overcome these limitations, β-titanium alloys have been designed over the past two decades. These alloys are free of toxic elements and exhibit a significantly lower elastic modulus, reducing the risk of stress shielding effect and making them promising alternatives to Ti-6Al-4V. In addition, β-titanium alloys also have relatively high strength, enhanced biocompatibility and excellent corrosion resistance. The incorporation of β-stabilizing elements such as Nb, Mo and Ta, which are highly soluble in titanium, further improves mechanical performance through solid solution strengthening.

Nevertheless, β-titanium alloys typically exhibit lower ultimate tensile strength (UTS) compared to stainless steels, cobalt-chromium alloys, and other titanium-based materials. This limitation can be addressed through advanced manufacturing techniques such as additive manufacturing. Selective Laser Melting (SLM), a powder-bed fusion process, enables the production of complex, near-net-shape 3D structures directly from metal powders. The rapid melting and solidification inherent to SLM yield a fine microstructure, enhancing mechanical properties. Moreover, SLM facilitates the fabrication of patient-specific implants tailored to individual anatomical requirements.

This study investigates the Ti-25Nb-4Ta-8Sn β-titanium alloy fabricated by SLM. Post-process heat treatment was performed to relieve internal stresses induced by rapid thermal cycles during SLM process. Microstructural and mechanical characterization of the alloy was carried out for both the as-built and heat-treated states. Considering the alloy's potential for biomedical applications, indirect cytotoxicity tests were conducted on extracts from the heat-treated specimens to evaluate biocompatibility.

Keywords: titanium; 3D printing; selective laser melting; microstructure; mechanical properties; biocompatibility

Properties of Co-28Cr-6Mo Alloy for Orthopedic Implants Prepared by Selective Laser Melting

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Cobalt-based alloys are widely used in medicine, particularly for dental and orthopedic implants, due to their excellent mechanical strength, corrosion resistance, and long-term biocompatibility. Among them, the Co-28Cr-6Mo alloy is one of the most common, especially in the production of knee joint replacements, where high wear resistance and structural reliability are essential. These implants are traditionally manufactured by precision casting, a well-established and cost-effective method that offers good control over final geometry. However, with the growing demand for customized, patient-specific implants and more efficient production processes, the potential of additive manufacturing, especially Selective Laser Melting (SLM), is being intensively investigated.

This study focuses on the detailed microstructural and mechanical characterization of Co-28Cr-6Mo alloy components fabricated via SLM and compares them with conventionally cast specimens. The alloy produced by SLM exhibited a fine-grained cellular microstructure, characteristic of metals solidified under rapid cooling conditions and directional solidification. As a result, the printed samples demonstrated significantly enhanced mechanical properties, achieving tensile strength values up to 1000 MPa and hardness of approximately 380 HV1, both higher than those of the cast material.

To further explore the potential of the material, thermal stability testing and microstructural analyses were performed. Based on the observed changes during annealing, appropriate post-processing heat treatment parameters were designed to optimize the mechanical performance without compromising material integrity.

Overall, the findings clearly demonstrate that with carefully optimized printing and post-processing conditions, additive manufacturing can produce Co-28Cr-6Mo components with superior performance. This opens up new possibilities for the fabrication of load-bearing orthopedic implants, particularly for knee prostheses, where high mechanical reliability and wear resistance are critical.

Keywords: cobalt alloys; additive manufacturing; selective laser melting; microstructure; mechanical properties

Novel zinc-based composites prepared by combination of mechanical alloying and spark plasma sintering

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Biodegradable zinc alloys have attracted considerable attention for medical implant applications due to their inherent biocompatibility and suitably moderate corrosion rates, which minimize toxic byproduct formation and hydrogen evolution. Nevertheless, their mechanical strength, corrosion resistance, and biological performance often fall short of clinical requirements. In this research, innovative powder metallurgy preparation techniques were tested. Based on the literature, this method is expected to enhance solid solution formation and induce significant microstructural refinement, thereby improving mechanical performance.

In this work, we have designed and fabricated a Zn–1Mg–1Si and Zn-1Mg-0.5Si composite to address these shortcomings by introducing biocompatible magnesium and silicon into the zinc matrix. Magnesium was selected for its well-established strengthening effect and excellent biocompatibility, while silicon was incorporated due to its known role in promoting bone calcification and extracellular matrix formation, as well as its potential to act as a hard reinforcing phase. Research focused on employing a powder-metallurgy route, which comprises high-energy mechanical alloying and a rapid consolidation technique, SPS (spark plasma sintering). Results showed that an increase in milling time positively affects powder size distribution of prepared alloys and solubility of alloying elements. By compaction via SPS were achieved ultrafine, homogeneous microstructures reinforced by finely dispersed Mg_2Zn_{11} intermetallic phases and pure silicon particles. Residual oxide structures originating from the surface of the initial powder particles were also observed. This microstructural architecture yielded exceptional mechanical properties, with compressive yield strengths exceeding 480 MPa and Vickers hardness values of 130 HV1. Tribological evaluation revealed reduced wear rates, and electrochemical testing in a simulated physiological medium demonstrated lower overall corrosion rates and more uniform degradation compared to pure, reference zinc.

