Biomaterial Interfaces
Room Central Hall - Session BI-ThP
Biomaterial Interfaces Poster Session

BI-ThP-1 Optimizing Regenerative Cell Infiltration in Vascular Grafts: Enhanced Strategies to Engineer Pore Microstructures During Fabrication, ***Aurora Battistella,*** University of Colorado at Boulder

Introduction: In tissue engineering, the goal is to create scaffolds that seamlessly integrate into the human body, guiding native tissue regeneration while slowly degrading. A crucial aspect of this process is achieving scaffold infiltration of functional cells. The initial phase centered on the material aspect, particularly different polymer behaviors, including degradation rates. Production methods represent another modifiable parameter to fine-tune the device structure, especially its porosity. Additionally, post-fabrication techniques can refine the microstructure and enhance interaction with the human body. The investigation originated with a control group, PCL+PEG-NB coaxially electrospun and air-dried. Ultimately, four groups were created by systematically altering one or more parameters and examined to assess their impact.

Methods: Coaxial electrospinning was used to achieve a strong core (PCL/PLCL) surrounded by a functionalized sheath (PEG-NB). The mixed condition was fabricated by directly blending sheath and core solutions for electrospinning. Samples were air-dried or freeze-dried. Surface topography, including fiber structure and porosity, was investigated by SEM. Uniaxial tensile testing was adopted to determine the impacts of different parameters on the mechanical properties of the graft. The groups were implanted subcutaneously and explanted at various time points (1, 4, and 16 weeks). Histological and fluorescent analyses were performed to visualize tissue morphology and cellular penetration.

Results: Freeze-dried samples demonstrate higher Young's Modulus and higher porosity, and, consequently, increased cell infiltration than their air-dried counterparts. PLCL shows faster degradation and higher cell infiltration than PCL. However, PLCL was mechanically weaker and had a less rigid structure than PCL. Mixed fibers also displayed increased degradation compared to the control and were shown to be slightly weaker in tensile tests.

Conclusions: Through systematic experimentation, we have uncovered the benefits of freeze-drying in enhancing scaffold porosity and cell infiltration, while also highlighting the importance of selecting polymers with suitable degradation rates. Work is still ongoing to determine optimal fabrication parameters. Moving forward, these insights may help to guide the development of advanced vascular grafts with improved regenerative capabilities, paving the way for more effective clinical applications in tissue engineering.

BI-ThP-2 Mass-Manufactured Surface Textures Enable Low-Cost Large-Volume Water Analyte Detection and Location Tracking, ***Liza White,*** *C. Howell,* University of Maine

Timely detection of aqueous analytes is critical for agriculture, aquaculture, industry, and municipalities. Currently, testing methods are limited to small volumes and discrete, one-location samples. In this work, we show that an industrially manufactured nanotextured diffraction surface can provide aqueous analyte information across multiple locations over time. Specifically, the aqueous solution can be scanned by changing the location or angle of the light source and detector. By positioning the diffraction surface behind or below an aqueous matrix, the analyte's 3D spatial information and approximate size are determined. The identification and quantification of the analyte can also be determined based on the measurement of light absorbance and transmittance unique to the chemical or biological components of the analyte. The novel development of a sensor capable of large-volume scanning and analyte location detection is beneficial in numerous aqueous sensing capabilities, potentially transforming aqueous analyte monitoring methods.

BI-ThP-3 Low Fouling Amphiphilic Zwitterionic Carboxybetaine/Perfluoropolyether Methacrylate Polymer Coatings, ***Onur Özcan,*** *F. Koschitzki, R. Wanka, M. Krisam, A. Rosenhahn,* Ruhr University Bochum, Germany

