Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials
Room Palm 1-2 - Session MD1-1-MoM

Development and Characterization of Bioactive Surfaces/Coatings I

Moderators: Mathew T. Mathew, University of Illinois College of Medicine at Rockford and Rush University Medical Center, USA, **Sandra E. Rodil**, Universidad Nacional Autónoma de México

10:00am **MD1-1-MoM-1 Hybrid Ceramic Coating with Enhanced Corrosion Resistance for Magnesium-Based Biodegradable Implants***, **Abdelrahman Amin [xml111@mocs.utc.edu]**, Diya Patel,* University of Tennessee at Chattanooga, USA*; Bryce Williams, Thomas McGehee, Alyssandra Navarro, Mostafa Elsaadany,* University of Arkansas, USA*; Hamdy Ibrahim,* University of Tennessee at Chattanooga, USA*; Merna Abdrabo,* The University of Tennessee at Chatanooga, USA

Biodegradable implants, recognized for their unique mechanical properties and compatibility with human bone, have become essential in various biomedical applications. Magnesium, a key material in such implants, is notable for its favorable biodegradability within the human body. However, one limitation of magnesium is its tendency to degrade too quickly, leading to a loss of mechanical integrity before bone healing is complete. This rapid degradation can undermine the implant's effectiveness, driving efforts to manage magnesium's high corrosion rate through various approaches. Among these, the development of protective coatings on magnesium alloys has shown significant promise. Such coatings provide a temporary protective layer, thereby slowing down the corrosion process and extending the implant's functionality. Hybrid coatings, particularly those combining Plasma Electrolytic Oxidation (PEO) with sol-gel techniques, have improved the ability to control and adjust corrosion rates while incorporating bioactive agents like hydroxyapatite (HA) nanoparticles. These nanoparticles contribute to enhanced bioactivity and osteoconductivity, further supporting bone healing. In this study, the primary objective is to explore how altering the key parameters of Sol-gel coating affects the corrosion resistance of a magnesium alloy substrate that has been pre-coated with a PEO layer. Specifically, the combined impact of varying HA concentration within the Sol-gel solution, dip time, and the number of layers deposited are examined. The findings of this work establish the relationship between the sol-gel coating process parameters and the corrosion properties of the developed hybrid coating leading to a better understanding of their effect on developing magnesium-based implants with superior properties.

10:20am **MD1-1-MoM-2 Functional Coatings by Low Vacuum Plasma for the Innovation in Regenerative and Reparative Medicine***, Pascale Chevallier, Carlo Paternoster, Francesco Copes,* Laval University, Canada*; Andranik Sarkissian,* Plasmionique Inc., Canada*; **Diego Mantovani [diego.mantovani@gmn.ulaval.ca]**,* Laval University, Canada **INVITED**

Over the last 50 years, biomaterials, prostheses and implants saved and prolonged the life of millions of humans around the globe. Today, nano-biotechnology, nanomaterials and surface modifications provide a new insight to the current problem of biomaterial complications, and even allows us to envisage strategies for the organ shortage. In this talk, creative strategies for modifying and engineering the surface and the interface of biomaterials, including metals, polymers from natural and synthetic sources, will be discussed. The unique potential of low-pressure low-temperature plasma surface modification will be detailed with the overall aim to envisage today how far innovation can bring tomorrow solutions for reparative and regenerative medicine. Applications for health will be emphasized, including biologically active-based, biomimetic, low-fouling, bactericidal, and antiviral coatings.

References

1. M. Shekargoftar, S. Ravanbakhsh, V. Sales de Oliveira, J. Buhagiar, N. Brodusch, S. Bessette, C. Paternoster, F. Witte, A. Sarkissian, R. Gauvin, D. Mantovani. Effects of Plasma Surface Modification of Mg-2Y-2Zn-1Mn for Biomedical Applications [https://www.sciencedirect.com/science/article/pii/S2589152924002825], *Materialia*, 102285, 2024.
2. S.H. Um, J. Lee, M. Chae, C. Paternoster, F. Copes, P. Chevallier, D.H. Lee, S.W. Hwang, Y.C. Kim, H.S. Han, K.S. Lee, D. Mantovani, H. Jeon. Biomedical Device Surface Treatment by Laser-Driven Hydroxyapatite Penetration-Synthesis Technique for Gapless PEEK-to-Bone Integration [https://onlinelibrary.wiley.com/doi/abs/10.1002/adhm.202401260] . *Adv Healthcare Mater*, 13, 26, 2401260, 2024.
3. M.E. Lombardo, V. Mariscotti, P. Chevallier, F. Copes, F. Boccafoschi, A. Sarkissian, D. Mantovani. Effects of cold plasma treatment on the biological performances of decellularized bovine pericardium extracellular matrix-based films for biomedical applications [https://www.explorationpub.com/Journals/ebmx/Article/10137]. *Exploration of BioMat-X*, 1, 2, 84-99, 2024.
4. L. Bonilla-Gameros, P. Chevallier, X. Delvaux, L.A. Yáñez-Hernández, L. Houssiau, X. Minne, V.P. Houde, A. Sarkissian, D. Mantovani. *Nanomaterials*, 14, 7, 609, 2024.
5. L. Marin de Andrade, C. Paternoster, P. Chevallier, S. Gambaro, P. Mengucci, D. Mantovani. Bioactive Materials, 11, 166, 2022.