Keywords: Zinc; bioresorbable materials; powder metallurgy; microstructure; mechanical properties

LIPSS pattern induced by excimer laser for myoblast cell guidance

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The presented study highlights the efficiency of employing a KrF excimer laser to create diverse types of periodic nanostructures (LIPSS – laser induced periodic surface structures) on polyether ether ketone (PEEK) and polyethylene naphthalate (PEN) substrates. LIPSS structures are very important both in tissue engineering and find also strong application in the field of sensor construction, and SERS analysis. By exposing the polymer films below their ablation threshold to laser fluence ranging from 4 to 16 mJ·cm^{-2} at 6,000 pulses, we studied both single-phase exposure at beam incidence angles of 0◦ and 45◦, and two-phase exposure. Atomic force microscopy analysis revealed that the laser-treated samples contained distinctive periodic patterns such as waves, globules, and pod-like structures each exhibiting unique surface roughness. Moreover, using analytical methods like EDS and XPS shed light on the changes in the atomic composition, specifically focusing on the C and O elements, as a result of laser exposure. Notably, in almost all cases, we observed an increase in oxygen percentage on the sample surfaces. This increase not only led to a decrease in the contact angle with water but also lowered the zeta potential value, thus showing that the modified samples have enhanced hydrophilicity of the surface and altered electrostatic properties. Last but not least, the samples were assessed for biocompatibility; we studied the interaction of the prepared replicates with mouse myoblasts (C2C12). The impact of globular/dot structures on the cell growth in comparison to pristine or linear LIPSS-patterned surfaces was determined. The linear pattern (LIPSS) induced the myoblast cell alignment along the pattern direction, while dot/globular pattern even enhanced the cytocompatibility compared to LIPSS samples. Through this comprehensive analysis, the research underscores the multifaceted implications of employing KrF excimer laser-induced nanostructures, ranging from surface morphology alterations to biocompatibility enhancements, thus, opening new avenues for advanced material engineering.

Keywords: Pattern; Nanostructure; Excimer laser; Polymer stability; Surface chemistry; Morphology; LIPSS; Cytocompatibility; Cell guidance

Fabrication of Hierarchically Structured Polyethylene Naphtalate Composites with Noble Metal Nanoparticles

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The development of micro- and nanopatterned and functionalized surfaces is lately undergoing extensive research for their intriguing multifunctional properties and wide variety of potential applications in either biomedical field, such as in tissue engineering, or optics and sensor fabrication. The combination of surface patterning and composite materials may lead to the creation of materials tailored to desired use. In the presented study, we focused on fabrication of hierarchically structured polyethylene naphtalate (PEN) substrates/scaffolds enriched with gold and silver nanoparticles for use in tissue engineering. The substrates were prepared by simple few step method. First, the major groove micropattern was replicated by soft lithography onto polydimethylsiloxane (PDMS) master from commercially available optical discs (CDs, DVDs). This method was proven as an affordable and precise method of obtaining periodical patterns on large surface and with optimal dimensions for tissue engineering. Subsequently, the PDMS master was used as a stamp for hot-embossing onto PEN surfaces enhanced by sputtered thin metal layers (gold, silver). During the hot-embossing process, the non-continuous metal layers form nanoclusters and nanoparticles under the influence of the elevated temperatures and as such are then embedded into the polymer surface. Resulting substrates are therefore hierarchically structured, with pronounced metal nanoparticles superposed on larger microscale grooves. Formation of superposed secondary globular structures on the grooved PEN surface was confirmed by both scanning electron microscopy (SEM) and atomic force microscopy (AFM), as well as was the chemical composition by X-ray electron spectroscopy (XPS) and energy dispersive spectroscopy (EDS).

The combination of changes in surface morphology, chemistry and wettability induced significant change in PEN antibacterial properties. PEN substrates enhanced by silver proved to have great antibacterial response against both gram-positive and gram-negative bacterial strains. The successful surface patterning and noble metal enhancement of PEN surfaces thus shows promise in use for instance as antibacterial implant coatings or as supportive scaffolds for growth of muscle cells and tissues.