Amphiphilic polymer systems have proven to be an effective and non-toxic approach to combat the challenges of biofouling.[1,2] We manufactured a variety of amphiphilic polymers consisting of carboxybetaine methacrylate (CBMA) and perfluoropolyether (PFPE) urethane methacrylate. These polymers were anchored to chemically functionalized substrates by photoinduced grafting-through polymerization.[1] Highly hydrated hydrogels may create a diffuse interphase and thus promote silt incorporation.[3] We were able to show that low amounts of PFPE already reduce silt uptake substantially. Captive bubble contact angle (CBCA) goniometry revealed that the polymer networks possess enough orientational freedom to quickly rearrange upon immersion in water. Dynamic diatom and bacteria accumulation assays revealed enhanced antifouling performances in most of the amphiphilic mixtures compared to the solely hydrophobic compound PFPE. We were further able to identify individual CBMA/PFPE compositions where the synergistic effect of hydrophilic and hydrophobic contents had the strongest impact on their marine anti-fouling and fouling-release properties.

[1] F. Koschitzki, R. Wanka, L. Sobota, J. Koc, H. Gardner, K. Z. Hunsucker, G. W. Swain, A. Rosenhahn ACS Appl. Mater, Interfaces 2020, 12, 34148-34160. [2] A. J. Ruiz-Sanches, A. J. Guerin, O. El-zubir, G. Dura, C. Ventura, L. I. Dixon, A. Houlton, B. R. Horrocks, N. S. Jakubovics, P. Guarda, G. Simeone, A. S. Clare, D. A. Fulton Prog. Org. Coat. 2020, 140, 105524 – 105533. [3] J. Koc, T. Simovich, R. Schoenemann, A. Chilkoti, H. Gardener, G. W. Swain, K. Hunsucker, A. Laschewsky, A. Rosenhahn Biofouling 2019, 35, 454-462

BI-ThP-4 Pore Size Impact on Oil-Release and Fouling Resistance of Macroporous Oil-Infused PDMS Systems, ***Regina Kopecz,*** *S. Böer, Z. Tiris, A. Rosenhahn,* Ruhr University Bochum, Germany

Since their invention, SLIPS have been known for their self-repairing properties, pressure stability, repellency of water and complex fluids, and low-fouling properties. We created a series of environmentally benign, non-fluorinated liquid paraffin-infused PDMS sponge systems with varying porosities including a thin interfacial PDMS membrane for controlled oil-release kinetics. Different pore volumes and varying interfacial roughness were fabricated by sugar and salt templating. The obtained porous polysiloxane networks were investigated using water contact angle goniometry, scanning electron microscopy, and light microscopy. The macroporous sponge systems revealed excellent oil-uptake and an oil-release between 3% and 14% of initial oil-loading during incubation in MilliQ water for seven days depending on the pore size. The resistance against bacterial fouling by dynamic attachment assays with the freshwater model organisms *Pseudomonas fluorescens*, *Escherichia coli*, and *Bacillus subtilis* was investigated. We found a correlation between bacterial adhesion and the porosity of the interface for the individual bacterial strains. As the porous polymer networks can be fabricated in any shape, they are promising low-fouling bulk materials for a wide range of applications in medicine.

BI-ThP-5 Advancing Catheter Care: Liquid-Infused Catheters as a Novel Approach to Combat CAUTIs, ***Zachary Applebee,*** *C. Howell,* University of Maine

Catheter-associated urinary tract infections (CAUTIs) pose a significant challenge in healthcare settings, leading to reduced patient outcomes, extended hospital stays, and increased healthcare costs. Although the current standard of care is to use systemic antimicrobials, there is growing concern that such treatment is contributing to the rise of antimicrobial resistance. Recently, liquid-infused catheters, in which a thin layer of biocompatible oil is used on the catheter surface, have emerged as a promising solution to reduce CAUTIs without the use of antimicrobials. In this work, we explore aspects of the use of liquid-infused catheters, including the potential for the liquid coating to be lost to the host as well as the integration of bioactive anti-inflammatory compounds into the coating. Our goal is to develop this novel technology further so that it can be translated into the clinic, helping to reduce CAUTIs without the need for antimicrobial treatment.