11:00am **MD1-1-MoM-4 Hydrogen-Treated Orthopedic Implants : A Novel Approach to Enhance Biocompatibility and Mitigate Inflammation***, **Ren-Jei Chung [rjchung@mail.ntut.edu.tw]**,* National Taipei University of Technology, Taiwan **INVITED**

The surface modification of cobalt-chromium-molybdenum (CoCrMo) alloy to create hydrogenated CoCrMo (H-CoCrMo) surfaces has shown promise as an anti-inflammatory orthopedic implant. Utilizing the electrochemical cathodic hydrogen-charging method, the CoCrMo alloy surface was hydrogenated, resulting in improved biocompatibility, reduced free radicals, and an anti-inflammatory response. *In vitro* studies demonstrated enhanced hydrophilicity and the deposition of hydroxyapatite. The cell study result revealed a suppression of osteosarcoma cell activity. Finally, the *in vivo* test suggested a promotion of new bone formation and a reduced inflammatory response. The diffusion of hydrogen to a depth of approximately 106 ± 27 nm on the surface facilitated these effects. The findings suggest that electrochemical hydrogen charging can effectively modify CoCrMo surfaces, offering a potential solution for improving orthopedic implant outcomes through anti-inflammatory mechanisms.

Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials
Room Palm 1-2 - Session MD1-2-MoA

Development and Characterization of Bioactive Surfaces/Coatings II

Moderators: Hamdy Ibrahim, University of Tennessee at Chattanooga, USA, **Sandra E. Rodil**, Universidad Nacional Autónoma de México

1:40pm **MD1-2-MoA-1 Surface Characteristics of Magnesium-Based Nanocomposite for Enhanced Biomedical Implants**, ***Merna Abdrabo* *[jgs684@mocs.utc.edu]***, *Tooba Tanveer, Abdelrahman Amin, Diya Patel,* University of Tennessee at Chattanooga, USA; *Thomas McGehee, Mostafa Elsaadany,* University of Arkansas, USA; *Hamdy Ibrahim,* University of Tennessee at Chattanooga, USA

Magnesium (Mg) possesses unique properties that make it a promising candidate for various biomedical applications. That includes biodegradability and an elastic modulus that is closer to that of the human bone compared to titanium and stainless-steel implants, significantly reducing the risk of stress shielding. However, the use of magnesium in biomedical implants has been limited by its high chemical reactivity and limited strength. Therefore, a significant amount of research has been focused on enhancing the strength and corrosion characteristics of Mg-based biomedical implants by developing nanocomposites through novel fabrication methods. This study focuses on investigating the surface properties of novel Mg-based nanocomposites containing boron nitride and silicon carbide nanoparticles. The examination includes testing the morphology, corrosion characteristics, microhardness, wettability, and in-vitro cytotoxicity of the prepared surfaces. In this work, a novel acoustic powder mixing technique, combined with powder metallurgy, is utilized to prepare the Mg-based nanocomposite samples. The findings of this work provide a good understanding of the effect of the process parameters on the corrosion characteristics of these novel materials, which could pave the way for the manufacturing of Mg-based implants with superior properties, contributing to advanced applications in the biomedical field.

2:00pm **MD1-2-MoA-2 Carbide Derived Carbon Conversion Coatings for Tribological Applications**, ***Mike McNallan [mcnallan@uic.edu]***, University of Illinois - Chicago, USA **INVITED**

Carbide Derived Carbon (CDC) is a unique structure of carbon that is produced by extraction of the metal component from a ceramic carbide. When the conversion is carried out at a temperature below 1200 degrees Celsius, the result is a disordered graphitic structure with largely sp2 bonding. This is because there is not sufficient thermal energy under these conditions for the carbon to relax fully from the ceramic structure to the equilibrium graphitic state.

Carbide Derived Carbon (CDC) has a slick, hydrophobic surface and a low coefficient of friction when paired with most other materials. Because it is grown into a ceramic surface, rather than deposited onto the surface by a CVD or PVD process, CDC coatings can be applied with minimal dimensional changes and are resistant to spallation in comparison to other tribological coatings. CDC coatings have been applied to SiC and WC ceramics by exposure to chlorine gas at temperatures in the range of 800 to 1000 degrees Celsius. In this temperature range, the metal species form volatile chlorides, while the carbon is left behind as a solid.

Tribocorrosion, in which synergistic degradation by corrosion and wear is a particular concern for orthopedic implants such as artificial joints. The Ti-6Al-4V alloy is popular for this application, and carbide ceramics are not favored for this application because of their inherent brittleness. Titanium is a strong carbide former, so titanium carbide surface layers can be formed on titanium alloys by a carburization treatment in a packed bed of carbon. Subsequently, a layer of carbide derived carbon (CDC) can be formed on the surface of the titanium carbide layer by chlorination or by an anodic electrolysis treatment in molten chloride salt. The formation of CDC can be verified by Raman spectroscopy and the improvement of tribocorrosion resistance can be verified by tribocorrosion testing at the free corrosion potential. The results demonstrate a dramatic decrease in corrosion when a CDC layer is present during mechanical sliding.

3:00pm **MD1-2-MoA-5 Some Safe Ancillaries? Fretting Corrosion May Be at the Origin of Some Degradations**, ***Jean Geringer [geringer@emse.fr]***, Mines Saint-Etienne, France; *Julie Scholler,* CHRU Strasbourg, 1 place de l'hopital BP 426 67091 Strasbourg cedex, France; *Sandra WISNIEWSKI, François Bonnomet,* CHRU Strasbourg, 1 place de l'hopital BP 426 67091 Strasbourg cedex, France., France

Ancillaries are tools for assisting surgeons and nurses during surgical operations. Most of the time, they are not involved in human tissues contact. However especially during orthopaedic operations, the tools, ancillaries, might be in contact with human tissues, drilling the femoral bone for instance. The focused ancillary is a clamp dedicated to avoid circulation of any liquid (physiological liquid for instance with or without some drugs).