Keywords: Noble-metal; Nanostructure; Replication; Excimer laser; Surface chemistry; Morphology; LIPSS; Polymer; Composite

Powder metallurgy as a tool for utilizing NiTi alloys in advanced applications

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NiTi-based composites, enhanced with titanium carbide (TiC) reinforcements, present a compelling opportunity to move beyond the alloy's established biomedical niche toward more robust structural and protective functions. This study explores the influence of different incorporation strategies on the performance of NiTi-TiC systems produced via powder metallurgy. The focus lies on how mechanical processing techniques affect the microstructural stability, distribution of reinforcement, and overall material cohesion. Challenges associated with high TiC content were addressed through controlled milling conditions, improving homogeneity and mitigating phase separation. Notably, the microstructural evolution during processing—shaped by both milling time and reinforcement origin—was found to directly influence wear resistance and phase balance. The refined composites exhibit promising characteristics for energy-absorbing and high-strength applications, suggesting that tailored processing pathways can unlock new functionality in NiTi alloys. The outcomes underscore the importance of optimized dispersion and phase control in designing next-generation metal matrix composites with enhanced mechanical behavior and durability.

Keywords: NiTi; mechanical milling; spark plasma sintering; phase composition; mechanical properties

3D Printing of TiAlV Biomedical Alloy Using DED Technology

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The alloy TiAlV is the most widely used titanium alloy. It has found application not only in the aerospace, automotive, and chemical industries but also in biomedicine. The dual-phase TiAlV alloy offers good corrosion resistance, a favorable strength-to-weight ratio, and a low elastic modulus. These properties make TiAlV suitable for the production of orthopedic implants. When there is a large difference between the elastic modulus of the metallic implant and that of the bone, the stress shielding effect may occur. This results in the mechanical stress being transferred through the metal implant rather than the bone, leading to bone degradation and loss.

By utilizing 3D printing technologies, it is possible to produce patient-specific biomedical implants. In addition, porous gyroid structures can be created to support the integration of the bone with the implant. The two main technologies used in metal 3D printing are Direct Energy Deposition (DED) and Selective Laser Melting (SLM). The key advantages of the DED technology over the more widespread SLM technology include the ability to print multi-material parts, repair high-value components, and print from not only powder but also wire. The disadvantages of DED include lower precision and higher demands on operator skills.

In this study, the Ti-6Al-4V alloy produced using the DED technology was examined in the as-printed and as-printed + heat-treated conditions. Stress relief annealing was performed at 820 °C for 1.5 hours in a vacuum. The results were compared with samples produced using SLM technology and with conventionally wrought material. The structure of the material was analyzed using stereomicroscopy, optical microscopy, and scanning electron microscopy. The measured mechanical properties included tensile properties, HV1 hardness, and thermal stability.

Keywords: Ti-6Al-4V, 3D Printing, Direct Energy Deposition, Selective Laser Melting, Implants

3D printed porous structures of Ti-6Al-4V alloy

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Additive manufacturing of metals, particularly 3D printing technologies such as Selective Laser Melting (SLM), has found widespread application in fields ranging from prototyping, aerospace to medicine. In the medical sector, SLM enables the production of highly customized implants tailored to individual patients. These implants can be designed with complex geometries and porous structures that are otherwise impossible to achieve using traditional manufacturing techniques. The benefits include enhanced osseointegration, reduced stress shielding, and improved overall biocompatibility. Among the materials used, the titanium alloy Ti-6Al-4V stands out due to its low density, excellent mechanical properties, corrosion resistance and biocompatibility. However, challenges remain in the additive manufacturing of titanium alloys. These issues are the presence of internal porosity, unideal microstructure and residual unmelted powder particles on the surface. These defects can negatively impact both mechanical strength and biological performance. This study aims to comprehensively address these issues through a combination of post-processing techniques, including Hot Isostatic Pressing (HIP), laser surface remelting, and chemical etching. In addition to evaluating how these methods reduce unwanted porosity and adhered powder particles, the work also investigates their influence on the alloy's microstructure and mechanical properties. The materials used in this work are porous lattice structures gyroid and diamond with varying elementary cell sizes fabricated from Ti-6Al-4V alloy by Selective Laser Melting.

Keywords: Selective Laser Melting (SLM), 3D printing, Ti-6Al-4V alloy, porous implants, Hot Isostatic Pressing

Biomimetic laser texturing of β-titanium alloy surfaces inspired by Schreger lines in tusk dentine

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Titanium alloys are extensively employed in biomedical implants due to their excellent mechanical strength and biocompatibility. However, their high elastic modulus (Gr5 ≥ 110 GPa) significantly exceeds that of natural bone (10–40 GPa), resulting in a mechanical mismatch that contributes to the stress shielding effect. Moreover, concerns regarding the potential cytotoxicity of alloying elements such as aluminum and vanadium in alpha-beta alloys have prompted a shift in focus toward β-type titanium alloys. Despite these advances, titanium remains bioinert and requires additional surface modifications to stimulate interfaces with the aim of effectively controlling the osseointegration process. Laser surface texturing has emerged as a highly effective technique for modifying implant surfaces, allowing precise control of micro- and nanostructures at multiple levels.