BI-ThP-6 Developing an Effective Coating Process for Nanoscale Cellulose Fibrils on Biodegradable Substrates, ***Sandro Zier,*** *D. Bousfield, C. Howell,* University of Maine

Bio-derived materials show the potential to replace plastic packaging with similar functionality while also having the advantage of biodegradability and recyclability. Cellulose, the most abundant polymer in the world, can be mechanically ground to have nanoscale dimension which provide good oil/grease and gas barrier properties. However, coating cellulose nanofibrils (CNF) as a thin film onto biodegradable substrates such as paper in a single step comes with significant challenges due to the unique way in which the CNF fibers interact with water. To overcome this challenge, we first simulated CNF coating onto paper to further understand the physics behind the process. We then developed a novel technique that uses a vacuum system to reduce the amount of water associated with the CNF as it is being

coated. We found that unlike previous attempts to coat CNF in a single step, which resulted in non-uniform layers, use of our method resulted in a smooth, continuous coating with anywhere between 12 and 28 g/m^2. Tests on gas permeability revealed the CNF coatings could decrease the amount of air that could pass through by ~500x, a critical result for plastic replacement products that serve to keep oxygen and other gasses away from the contents of the package. Finally, analysis of the ability of the CNF coatings to resist oil and grease showed an increase of ~10 times compared to uncoated controls. Our results show that by using our method, nanoscale cellulose fibrils can be effectively coated as a one-step process, preserving their unique properties and laying the foundation for their adoption as plastic replacements.

BI-ThP-7 The Surface Enhancement of Electro-Spun Polycaprolactone (PCL) Using Room Temperature Atomic Layer Deposition of Magnesium Oxide for Use as a Novel Resorbable Membrane for Dental and Corneal Surgery, ***Harshdeep Bhatia,*** University of Illinois - Chicago*; F. Esmaeilabadi,* Northern Illinois University*; C. Sukotjo, C. Takoudis,* University of Illinois - Chicago*; S. Vahabzadeh,* Northern Illinois University

Polycaprolactone is a popular biomaterial used for dental and corneal surgery. Recently MgO ALD at room temperature has been used to enhance the surface of resorbable membranes. In this study, electro-spun polycaprolactone was coated with different film thickness of magnesium oxide and tested for surface properties and cell proliferation. The ALD was performed at room temperature using a commercial ALD reactor, ALD150 LE. The source of Mg was bis(ethylcyclopentadienyl) Mg(eCp)$_2$ while ozone was used as the oxidizing agent. The composition and thickness of the as-deposited film were characterized by X-ray photoelectron spectroscopy and spectroscopic ellipsometry, respectively. The surface was also viewed using a scanning electron microscope. The water contact angle was measured right after deposition and 24-hour after deposition. A cell proliferation study was also performed to determine if the film had any toxic effects on cells.

BI-ThP-8 Label-Free High-Resolution Molecular Imaging of Sex Steroid Hormones in Zebrafish by Water Cluster Secondary Ion Mass Spectrometry (Cluster SIMS), *N. Sano,* Unit B6, Millbrook Cl Chandler's Ford, UK*; E. Lau, J. von Gerichten,* University of Surrey, UK*;* ***Kate McHardy,*** *P. Blenkinsopp,* Ionoptika, Ltd., UK*; M. Al Sid Cheikh, M. Bailey,* University of Surrey, UK

Sex steroid hormones are essential biomolecules for vertebrates and are involved in the maintenance of pregnancy, development of secondary sexual characteristics and diseases such as osteoporosis and breast cancer. Visualising the distribution of steroids contributes to further understanding of disease. However, analysis of steroids is difficult; their low polarity leads to poor ionisation efficiency, meaning they need to be derivatised for conventional analyses. Furthermore, the steroid signals overlap with a MALDI matrix background.

Water Cluster SIMS is a high-sensitivity mass spectrometry technique for imaging complex-mixture materials without derivatisation or the use of matrix. We demonstrate imaging of sex steroid hormones in zebrafish (an ideal vertebrate model organism) with a Water Cluster SIMS instrument.