New results

This study aimed at establishing the treatment effect on 304 stainless steel. Due to multiple usages, the ancillaries might be washed and might exhibited some corrosion marks after certain amount of time. The observations do highlight some surface degradations (cleanliness) and some corrosion marks (corrosion). It is worth noting that the corrosion is visible by human eyes (some rust with red-orange color). The highlighting point is the surface state. Some 1-10 µm debris are on the top surface of the ancillary. 304L is the stainless steel. Thanks to brossing polishing surface, starting corrosion is on. The specific surface is increasing due to this treatment that might be deleterious.

Conclusions & significance

The corrosion effect was highlighting on this ancillary. For better knowledge, the authors have to do more investigations on many ancillaries.

Acknowledgements

The authors acknowledge Ms. M. Mondon, Mines Saint-Etienne, for allowing to use scanning electronic microscope facilities and manufacturing processes.

3:20pm **MD1-2-MoA-6 Surface Modification Strategies for Improved Bioactivity: CAP-p15 Functionalization on Titanium and 316L SS Implants**, *Guadalupe Ureiro-Cueto,* Universidad Nacional Autonoma de Mexico, Mexico; ***Sandra E. Rodil [srodil@unam.mx]***, Instituto de Investigaciones en Materiales, UNAM, Mexico; *Gonzalo Montoya-Ayala, Higinio Arzate,* Universidad Nacional Autonoma de Mexico, Mexico

Titanium-based implants and austenitic 316L stainless steel (316L SS) are widely used in medical applications due to their mechanical strength and biocompatibility. However, their bioinert nature often limits osseointegration, particularly for long-term use. To address this, surface modifications—such as oxide layer formation, sandblasting, and peptide functionalization—have emerged as promising strategies to enhance bioactivity and bone regeneration.

This study explores the biofunctionalization of amorphous titanium oxide ($aTiO_2$) surfaces deposited on Titanium and 316L SS substrates with a cementum attachment protein-derived peptide (CAP-p15). For titanium-based implants, CAP-p15 functionalization significantly improved human oral mucosal stem cell (hOMSC) proliferation, attachment, and osteogenic differentiation, as evidenced by increased alkaline phosphatase (ALP) activity, mineralization, and expression of osteogenic markers (RUNX2, BSP, BMP2, OCN). Similarly, on 316L SS surfaces, CAP-p15 enhanced human periodontal ligament cell (HPLC) attachment, spreading, and the formation of carbonated apatite in artificial saliva, indicating improved bioactivity.

These findings demonstrate that CAP-p15 functionalization is a versatile and effective approach to enhancing the osseointegration and bioactivity of titanium and 316L SS implants. It offers a promising pathway for bone tissue regeneration and long-term implant success.

4:00pm **MD1-2-MoA-8 Noble Nanoparticles Arrays Coating for Electrochemical (EC) and Surface-Enhanced Raman Spectroscopy (SERS) Biosensors**, ***Ting-Yu Liu [tyliu@mail.mcut.edu.tw]***, Ming Chi University of Technology, Taiwan **INVITED**

We have demonstrate a facile and low-cost preparation process to fabricate the laser scribed graphene (LSG)-based electrochemistry (EC) and surface-enhanced Raman spectroscopy (SERS)substrate for bio and environmental detection. LSG substrate was fabricated via laser scribed and deposited the Au nanoparticles on the LSG by thermal evaporation or electrochemical deposition. 3D porous microstructure of LSG can improve the SERS signal of Au@LSG substrate, and further fine-tune the thickness of Au nanoparticles (5-25 nm) to optimize the EC-SERS enhancement. The developed sensor demonstrates exceptional performance in detecting uremic toxins. The results show that 20 nm of Au nanoparticles coated on LSG substrate obtains the highest SERS enhancement effects, and successfully detects the dye molecules (rhodamine 6G, R6G) and uremic toxins (urea, uric acid and creatinine). The EC-SERS signals of R6G would enhance 17 times at the potential of -1.3 V, compared to SERS signals without applying an electric field. Moreover, the urea also displays 4 times higher at the potential of -0.2 V. Furthermore, it achieves remarkably low detection limits (10^{-3} M for creatinine/uric acid, 10^{-4} M for urea) and offers distinct, concentration-dependent responses for different toxins in cyclic voltammetry (CV) measurements. The detecting molecules could be selected to enhance SERS signals by different voltages, showing the capability of selectively detecting biomolecules, bacteria, and virus, which can solve the problem of complex sample pretreatment.

4:40pm **MD1-2-MoA-10 Flexible Implantable Microelectrode Arrays with Electrodeposited Nanoporous Platinum for Electrophysiology and Non-Enzymatic Glucose Sensing**, ***Chih-Ching Tseng [960076@gmail.com]***, *Yu-Lin Lee,* National Taipei University of Technology, Taiwan*; Pu-Wei Wu,* National Yang Ming Chiao Tung University (NYCU), Taiwan*; Po-Chun Chen,* National Taipei University of Technology, Taiwan

For neuroscience research, scalability in regard to the length and dimension of implantable neuro devices was required owing to differences in species and brain regions. For the clinical investigation of neurological disorders, including Alzheimer's disease, Parkinson's disease, and epilepsy, specifically designed implantable neuro devices for precise focus localization have emerged. Among them, in Alzheimer's disease (AD) studies, the metabolic hypothesis of AD is among the models that have gained much traction because glucose hypometabolism is one of the early markers of AD that precede clinical dementia. While a strong argument can be made that reduced glucose uptake is merely a consequence of neurodegeneration, the metabolic hypothesis asserts that brain glucose metabolism is nonetheless an integral part of AD progression and the precipitation of cognitive deficits.