This study reports the implementation of a biomimetic structure inspired by the Schreger lines observed in the ivory, which form continuously changing patterns such as corrugated sets of dentine tubules. The laser ablation of titanium alloy Ti25Nb4Ta8Sn was performed by shifted Laser Surface Texturing (sLST) technique using nanosecond SPI laser G3 series. The successful utilization of the laser surface scanning algorithm enabled the formation of intersecting circular arc patterns with an 8 mm radii in two mirrored series and a spacing of 140 µm in both directions. A continuous 2D pattern extends from the center of the 12 mm titanium coupon, shifting from a straight region into criss-crossing lines with variable convex/concave angles. This results in a biomimetic structure that resembles the internal organization of Schreger lines, exhibiting an 'X'-type pattern at the center, gradually transitioning to a 'C' configuration toward the edges of the coupon. Scanning electron (SEM) and confocal laser scanning microscopy (CLMS) revealed a stepped macrostructure characterized by lines with a depth of 60 µm and a thickness of 50 µm. Furthermore, the surface exhibited continuously varying diamond-shaped features covered by moss-like formations composed of thin filamentous nanostructures. Microstructural characterization and microhardness profiling to a depth of 300 µm confirmed the existence of a thermally affected zone and the formation of a needle-like secondary α-Ti phase. The sLST technique has proven to be a versatile method for fabricating complex macrostructures with high nanoscale-specific surface area and exhibits significant potential for enabling further bioactive surface modifications.

Keywords: Ti25Nb4Ta8Sn, Laser texturing, Schreger pattern, Nanostructure

Synthesis of positively charged CeO_2 nanoparticles via precipitation method using hexamethylentetramin

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Cerium oxide (CeO_2) is an important rare-earth material known for its ability to switch between two oxidation states, Ce^{3+} and Ce^{4+}. This redox behavior depends on conditions such as temperature and pH and is further enhanced by the high oxygen mobility and efficient electron transfer on the surface of the nanoparticles. These characteristics make CeO_2 nanoparticles highly effective in both catalytic and biomedical fields. Cerium oxide nanoparticles have been extensively investigated for their potential to mitigate oxidative stress at the cellular level due to their intrinsic antioxidant properties [1].

However, growing scientific attention is being directed toward their other noteworthy biological properties, such as neutralizing reactive species and/or modulating cytokine activity. Moreover, they contribute to cellular protection against damage, rendering them promising candidates for the treatment of conditions such as Alzheimer's disease, ischemic stroke, retinal degeneration, chronic inflammation, and cancer. The surface charge of individual particles, aggregates, agglomerates, or complex core-shell structures is therefore a crucial factor governing their interactions at the molecular level and within biological environments [2].

CeO_2 nanoparticles can be tailored to possess positive, negative, or neutral surface charges by selecting appropriate precipitation agents, such as hexamethylenetetramine (HMT) to induce positive charges or polyvinylpyrrolidone (PVP) for negative charges.

In this study, positively charged CeO_2 nanoparticles were synthesized via a precipitation method using hexamethylenetetramine (HMT), cerium nitrate $Ce(NO_3)_4 \cdot 6H_2O$ (CNH), and hydrogen peroxide (HP). The synthesis process involved separately mixing hexamethylenetetramine (HMT) and CNH in deionized water, followed by stirring, washing, centrifugation, and sonication for various durations at 25°C and 75°C During synthesis, the oxidation degree of $Ce(OH)_3$ was regulated by the controlled addition of hydrogen peroxide (H_2O_2).

These findings demonstrate that prolonged stirring leads to particle growth, highlighting the dependence of dispersion behavior on both reaction duration and thermal conditions. Dynamic light scattering (DLS) revealed a time- and temperature-dependent aggregation process, resulting in particle sizes ranging from 75 to 100 nm and a positive zeta potential of +38 mV. UV–Vis spectroscopy confirmed the characteristic absorbance profile of CeO_2 nanoparticles, indicative of their optical activity and nanoscale dimensions. High-resolution transmission electron microscopy (HRTEM) images revealed well-resolved lattice with high crystallinity and uniform morphology.