An adult female zebrafish was prepared for this work. It was embedded while fresh in 0.75% HPMC and 0.25% PVP embedding media to facilitate sectioning. The whole block was flash-frozen in a dry-ice and isopropanol bath. The sample was sectioned to 20 µm at -25 °C and thaw-mounted onto a conductive indium-tin-oxide (ITO) coated glass. The section was dried while frozen in a vacuum desiccator, and then directly analysed without any matrix application for the analysis. The Cluster SIMS analyses were then performed with the J105 SIMS Cluster SIMS (Ionoptika Ltd), using a 70 keV $(H_2O)n$ beam, where n is in the range of 15,000-35,000, and also separately with a 40 keV C_{60} beam. High-resolution images were acquired with a pixel size of < 1 micron.

Water Cluster SIMS uses a high-energy beam of ionised clusters of water to sputter and ionise molecules from a surface. It is far less damaging and generates far fewer fragment ions than traditional ToF SIMS, but retains many of the benefits of that technology such as high-spatial-resolution imaging. As a result, detailed images of the distribution of sex steroid hormone molecules in the zebrafish are visible. Preliminary data shows that it is possible to map the chemical distribution of steroids in the ovary area. In addition, we also detected lipid ions related to the embryo or oocyte around the ovary area as unique distributions.

BI-ThP-9 Fouling Inhibition by Replenishable Plastrons on Microstructured, Superhydrophobic Carbon-Silicone Composite Coatings, ***Louisa Vogler,*** *E. Manderfeld, A. Rosenhahn,* Ruhr University Bochum, Germany

Superhydrophobic surfaces (SHS) exhibit the outstanding ability to retain stable air layers underwater (the so-called plastron), making them resistant to the adhesion of marine organisms and therefore counteracting the detrimental impact of marine biofouling without the use of toxic substances.[1] Since the longevity of such plastrons is limited, we recently established an approach to replenish plastrons on submerged surfaces by Joule heating by only 1-2 °C.[2] In this work mechanically stable, conductive carbon-silicone composite coatings with replenishable plastrons were fabricated by 3D printing. For the fabrication, a striped, an intersected striped, and a hierarchically-shaped mold were used.[3] Characterization of the differently structured coatings was carried out by scanning electron microscopy, water contact angle goniometry as well as dynamic attachment assays against the marine diatom *Navicula perminuta*. We demonstrated that the resulting microstructured, superhydrophobic coatings revealed a plastron formation when being submerged in water, which greatly reduced the adhesion of diatoms on such surfaces by up to 84 %. Furthermore, plastron replenishment and growth of the conductive coatings were accomplished by Joule heating.[3]

[1] G. B. Hwang, K. Page, A. Patir, S. P. Nair, E. Allan, I. P. Parkin, *ACS Nano* **2018**, *12*, 6050., [2] T. Simovich, A. Rosenhahn, R. N. Lamb, *Adv. Eng. Mater.* **2020**, *22*, 1900806., [3] E. Manderfeld, L. Vogler, A. Rosenhahn, *Adv. Mater. Interfaces* **2024**, *2300964*, 1.

BI-ThP-10 iCVD Polymer Thin Film Bio-Interface-Performance Based on Functional Groups and Aerohydrogels, ***Torge Hartig,*** *J. Paulsen, W. Reichstein, M. Hauck,* Kiel University, Germany*; M. Taale,* Universität Heidelberg, Germany*; T. Strunskus,* Kiel University, Germany*; C. Selhuber-Unkel,* Universität Heidelberg, Germany*; A. Amin,* National Research Centre, Giza, Egypt*; R. Adelung,* Kiel University, Germany*; B. Freedman,* Harvard University*; F. Schütt, F. Faupel, S. Schröder,* Kiel University, Germany

Interactions of biological species with polymer surfaces are dependent on various factors such as roughness, surface functional groups, wetting, residual liquids and defects. In conventional wet chemical polymers these different influences on the bio-interface cannot be examined independently. Initiated Chemical Vapor Deposition (iCVD) is an all-dry technique used to deposit ultrathin polymer films, which are defect-free and surface-conformal. Via iCVD polymer surfaces can be tailored precisely in monomer-composition, enabling the isolated examination on the bio-interface performance based on functional groups. The influence of the functional groups was examined regarding human fibroblasts, cancer cells and respiratory viruses, including in silico analysis of the interaction of key protein structures with the defined surfaces.