In this study, a flexible microelectrode array device is developed with a polyimide substrate, nanoporous platinum microelectrode array, and a biocompatible Parylene C package. This device has low electrochemical impedance with an improved signal-to-noise ratio and high sensitivity of glucose concentration by non-enzymatic electrochemical detection. The nanoporous Pt microelectrode demonstrated excellent electrochemical performance of 88.2 ($\mu Acm^{-2}mM^{-1}$) and 37.02 ($\mu Acm^{-2}mM^{-1}$) using a chronoamperometry (i-t) test method in PBS and ACSF, respectively.

Additionally, we dedicate to maintaining animal welfare ethics and reducing the consumption of animal experiments by developing an artificial prosthesis with agarose to mimic the brain tissue. We successfully developed a prosthesis with tunable impedance, in which we can simulate different neural diseases by adjusting its conductivity to reduce unnecessary animal experiments. The flexible platinum microelectrode shows its high sensitivity to the variation of glucose concentration in the agarose brain prosthesis.

5:00pm **MD1-2-MoA-11 A Self-Assembled Silica Nanobead Column-Driven Biosensing Platform for Point-of-Care Diagnostics**, ***KangKug (Paul) Lee [klee3@wilberforce.edu]***, *Eduardo Diaz, Saiyd Harvin, Isaiah Williams,* Wilberforce University, USA

An innovative biosensing platform incorporating self-assembled silica nanobead-packed columns has been developed and demonstrated for point-of-care (POC) diagnostic applications. This approach is unique in its dual-purpose functionality: the self-assembled silica nanobead-packed column functions as an efficient whole blood/plasma separator via its nanoporous membrane structure while simultaneously serving as a sensitive biosensor, enhanced by its large surface area that facilitates biological interactions. The biosensing capability was demonstrated and quantified through a capillary-driven lateral flow colorimetric assay, highlighting its potential for POC diagnostics. This nanobead-packed biosensing platform offers a simple, practical, disposable, inexpensive, and user-friendly solution. It is particularly valuable for physicians, nurses, and patients in hospitals worldwide, as well as in resource-limited settings, field environments, and home-care situations.

5:20pm **MD1-2-MoA-12 Modelling Complexities of Tribocorrosion Processes: Evaluation and Validation**, ***Avirup Sinha [asinha38@uic.edu]***, University of Illinois at Chicago, USA*; Feyzi Hashemi,* Flinders University, Australia*; Maansi Thapa, Bill Keaty, Yani Sun,* University of Illinois at Chicago, USA*; Reza Hashemi,* Flinders University, Australia*; Mathew T. Mathew,* University of Illinois at Chicago, USA

Introduction:

Biomedical implants are vital medical devices surgically placed to replace or support damaged tissues and organs. Modular implants, such as hip replacements, improve adaptability for diverse patients but introduce challenges like tribocorrosion—a complex interaction of tribology and corrosion. Tribocorrosion releases debris, ions, and particles into surrounding tissues, causing reactions, systemic toxicity, and infections. Biocompatible materials like Ti6Al4V are commonly used in implants. Although various experimental methods exist to study tribocorrosion, limited mathematical modeling efforts have been undertaken. This study reviews available models to identify those most suitable for implant applications, with two aims: a) validating model efficiency using literature data, and b) conducting experiments to generate data for further validation.

Methodology:

Aim 1: Electrochemical current evolution is a key measure of tribocorrosion. Models like "Olsson and Stemp," "Feyzi and Hashemi," and the Uhlig model predict tribocorrosion currents, but their efficiency remains insufficiently tested. Data from M.T. Mathew et al.'s "Tribocorrosion Behaviour of TiCxOy" was selected for its robust dataset, clear graphical representation, and systematic evaluation across varying voltages, ensuring analytical versatility. Aim 2: Fretting-corrosion experiments were conducted using a custom-built tribocorrosion apparatus (Pin- on-flat) to validate models against experimental outcomes. Materials included Ti6Al4V and CoCr bases with a Zr pin. Testing was performed in 0.9% saline at 83N load and ±6mm amplitude at 1Hz frequency.

Results:

Aim 1 demonstrated that Mischler's model outperformed Olsson and Stemp's in predicting experimental data. While Olsson's model worked well at -0.5V, it struggled at +0.5V due to assumptions about voltage- dependent oxide film growth, making it better suited for lower voltage predictions. Aim 2 revealed Feyzi and Hashemi's model best predicted tribocorrosion behavior, though significant variance highlighted the need for refined assumptions. Olsson and Stemp's model showed promise with adjustments to variables like oxide layer thickness, emphasizing its role in tribocorrosion modeling.

Conclusions:

The study concludes that tribocorrosion current is influenced by multiple factors, and model predictions improve with accurate variable inputs. Further research is needed to refine models, including developing experimental procedures to determine assumed variable values (e.g., asperity radius) and creating real- time computational models to compare experimental and predicted results.

Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials
Room Palm 1-2 - Session MD2-WeM

Surface Response to Biological Environments, Biointerphases, and Regenerative Biomaterials

Moderators: Po-Chun Chen, National Taipei University of Technology, Taiwan , **Jean Geringer**, Ecole Nationale Superieure des Mines, France, **Hamdy Ibrahim**, University of Tennessee at Chattanooga, USA

9:20am **MD2-WeM-5 Green Fabrication of Conductive Carbon Thin Film Patterns for Biosensors***, **Ying-Chih Liao [liaoy@ntu.edu.tw]**,* National Taiwan University, Taiwan **INVITED**

The demand for sustainable and cost-effective materials in biosensing is growing, especially for real-time and portable health monitoring. However, conventional electrode fabrication methods often require multiple processing steps and use non-renewable materials. This reliance raises environmental concerns and limits scalability. In this study, a green approach is developed to directly transform biodegradable bacterial cellulose (BC) into conductive carbon thin films using CO_2 laser-induced carbonization under ambient conditions for biosensor fabrication. Bacterial cellulose (BC) a biopolymer generated by specific bacteria, features a highly porous, nanoscale fibrous structure along with notable mechanical strength and biocompatibility. These properties make it a highly versatile material for biomedical applications. The laser-induced carbonization process leverages these unique structural features of BC, converting it into a conductive carbon matrix suitable for electrochemical applications. This one-step technique involves the precise application of a CO_2 laser, which locally heats the BC, breaking down organic components and rearranging carbon atoms to create conductive graphitic structures.

This approach integrates essential elements into the BC matrix, enhancing conductivity and sensor functionality without requiring complex post-treatments. The laser-induced carbonized BC electrode offers promising detection capabilities for glucose and lactate, enabling concurrent sensing in phosphate buffer solution (PBS) and demonstrating selectivity, reproducibility, and stability, verified through differential pulse voltammetry (DPV). This streamlined laser carbonization method facilitates electrode fabrication and yields electrodes capable of application in real sweat sample analysis.These characteristics highlight BC-based electrodes as highly promising candidates for portable, cost-effective on-site biosensors for monitoring key biomarkers in sweat, underscoring the potential of laser-induced carbonization in advancing sustainable, high-performance materials for health monitoring technologies.

11:00am **MD2-WeM-10 Functionalized Graphene for Sensor Applications***, **Chi-Hsien Huang [chhuang@mail.mcut.edu.tw]**,* Ming Chi University of Technology, Taiwan **INVITED**

Graphene (G), a one-atom-thick, two-dimensional material, exhibits great potential as a biosensor transducer due to its high sensitivity to foreign atoms or molecules. However, its inertness limits its application, making functionalized graphene is very crucial for biosensor applications. In this presentation, I will talk about an atomic layered composite of graphene oxide/graphene (GO/G) by functionalizing chemical vapor deposition (CVD)-grown bilayer graphene (BLG) using our developed low damage plasma treatment (LDPT). This process selectively oxidized only the top layer of BLG, leaving the bottom layer intact. The GO top layer provides active sites for stable covalent bonding with biorecognition elements, while the G bottom layer acts as a sensitive transducer. With this GO/G composite, we constructed a solution-gated field effect transistor (SGFET)-based biosensors for miRNA-21, a cancer biomarker and p-tau 217, a Alzheimer's disease biomarker. In addition, laser induced graphene attracts a lot of attention because the preparation is low-cost, easy pattern fast and environment friendly. However, the electrochemical performance of standalone LIG is limited. To address this, the study enhances LIG by synthesizing nickel-iron Prussian blue analogues through co-precipitation and calcination, forming porous NiFe-Oxide, which is subsequently deposited onto the LIG surface via a facile physical deposition method. The porous NiFe-Oxide@LIG electrode material demonstrates excellent electrochemical sensing capabilities due to its high conductivity, improved surface area, enhanced active sites, and superior electrocatalytic performance for detecting the antioxidant propyl gallate (PG).

Keywords: graphene, LIG, sensor, biomarker

References:

1. S. Chinnapaiyan, N. R. Barveen, S.-C. Weng, G.-L. Kuo, Y.-W. Cheng, R. A. Wahyuono, C.-H. Huang*. Sensors and Actuators B: Chemical, 423, 136763, 2025

2. S.-H. Ciou, A.-H. Hsieh, Y.-X. Lin, J.-L. Sei, M. Govindasamy, C.-F. Kuo*, C.-H. Huang*. Biosensors and Bioelectronics, 228, 115174, 2023.

3. C.-H. Huang*, W.-T. Huang, T.-T. Huang, S.-H. Ciou, C.-F. Kuo, A.-H. Hsieh, Y.-S. Hsiao, Y.-J. Lee. ACS Applied Electronic Materials, 3, 4300-4307, 2021.

4. C.-H. Huang*, T.-T. Huang, C.-H. Chiang, W.-T. Huang, Y.-T. Lin. Biosensors and Bioelectronics, 164, 112320, 2020.

11:40am **MD2-WeM-12 Surface Functionalization of Indium Tin Oxide via (3-Aminopropyl) Triethoxysilane and Glutaraldehyde for Enhanced Sensitivity in Glucose Detection***, **Kai-Jhih Gan [jameswsalebron@gmail.com]**, Jialong Xiang,* Fuzhou University, China*; Kuei-Shu Chang-Liao, Bo-Syun Syu,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China

In this study, (3-aminopropyl)triethoxysilane and glutaraldehyde were employed to functionalize the surface of indium tin oxide (ITO) thin films, followed by a comprehensive analysis of their material structure and properties. The structural characteristics of the ITO thin films before and after surface modification were investigated using atomic force microscopy and x-ray diffraction. The chemical composition of both the surface-modified layer and the ITO thin films was confirmed via x-ray photoelectron spectroscopy. Additionally, the structure of the ITO-based glucose biosensor fabricated with the modified films was characterized using transmission electron microscopy and energy-dispersive spectroscopy. The results reveal that surface modification of the ITO thin films not only optimized their surface properties but also enhanced the effective contact area, thereby improving the sensor performance. ITO sensing patch exhibited a broad linear response range for glucose detection, from 10 fM to 10^{10} fM, under optimized conditions.