Keywords: Cerium oxide, Positive charge, Precipitation, DLS, UV-Vis, HRTEM

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Physiological flow generation using a dynamically controlled peristaltic pump with variable occlusion: Modeling, prototyping, and experimental validation

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Peristaltic pumps have emerged as crucial components in biomedical applications due to their ability to handle sensitive fluids without direct contact between the pump mechanism and the medium. This research focuses on the design and advanced control of a rotary peristaltic pump capable of producing physiologically relevant pressure and flow waveforms, with particular attention to cardiopulmonary bypass (CPB), extracorporeal membrane oxygenation (ECMO), and cardiovascular simulation environments. Conventional peristaltic pump control is typically limited to constant-speed operation, achieving only average flow regulation while neglecting dynamic parameters such as instantaneous pressure and waveform morphology. These limitations can hinder clinical efficacy, particularly where pulse characteristics influence outcomes, such as improved organ perfusion or reduced hemolysis. In response, this study proposes a control-oriented design of a peristaltic pump that enables dynamic waveform shaping through variable occlusion and real-time control of rotor speed.

To describe the system behavior and enable model-based control, several modeling strategies are explored. A grey-box model based on hydraulic-electrical analogies and Windkessel-type representations is developed, capturing the nonlinear interaction between the pump and compliant vascular analogs. In parallel, data-driven approaches—including neural networks—are investigated to model the system without explicitly defining the underlying physics. Early results demonstrate that both approaches offer complementary advantages: physics-based models provide interpretability and control design capability, while neural networks offer flexibility in capturing unmodeled dynamics and system nonlinearities. To enhance control fidelity, a unique prototype of a peristaltic pump with electronically actuated occlusion was constructed. Experiments show that controlled occlusion significantly influences pressure dynamics, offering a new degree of freedom in waveform modulation. The prototype system demonstrates the ability to vary occlusion in synchrony with rotor movement, enabling complex, repeatable waveform patterns that can mimic physiological signals from human and animal aortas.

Keywords: peristaltic pump, pulsatile flow control, dynamic occlusion, physiological waveform

Layer-specific residual strains in human carotid arteries revealed under layer separation

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Residual stresses are considered as a significant factor influencing the stress-states in arteries. These stresses are typically observed through opening angle of a radially cut artery segment, often regarded as a primary descriptor of their stress-free state. However, it was shown these segments are not stress free without layer separation and the experimental evidence regarding the impact of releasing the residual stresses in different artery layers is scarce in literature. In our study, two experimental protocols, each employing different layer-separating sequences, were performed on 17 human common carotid arteries harvested from autopsies, to explore the residual strains in different artery layers. In the first experimental protocol, the artery segment was cut first and then followed by layer separation, whilst in the second experimental protocol, the layers were separated first with the incision being made subsequently. The differences in opening angles between both protocols were found statistically insignificant, but the implementation of the second protocol enabled observations of length changes of each layer. While the media exhibited opening behaviour (reduced curvature), a contrasting trend was observed for the adventitia curvature, indicating its closing behaviour. In addition to the different bending effect, length changes of both layers after separation were observed, namely shortening of the adventitia and elongation of the media. The biggest opening angles were observed in intact samples, presumably due to the shortening effect of adventitia, which forced the free ends farther apart from each other, resulting in larger opening angles. The results point out that not all the residual stresses are released after a radial cut but a significant portion of them is released only after the layer separation. Considering the different mechanical properties of layers, this may significantly change the stress distribution in the arterial wall and should be considered in its biomechanical models.

Keywords: carotid arteries, residual strains, deformation, layer-specific, curvature

Assessment of Hemolysis in Peristaltic Pumps: Influence of Occlusion and Realistic Pressure Boundary Conditions

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Hemolysis caused by mechanical stress remains a major concern in extracorporeal blood circuits, with peristaltic pumps being a common source of red blood cell damage. Computational fluid dynamics (CFD) can help assess hemolytic potential, but most existing studies rely on simplified, constant boundary conditions that do not reflect the dynamic nature of pump operation.

In this study, we investigate hemolysis in a peristaltic pump using CFD simulations supported by experimental measurements. Pressure waveforms were recorded at the pump's inlet and outlet under clinically relevant conditions. These measured waveforms were applied as time-dependent boundary conditions in the CFD model, allowing more accurate representation of the pump's transient behavior.

Hemolysis was estimated using the Eulerian power-law model, which accounts for cumulative shear exposure within the flow. We compared two typical pump configurations—full occlusion and under-occlusion—and analyzed the resulting differences in shear stress distributions and hemolysis predictions. The results show that occlusion level has a significant effect on the flow field and the associated blood damage.

By combining experimentally measured pressure data with detailed CFD modelling and hemolysis estimation, this study offers a practical and improved method for evaluating blood damage in peristaltic pumps. The findings can support safer design and better-informed clinical operation of extracorporeal circuits.