Furthermore, the iCVD conformal coatings are used to fabricate freestanding aerohydrogels. For this tetrapodal ZnO is coated dry-chemically and etched wet-chemically to create a freestanding polymer thin film scaffold with >99% empty space. The compressive properties of the well-defined aerohydrogels can be tailored by the gas phase composition and resulting crosslinking during the iCVD process. The aerohydrogels are used in 3D cell culture application for muscle cells.

BI-ThP-11 Bacterial Co-Culture Methods to Enhance Growth Rates in Mycelial Biomaterials, ***Lindsay Pierce,*** *M. Tajvidi, C. Howell,* University of Maine

Mycelia, the hair-like projections that make up the majority of fungal tissue, are gaining attention as a non-toxic, low-cost replacement for chemical adhesives and binders in bio-composite materials. However, the growth of fungal mycelia is a slow process which can take up to several weeks to complete. In this work, we explore the use of bacterial co-culture as a natural method to increase the growth rate of fungal mycelia in bio-composites made of wood particulates. In nature, fungi co-exist and compete with bacteria for space and resources, and previous work has demonstrated that the presence of some species of bacteria can enhance the rate of mycelial spread in response to competition pressure. We adapt these observations to mycelial bio-composites, examining the effect of the extract of a range of species in 3D constructs. Our results show how the use of bacterial co-culture methods can help to enhance the growth rate of mycelial biomaterials, potentially reducing the manufacturing time of these all-natural materials.

BI-ThP-12 Vascularization to Enhance Growth Rates in Mycelial Biomaterials, ***Anna Folley***, *M. Tajv, C. Howell,* University of Maine

Wood bio-composites are of increasing interest as sustainable building materials; however, they are frequently manufactured using hazardous chemicals as particle binders, which reduces their value as eco-friendly products. Fungal mycelia, the fine threads that make up most fungal biomass are a natural alternative to chemical binders, yet their slow growth is one of the major limiting factors in their widespread adoption. In Nature, living organisms use vascular systems to enhance growth rates by delivering nutrients and other essential materials to tissue. Here, we work to develop an internal vascular network for wood bio-composites in an effort to increase the delivery of oxygen and moisture to the fungal mycelial, enhancing the rate of growth. We use modeling to determine the optimal arrangement of vascular channels which maximizes delivery throughout the composite structures while minimizing the impact on strength. We then use 3D printing of specialized molds to create the vascularized bio-composites, testing the rate of growth both with and without active moisturized airflow through the channel network. Our results show how the use of an internal vascular system in wood composite biomaterials can be used to enhance the growth rate of fungal mycelial as a binder, lowering the barriers to wider adoption of this approach for eco-friendly building materials.

BI-ThP-13 Self-Assembled Multifunctional Thin Films with Cerium Dioxide Nanoparticles, ***Daniela Topasna***, *A. Psczulkoski, M. Albertson, S. Harris,* Virginia Military Institute

This study investigated multifunctional ionic self-assembled monolayers thin films composed of cerium dioxide nanoparticles and polymer. Samples of films werefabricated using different molarities, substrates, and layer compositions. Various characterization techniques and tests, such as optical spectroscopy, SEM, EDS, and temperature tests, reveal useful optical and antibacterial properties of these films, with potential applications in biomedicine, remote sensing, or consumer industry.