12:00pm **MD2-WeM-13 Magnetron-Sputtered Ti-Based Thin Films: A Versatile Platform for Biopotential Sensing and Neurorehabilitation***, **Claudia Lopes [claudialopes@fisica.uminho.pt]**,* CF-UM-UP, University of Minho, Portugal*; Patrique Fiedler,* Technische Universität Ilmenau, Germany*; Jean-Francois Pierson,* Institut Jean Lamour - Université de Lorraine, France*; Brigitte Vigolo,* Institut Jean Lamour - Université de Lorraine (F), France*; Nelson Azevedo,* Nellson Azevedo & Terapias Globais, Portugal*; Michael Cullinan,* Department of Mechanical Engineering, The University of Texas at Austin, USA*; Armando Ferreira, Filipe Vaz,* CF-UM-UP, University of Minho, Portugal

Four distinct Ti-based thin film systems, doped with different metals (Au, Ag, Cu, Al), have been prepared by magnetron sputtering, allowing precise control over their chemical composition and microstructure. The strategic incorporation of these metals induces significant variations in phase composition, grain morphology, crystallographic orientation, and surface topography, which directly impact the electrical conductivity, mechanical flexibility, and electrochemical stability. These tunable properties are crucial for optimising their performance in biomedical applications, particularly as functional interfaces for biopotential sensing.

All the systems exhibit three distinct regimes based on their chemical composition. At low metal contents, Ti-based films establish α-Ti(metal) metastable solid solutions. For intermediate metal/Ti ratios (0.2 - 1.0), the precipitation of intermetallic phases leads to high structural disorder, giving rise to different microstructures depending on the metal type. At higher ratios (> 1.0), the systems display contrasting morphologies, from well-defined domains to amorphous structures. The mechanical properties vary accordingly: Ti-Au and Ti-Cu films demonstrate superior toughness ($H/E \approx 0.1$) and high elastic recovery, whereas Ti-Ag and Ti-Al, characterised by columnar and brittle intermetallic structures, exhibit lower plastic deformation resistance ($H/E < 0.04$). Electrical resistivity is also metal-dependent, with Ti-Au and Ti-Cu films maintaining nearly constant resistivity (~180 μΩ·cm) due to their Thin Film Metallic Glasses-like morphology, while Ag- and Al-rich films exhibit resistivity variations (130–270 μΩ·cm) linked to their crystalline structures.

These Ti-based systems have been implemented as advanced dry biopotential electrodes, namely on the integration of novel neuro-rehabilitation systems combining electroencephalography (EEG), electrocardiography (ECG), electromyography (EMG), and functional electrical stimulation (FES). Ti-Au and Ti-Cu electrodes demonstrated superior electromechanical performance and in vivo signal acquisition, outperforming conventional Ag/AgCl electrodes. Their dense, disordered structures contribute to enhanced durability, while Ti-Cu electrodes exhibited prolonged reusability, maintaining high-fidelity signal recording for at least 24 hours. The integration of these biocompatible, flexible thin films onto polymeric substrates ensures mechanical adaptability and stable skin-electrode interaction, reinforcing their potential in bioelectronic and neurorehabilitation systems.

Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials
Room Golden State Ballroom - Session MD-ThP
Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials Poster Session

MD-ThP-4 Effects of Electrical Stimulation with Iridium Oxide Plasma Protein Hybrid Film on Nerve Cells*, **Po-Chun Chen [cpc@mail.ntut.edu.tw]**,* National Taipei University of Technology, Taiwan

Iridium oxide (IrOx) is a well-known material for neural stimulation, but its rigidity and lack of bioactivity limit its biomedical application. To address this, an IrOx film incorporating plasma proteins (IrOx-PP) was developed to enhance biocompatibility and promote neuronal growth. The addition of plasma proteins created bioactive sites that improved cell adhesion and differentiation while maintaining the electrochemical properties needed for neural stimulation. The IrOx-PP hybrid films showed significantly higher cell viability and metabolic activity, with electrical stimulation further enhancing cell growth and bioactivity. Neurite length increased significantly under electrical stimulation, with the IrOx-PP hybrid films showing the greatest enhancement. In addition, cells on IrOx-PP hybridfilms expressed higher levels of the neuronal markers, indicating their superior potential for promoting neuronal differentiation and neurite outgrowth compared to pure IrOx films. This result demonstrated that the IrOx-PP hybrid film can potentially serve as a platform for advanced neural interfaces, providing improved tissue integration.

MD-ThP-5 Antibacterial Coating of Additively Manufactured Biodegradable Implants*, **Jan-Ole Achenbach [achenbach@kcs-europe.com]**, Rainer Cremer,* KCS Europe GmbH, Germany

Presently used metallic bioimplants are non-degradable and remain permanently inside the body, in some cases require a secondary surgery for removal.To overcome such problems, biodegradable metallic implants (Fe-Mn, Mg, Zn) are being developed around the world. Mg based alloys are recently being commercialized for dental, trauma and orthopedic applications. However, due to higher degradation rates and hydrogen evolution, their use is not being extended to applications that require implants to remain in the body for longer periods of time. The degradation rates of Mg based alloys can be reduced by incorporating fine grain structure and also with suitable coating.