Keywords: Hemolysis, Peristaltic pump, Extracorporeal circuit, Blood damage modelling

Predicting functional severity of carotid stenosis using coupled 3D-0D simulations with cerebral autoregulation

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This work seeks to address a commonly overlooked aspect in computational studies of blood flow in patient-specific carotid arteries–the complex nature of cerebral hemodynamics and its autoregulation. A recurring theme in the existing literature is the use of hypothetical scenarios to assess the hemodynamic impact of disease progression, such as atherosclerosis. These scenarios often involve artificially modifying model geometry to represent different degrees of stenosis. However, such modifications are often implemented without adapting the outlet boundary conditions in the simulation, which may no longer remain valid in the presence of advancing atherosclerosis. This is particularly relevant for the internal carotid artery (ICA), as it is connected to cerebral vasculature governed by several autoregulatory mechanisms. These mechanisms aim to maintain adequate and stable perfusion even under lower levels of cerebral perfusion pressure, such as those caused by increasing degrees of stenosis. This regulation is typically mediated via adjustments in vascular tone (i.e., compliance), resulting in smooth muscle relaxation and a consequent decrease in resistance, which in turn compensates for the pressure loss and helps preserve cerebral blood flow.

Moreover, recent studies suggest that the autoregulatory range is substantially narrower than traditionally assumed, and even within this interval, cerebral blood flow subtly declines as perfusion pressure drops. This challenges the classical concept of a flat and wide autoregulatory plateau, further emphasizing the need for more refined modelling approaches. Consequently, neglecting cerebral autoregulation in such simulations may substantially influence its results and the conclusions drawn from them, especially when evaluating the hemodynamic severity of stenosis.

To address this gap, a coupled 3D–0D simulation framework was developed, combining a 3D patient-specific model of carotid bifurcation with a 0D model of cerebral hemodynamics that incorporates autoregulatory mechanism. This framework enables the prediction of cerebral blood flow under different degrees of ICA stenosis by dynamically capturing the pressure loss and the resulting flow while accounting for cerebral autoregulation. More importantly, it provides a means to estimate the degree of stenosis beyond which autoregulatory capacity is exhausted and cerebral perfusion is likely to be compromised. Given that in clinical practice the severity of carotid stenosis is usually assessed based solely on geometrical criteria (e.g., NASCET or ECST method), the model introduces a complementary hemodynamic perspective focused on autoregulatory response.

For this particular case, the proposed methodology offers a more physiologically relevant alternative to classical setups with fixed boundary conditions (e.g., 3-parameter Windkessel models), where parameters such as vascular resistance are held constant. In contrast, the 3D-0D coupled simulation with the cerebral model modulates these parameters via autoregulatory mechanisms that directly

respond to simulated pressure affected by stenosis. This highlights the importance of incorporating cerebral autoregulation in hemodynamic simulations when predicting future scenarios with highdegree stenosis, where such an adaptive boundary condition may improve the predictive accuracy of the resulting flow conditions in the carotid bifurcation.

Keywords: Carotid stenosis, cerebral autoregulation, functional severity, prediction, 3D-0D simulation

Nonlinear Anisotropic Constitutive Description of the Human Basilic Vein

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In recent decades, there has been a consistent rise in the number of patients requiring hemodialysis. For these individuals, the creation of an arteriovenous fistula (AVF) remains the gold standard method for establishing reliable vascular access. Despite the central importance of AVFs in hemodialysis, their successful maturation and sustained functionality remain problematic, with fewer than one-third maintaining patency without additional interventions over a three-year period. To better understand and address these complications, computational biomechanics has emerged as a vital approach for analyzing the mechanical factors underlying vascular pathologies, such as insufficient AVF maturation and the development of stenosis.

A key component in constructing accurate computational models is a well-defined constitutive description of vascular tissue. Without it, simulations are limited to simplified representations, usually resulting in vessels being modelled as rigid tubes. However, there is currently a significant lack of published data regarding the mechanical behavior and constitutive modeling of veins in the upper extremity. This study aims to address that shortcoming by characterizing the biomechanical properties of the human basilic vein (BV) and comparing them with those of the great saphenous vein (GSV).

To achieve this, uniaxial tensile testing was performed in two orthogonal directions to assess tissue behavior. Findings indicate that the elastic characteristics of BVs, as described by tangent modulus, do not differ significantly from those of GSVs. Additionally, anisotropy, defined as directional variation in elasticity, appears to be less pronounced in BVs. Experimental data were modeled using a 4-fiber-family exponential strain energy density function, which provided an excellent fit, as reflected by coefficients of determination ranging from 0.97 to 0.99 for most averaged datasets. These derived parameters are suitable for use in computational simulations aimed at evaluating the mechanical performance of venous conduits in vascular access applications.