BI-ThP-14 Electroanalytical Investigation of Preferred Crystal Growth of Piezoelectric Gamma Glycine Biocrystals from Solution-Organic Film Interfaces, ***Bijay Dhungana***, *C. Neal,* University of Central Florida*; X. Wang,* University of Wisconsin-Madison*; S. Seal,* University of Central Florida

Materials with piezoelectric properties, capable of inter-converting mechanical and electrical energy, hold promise as actuators, transducers, sensors, and energy harvesters in modern devices. Due to economic and application-specific constraints for traditional piezoelectric materials, biomaterials with advantages such as biocompatibility, biodegradability, renewable sourcing, and low cost are being studied for wearable and implantable energy-harvesting devices and tissue engineering frameworks. Developing corresponding manufacturing methods is crucial for effective, reliable future production. The presented study utilizes a combination of electroanalytical methods to characterize the nucleation and preferred growth of piezoelectric γ-phase glycine biocrystals at a molecular film interface. Herein, a self-assembled monolayer (SAM)-modified gold electrode surface was utilized to induce the preferred growth of γ-phase over non-piezoelectric polymorphic structures (α,β) through formation of an initial SAM-aqueous glycine coordination structure. We first assess interaction between SAM films and glycine in aqueous solutions electrochemically by focusing on adsorption behavior determined as transient, charging currents and changes in open circuit potential. Continuous measurements of potential change were complemented by linear sweep voltammetry measurements, to characterize SAM-glycine interface character/strength, and electrochemical impedance spectroscopy (EIS), to reflect changes in the growing crystal layer character. Results from these studies were fit to relevant models (adsorption isotherms and equivalent circuit diagrams, respectively) which were then interpreted in relation to physicochemical processes mediating crystal formation behaviors. Conclusions drawn from these studies provide necessary insights into the biocrystallization process for future manufacturing processes of environmentally friendly piezoelectric materials.

BI-ThP-15 Towards a Biomimetic Approach to Transition Metal Sensing in Water, ***William Maza***, *K. Fears,* US Naval Research Laboratory

Nature has evolved to express biological molecules displaying extremely high affinities for transition metals. For example, siderophores are known to bind Fe^{3+} with binding affinities exceeding 10^{20} M^{-1}. The core structure of a number in this class of biomolecules is comprised of a cyclic peptide ring. However, the cost of expressing and isolating these molecules makes their commercialization prohibitively expensive and impractical. Here we demonstrate that cyclic peptides that demonstrate reasonable affinities for transition metals can be synthesized at an appreciable scale. Moreover, we further demonstrate that by including the intrinsic naturally fluorescent amino acid tryptophan in the structure of the cyclic peptide we can use fluorescence spectroscopy to determine the presence of transition metals in water. The α- and β-K_3W_3 cyclic peptides discussed here display different affinities for both Ni^{2+} and Zn^{2+}. In both cases, the α-K_3W_3 bind more tightly to the transition metals compared to the β-K_3W_3 by a factor of nearly two in the case of Ni^{2+} and a factor of four for Zn^{2+}.

BI-ThP-16 Optical Tweezers for Electrochemically Manipulated Force Measurements, *J. Appenroth, I. Peters, M. Valtiner,* ***Laura Mears***, Vienna University of Technology, Austria

Force measurements can vary in magnitude dramatically depending on the number of individual bonds or interactions that take place. Optical tweezers offer a highly sensitive measurement of forces during binding events of either just a few or even single molecules. In order to bring two molecules together optical tweezers commonly use two beads decorated with the relevant molecules. These beads are either in the optical trap or immobilized by suction to a micropipette or other such mechanism. However this change in geometry compared to techniques such as atomic force microscopy (AFM), may impact the comparability of results with AFM. While AFM is an incredibly flexible technique with many different in situ environmental changes, the force sensitivity is approx. an order of magnitude less than optical tweezers. We have taken inspiration from scanning probe microscopy to overcome some of the environmental limitations of the optical tweezers to include a gold STM tip. This tip can be modified in a similar way to AFM tips and can also form part of a three-electrode electrochemical cell. Here, we present some of our first results with the system on biorelevant molecules. The electrochemical manipulation allows the probability of a binding event to occur to be increased by changing the surface potential of the tip or the oxidation state of any molecules bound to it. This is particularly useful in the context of using force measurements to determine the free energy of a bond using Jarzynski's equality. In that calculation unbinding events with small values in the Gaussian distribution of forces carry more weight than the larger values. Therefore, we hope our changes to the optical tweezer set up can further our understanding of single molecule interactions and the application of Jarzynski's equality.

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