The proposed study envisages the design of soft tissue anchors, the development of Mg and Fe-Mn alloy powders with suitable composition, and demonstration of additive manufacturing process for the manufacture of prototypes. The proposed work also involves detailed characterization (microstructural, mechanical and biological) of additive built and surface modified coupons as well as components.

The project is being worked on as part of the "Additive Manufacturing" call for proposals of the Indo-German Science and Technology Centre. In the sub-project "Antibacterial and corrosion-inhibiting coatings for soft tissue anchors" of the joint project, KCS Europe is working on the surface refinement of the anchors. Here, silver-based layers are to be developed using Physical Vapour Deposition and applied to biodegradable implants which, in addition to an antibacterial effect, can also guarantee the integrity of the anchors for a defined period of time.

MD-ThP-6 Copper-Based Biocidal Thin Film Characterised by X-Ray Photoelectron Spectroscopy*, Jonathan Counsell,* Kratos Analytical Limited, UK*; **David Surman [dsurman@kratos.com]**,* Kratos Analytical Inc., USA*; Heather Yates,* University of Salford, UK

The presence of pathogenic microbes on surfaces is a problem in healthcare environments, especially with the increasing prevalence of antibiotic-resistant bacteria. One solution is to develop anti-microbial surface coatings which for clinical and high traffic areas. Here we investigate the surface properties of anti-microbial copper oxides and photocatalytic titania on different substrates formed via chemical vapour deposition (CVD). The deposition is sequential with copper oxide deposited before the titania mimicking the industrial inline process. The surface properties were investigated using X-ray photoelectron spectroscopy (XPS). XPS was used to determine both lateral and depth information from the copper–titainia composite thin film. Despite titania deposition occurring after the copper oxide process, copper was observed at relatively high concentration, suggesting mobility through the titania and segregation to the near-surface region. Ion sputter profiling shows a significant depth distribution of the copper and titanium through the film. Herein, we highlight the insight provided by XPS and how the technique exposes the oxidation states of copper, the presence of contaminants, and the chemical bonding at both the surface and into the bulk.

MD-ThP-8 Microfluidic Engineered Surface Modified Liposomes Encapsulating Mitochondria for Enhanced Cellular Uptake and Bioavailability in Cell Therapy*, **Yen-Chin Hsu [yenchin18758@gmail.com]**, Yu-Jui Fan,* Taipei Medical University, Taiwan

Mitochondrial dysfunction plays a crucial role in the development of degenerative diseases such as neurodegenerative diseases, cardiovascular diseases, and metabolic syndrome. Although mitochondrial transplantation offers a potential therapeutic solution, its clinical implementation is limited by obstacles such as mitochondrial degradation, poor cellular uptake, and immune system recognition. To overcome these challenges, this study introduced a microfluidic-engineered liposome encapsulation technology to enhance mitochondrial stability, bioavailability, and intracellular delivery efficiency for cell therapy applications.

The microfluidic system is used to manufacture liposome-encapsulated mitochondria, which can precisely control liposome size, charge, and encapsulation efficiency. By combining zwitterionic phospholipids (1,2-dioleoyl-sn-glycero-3-phosphocholine, DOPC) and cationic quaternary ammonium lipids, surface charge modulation is achieved, optimizing the electrostatic interaction between liposomes and mitochondrial membranes, and promoting efficient cellular uptake via the endocytic pathway. Dynamic light scattering (DLS), zeta potential analysis, fluorescence microscopy, and flow cytometry were used to characterize the structural integrity, surface charge distribution, and encapsulation efficiency of the engineered liposomes.

Cellular uptake and viability studies in AC16 cardiomyocytes and fibroblasts showed that liposome-encapsulated mitochondria exhibited improved viability compared with unencapsulated mitochondria after delivery into cells. The appropriate level of cationic charge facilitates membrane fusion and uptake, enhancing biocompatibility, which has been confirmed by ROS testing and live/dead staining assays.

The results indicate that microfluidics-based liposome engineering enhances mitochondrial transplantation by improving mitochondrial delivery efficiency and cellular bioavailability through surface charge tuning. Future research will focus on optimizing lipid composition, evaluating long-term mitochondrial stability, and performing in vivo validation to establish the translational potential of microfluidic-engineered liposome-encapsulated mitochondria in regenerative medicine.

MD-ThP-11 Corrosion Stability and Electrical Performance of Ti-Au Thin Film Electrodes for Biosignal Acquisition*, **Sara Inácio [saramsinacio@gmail.com]**, Carolina Durães, Ana Camarinha, Armando Ferreira, Cláudia Lopes, Filipe Vaz,* University of Minho, Portugal

Biosignal sensing plays a crucial role in research and healthcare, especially in e-health applications, as it provides extensive information about the health and emotional condition of individuals. In the same way, the existence of reliable and high-performing biopotential electrodes capable of monitoring for long periodsis vital since they enable reliable diagnosis of vital physiological functions. Traditionally, standard silver/silver chloride (Ag/AgCl) electrodes are valued for their low impedance and stable performance, ensuring high signal to noise ratios. However, their use in e-health applications and prolonged monitoring is severely hindered by several factors, such as gel dehydration and the occurrence of skin allergic reactions,highlighting the importance of novel dry electrodes.

In this study, the performance of Ti-Au thin films deposited onto flexible polymeric substrates as dry electrodes was investigated. Ti and Au are biocompatible metals, making them ideal for biomedical applications. Additionally, Au has excellent mechanical properties and high electrical conductivity, which are essential for low-amplitudebiopotential recordings. This work aimed to investigate the influence of the Au content and the growth geometries on the corrosion behavior and the overall performance of the electrodes. The Ti-Au thin films were deposited using the magnetron sputtering technique withGLancing Angle Deposition (GLAD) to produce different geometries/architectures.