Keywords: Basilic vein, Constitutive model, Great saphenous vein, Hyperelasticity, Vascular access.

Preparation and characterization of TiAlV/Zn composite materials

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This work focuses on the preparation and characterization of TiAlV/Zn composite materials intended for biomedical applications. The primary goal of this research is to develop a material that combines good biocompatibility with acceptable mechanical properties suitable for use as bioimplants. By introducing zinc into a reinforcement structure made of a titanium alloy, it is expected that the osseointegration of implants produced from this composite will be significantly improved. For this purpose, three different geometries of reinforcement structures made from the widely used Ti-6Al-4V titanium alloy were fabricated using the additive manufacturing method known as selective laser melting (SLM). These porous reinforcements were subsequently infiltrated with molten pure zinc or a Zn-4Al-3Cu alloy. To achieve effective infiltration, two different techniques were applied: vacuum-assisted suction using a vacuum pump and centrifugal casting. These two approaches made it possible to obtain different infiltration efficiencies and to investigate how the infiltration method influences the final material properties. The mechanical properties of the resulting composite materials were characterized by compression tests. The results of the compression tests were compared with the mechanical properties of the original Ti-6Al-4V reinforcement structures.

Keywords: Ti-6Al-4V alloy, TiAlV/Zn composite materials, centrifugal casting, Zn-4Al-3Cu alloy, infiltration

Session 5: Smart structures and metamaterials

Engineering Lattice Metamaterials – Simulation and Experimental Validation

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Lattice metamaterials form a class of manmade, lightweight, and periodic structural morphologies which can be tailored towards multifunctionality and improved mechanical performance. For fully exploiting such materials their mechanical response has to be assessed in a reliable manner using either numerical or experimental methods. Herein it will be shown how the finite element method can be utilized to predict non-linear deformation and stress states within lattice metamaterials. Large deformations involving buckling as well as material non-linearities such as superlasticity, plasticity, or damage will be addressed.

First, discrete models of lattice metamaterials are presented where the lattices are modeled in their entire complexity, that means, each lattice member is explicitly resolved. The focus is on beam element based models which show high accuracy and computational efficiency. The capabilities and limitations of these models are discussed using several investigations on single cells or finite sized lattices. Examples are the study on the effect of pre-stress on the buckling response of collinear square lattices and the investigation of elasto-plastic damage evolving in triangular cells in the post-buckling regime. Furthermore, the validation of these models against experimental results is presented where especially the influence of boundary conditions and imperfections are addressed. Eventually, a beam base model is utilized for designing and optimizing a lattice metamaterial applied in the trailing edge of a morphing wing.

Second, the concept of micropolar continuum modeling of lattice metamaterials is introduced. Instead of resolving each lattice member explicitly, the metamaterial is considered as homogeneous material showing the same effective mechanical response as the discrete lattice structure. In contrast to classical Cauchy continuum theory additional rotational degrees of freedom are introduce at each material point. The implications of this modification are briefly introduced and homogenization approaches for obtaining the effective micropolar constants are presented. Eventually, a geometrically nonlinear micropolar continuum model is used for estimating the buckling response of lattice beams. The results are compared to discrete models showing the capabilities of such models for estimating critical loads and predicting the post-buckling response

Keywords: lattice metamaterials, finite element method, material non-linearities, discrete beam models, micropolar continuum theory

Development of Smart Metamaterial Structures via Additive Manufacturing

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This work presents an innovative approach to the development of smart metamaterial structures with integrated sensing functionality. The research focuses on two interconnected areas: (1) the integration of sensors into 3D-printed structures during fabrication, carried out in partnership with Taipei Tech (Taiwan), and (2) the design and mechanical optimization of bistable auxetic architectures.

A custom SLA-based 3D printing platform was developed specifically for the automated embedding of functional elements, including piezocomposite sensors, directly into polymer-based structures during the additive manufacturing process. This in-situ integration significantly reduces the number of post-processing steps and improves sensor sensitivity by embedding sensing elements within the structure's volume, rather than on its surface. While current work employs piezocomposite sensors, future efforts aim to incorporate piezoceramic sensors into ceramic or metallic structures fabricated via multi-material additive manufacturing.

In parallel, the current study explores bistable auxetic structures featuring square unit cells with newly designed bridging elements. These elements serve to reduce localized mechanical stress in regions of maximum deformation, where conventional auxetic geometries exhibit strain levels that surpass the elastic limits of even advanced materials such as NiTi-based shape memory alloys. The novel cell topology enhances the structural reliability and bistable behavior of the auxetic material to achieve the desired shapes.