Results showed that the Au/Ti ratios varied between 0.07 and 0.80, with the films exhibiting crystalline structures for Au contents lower than 0.08 and amorphous structures for higher contents. Also, the morphology was highly influenced by the Au content,with the films evolving from columnar growth (Ti-rich films) to a dense and featureless microstructure for Au contents (Au/Ti ≥ 0.12), with a high impact on the surface roughness of the final electrodes. The electrical properties showed that regardless the Au content, the films prepared in a conventional geometryexhibit an electrical resistivity around 5μΩ.m. However, for the films prepared by GLAD, with tilted angles higher than 60º, the electrical resistivity increases one magnitude order (25.33 μΩ·m). The assessment of the electrode's longevity was carried out by testing the Ti-Au thin films' corrosion behaviour in artificial sweat through open-circuit potential (OCP), electrochemical impedance spectroscopy (EIS), and potentiodynamic polarization (PD) tests.

MD-ThP-13 Surface Modification of AISI 316L Steel by Anodic Oxidation and Its Effect on the Viability of HFOb Cells*,* ***Luz Alejandra Linares Duarte [alejandra.linarespr@gmail.com]****, Enrique Hernández Sánchez, Cintia Proa Coronado, Ángel Ernesto Bañuelos Hernández, Nury Pérez Hernández,* Instituto Politécnico Nacional, Mexico*; Raúl Tadeo Rosas,* Universidad Autónoma de Coahuila, Unidad Torreón, Mexico*; Yesenia Sánchez Fuentes,* Instituto Politécnico Nacional, Mexico

AISI 316L stainless steel is one of the low-cost materials that is suitable for medical applications. That condition is because of its high corrosion resistance and low response to human fluids. This study is on the surface modification of the austenitic stainless steel AISI 316L by the anodic oxidation technique and the effect of that on the biocompatibility of the steel. Three conditions of steel were evaluated: 1) non-treated material, 2) anodized samples, and 3) annealed-anodized samples, in which the samples were exposed to a thermal treatment at 600 °C for 8 min to promote the formation of a passive layer. The steel samples were exposed to the anodic oxidation technique with a constant work potential of 60 V and 30 min exposure time. Ethylene glycol, distilled water, and ammonium fluoride (NH4F) were used as the electrolytic fluid. Likewise, the effect of the analyzed surfaces on the cellular viability of human fetal osteoblast (HFOb) cells was evaluated using a resazurin reduction (Cell Titer Blue) assay. Scanning electron microscopy (SEM) and energy dispersive scanning (EDS) were applied to determine the morphology and nature of the microporous surface, showing a well-defined matrix of nanoporous on the AISI 316L steel, with diameter in the range of 100 to 140 nm. On the other hand, in-vitro assays indicated that after 72 h of culture, the best cellular viability was found with annealed-anodized samples. These results open the possibility of generating materials with better capability to promote cellular proliferation in the metallic materials.

Keywords: anodic oxidation, cell proliferation, biomaterials, nanoporous

MD-ThP-14 Electrochemical and Antimicrobial Coating: Increasing the Ionic Charge on Titanium Surfaces as a Preventive Strategy for Titanium Implants*,* *João Pedro dos Santos Silva,* École des mines de Saint-Étienne, France*; Daniela Buenos Ayres de Castro, Mariana Mireski, Catia Sufia Alves Freire de Andrade, Maria Helena Rossy Borges,* Universidade Estadual de Campinas, Brazil*;* ***Jean Geringer [geringer@emse.fr]****,* École des mines de Saint-Étienne, France*; Valentim Adelino Ricardo Barão,* Universidade Estadual de Campinas, Brazil

Peri-implant conditions and the electrochemical degradation of titanium (Ti) are critical factors in the failure of biomedical implant treatments. Developing functional surfaces to address these challenges is essential. Cationic coatings have proven to be an effective strategy for reducing biofilm formation and enhancing corrosion resistance. This treatment focuses on increasing the surface charge of implants and provides antimicrobial properties without the use of pharmaceutical agents, making the approach safer, more cost-effective, and sustainable. Thus, this coating was developed in two stages: (1) functionalization with hydroxyl groups (-OH) using plasma electrolytic oxidation (PEO), incorporating bioactive elements and enhancing surface functionalization; (2) silanization with tetraethylorthosilicate (TEOS) or 3-glycidyloxypropyltrimethoxysilane (GPTMS), which bind to alkaline surfaces and promote proton release through chemical reactions. Four groups (untreated Ti, PEO, PEO + TEOS, and PEO + GPTMS) were evaluated for surface characterization, electrochemical performance, and antimicrobial activity. Micrographs showed distinct morphologies in the silanized groups, with the alkalinization step generating pores that enhanced topography and roughness. The superhydrophilic affinity created by alkalinization evolved into hydrophobic (TEOS) and superhydrophobic (GPTMS) characteristics after silanization. The presence of amine groups, detected by X-ray photoelectron spectroscopy (XPS), indicated an increase in surface charge, confirmed by zeta potential measurements. Positively charged surfaces demonstrated superior electrochemical performance and greater antimicrobial potential against Streptococcus mitis biofilm formation (24 h). In conclusion, cationic coatings show promise for implantable devices, offering improved resistance in adverse environments and antimicrobial properties.

Author Index

Bold page numbers indicate presenter