Although sensing elements have not yet been integrated into the bistable auxetic structures, nor have their effects been evaluated through FEM simulations, these architectures have been thoroughly analyzed and tested from a mechanical standpoint. To facilitate this, a dedicated experimental test rig was developed to enable repeatable bistability testing, which cannot be performed reliably using standard mechanical testing equipment.

Together, these two lines of research—sensor integration and bistable auxetic design—form a foundation for future multifunctional material systems that combine customized mechanical performance with embedded sensing. The developed methods and technologies offer new possibilities for applications in soft robotics, adaptive mechanical components, and structural health monitoring.

Keywords**:** Smart Materials, Embedded Sensing, Additive Manufacturing, Bistable Structures, Auxetic Metamaterials

work-package A.3.2 - Metamaterial structures based on a multidisciplinary model

Characterization of 3D-Printed Porous Structures of Ti-6Al-4V Alloy as Components of Depot Systems for Local Drug Delivery in Biomedical Applications

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Current advancements in additive manufacturing, particularly in selective laser melting (SLM/LPBF) technology, enable the design and fabrication of biomedical implants with complex geometries and porous structures. These innovative structures significantly improve osseointegration and reduce elastic modulus, thereby bringing their properties closer to bone. Ti-6Al-4V alloy is widely utilized in the biomedical field due to its biocompatibility and mechanical properties. Nevertheless, comprehensive optimization of 3D printed implant properties for clinical use necessitates a deep understanding of the influence of manufacturing parameters, post-processing, and surface treatments on their final mechanical stability, biological response, and antibacterial capabilities.

Within this work, results focused on the optimization of 3D printed Ti-6Al-4V structures are summarized and critically evaluated. The role of post-processing, specifically hot isostatic pressing (HIP), on the microstructure and mechanical properties of porous Gyroid and Dodethick structures, fabricated by LPBF technology, is investigated. It is demonstrated that HIP effectively reduces internal porosity, which leads to a significant improvement in ductility (from 6% to 17%) and bending strength, while compressive strength remains stable. These findings provide valuable and reproducible data for predicting the behavior of implants subjected to various loading conditions.

Furthermore, a detailed study of the laser modification of the surface of 3D printed triply periodic structures is being conducted. The impact of a pulsed laser on the surface state, its chemical composition, and subsequent biocompatibility is analyzed. Electrochemical measurements and topographical surface analysis provide a detailed insight into the changes in the passivation layer and its corrosion resistance, which is crucial for long-term implant stability in an aggressive physiological environment. These results contribute to a better understanding of the interaction between the laser beam and complex 3D printed structures.

Concurrently, an innovative sol-gel coating based on TiO_2, containing hydroxyapatite and silver, is being developed and characterized. This coating is applied to 3D printed porous gyroid and dodethick structures. These coatings are designed as efficient systems for targeted delivery of antibacterial agents. Their homogeneity, adhesion, and, most importantly, significant antibacterial effects against both Gram-positive and Gram-negative bacteria (e.g., E. coli) are demonstrated, while maintaining excellent biocompatibility in in vitro tests with osteoblasts. This approach represents a significant step forward in addressing the problem of periprosthetic infections, one of the most serious complications of orthopedic surgeries.

Keywords: 3D printing, Ti-6Al-4V, Biomedical applications, Surface treatments, Material characterization

work-package B.1.3 - Depot biomaterials for local drug release

Development of Novel Concept of Peristaltic Pump

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This paper deals with the development of a novel peristaltic pump concept. This development involved many stages.

The initial motivation was to develop an additional actuator in the aorta for cases where heart implants are insufficient. The conceptual development started with the idea of distributed actuators. While no real peristaltic pumps use such a concept, many such approaches, mostly motivated by bionics, have been described. Due to the self-carrying requirement for the intended aorta assist pump, the concept of mechatronic stiffness was introduced. However, such concepts originating from nature have already been proposed and described. Finally, the actuation method of the proposed peristaltic pump is novel. It is based on a couple of rods that lean on both tubes and the actuator to create a force perpendicular to the tubes' axis. This enables the use of the narrow space between the tubes for the actuators.

Additionally, several concepts use rotational actuation around the tubes' axis or an axis that is either perpendicular or inclined to the tubes' axis.

A serious problem with current peristaltic pumps is that they damage red blood cells due to the pressure in the compressed tube. One possible remedy could be to modify the pressures using distributed actuation or to use a partially closed tube with valves.

Advanced simulations are now being used to investigate the concept of a novel peristaltic pump.

Key words**:** peristaltic pump, distributed actuators, mechatronic stiffness, longitudinal actuation, translational and rotational actuators

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