

# Monday Afternoon, May 12, 2025

## 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 Abd rabo, 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*, 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 sp<sup>2</sup> 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.

2:40pm **MD1-2-MoA-4 Nano-Mechanical Characterization of Sol-Gel Nanocoatings in the Context of Antibacterial/Antiviral Advanced High-Traffic Surfaces**, *Ilaria Favuzzi, Edoardo Rossi*, Università degli studi Roma Tre, Italy; *Angelo Meduri, Mario Tului, RINA-CSM*, Italy; *Marco Sebastiani*, Univeristà degli studi Roma Tre, Italy

The global pandemic caused by the SARS-CoV-2 virus has prompted a re-evaluation of surface hygiene practices, leading to an increased focus on the use of antimicrobial coatings. Sol-gel methodologies, known for their durability and cost-effectiveness, have emerged as a leading technology. MIRIA European project aims to advance sol-gel technologies, utilising nanoparticles such as silver or copper to enhance safety in a variety of public environments (e.g. hospitals, public transportation) and contribute to infectious disease management strategies.

In this work, antimicrobial thin films were deposited via dip coating on glass substrates starting from silicon-based hybrid organic-inorganic sol-gel formulations. The formulations differed in terms of the organosilicon additives and the presence of nanoparticles. A nanomechanical integrated protocol was applied to assess mechanical proprieties, adhesion and wear durability, by using three primary testing methodologies: nanoindentation, scratch, and wear testing. Nanoindentation was conducted using a KLA G200 Nanoindenter in CSM mode to extract the elastic modulus and hardness of the films, with appropriate models employed to correct for substrate influences. Subsequently, abrasive wear tests were conducted in accordance with the UNI-EN1071-6 standard, while scratch resistance was evaluated using the same nanoindenter, configured for nano-scratch testing with a rounded cone tip and lateral force measurement. Moreover, the antibacterial efficacy against *Staphylococcus aureus* and the antiviral efficacy against the MOI0.5 virus were evaluated.

Two data-based interpretation models were employed to extract intrinsic hardness and modulus of the films from nanoindentation data. An increase in stiffness was observed in the nanoparticle-filled formulations. This is associated with improved adhesion (scratch critical loads), as an increase in modulus results in the maximum contact shear stress occurring at higher depths, thereby causing later chipping during scratch. The wear performance of the coatings was evaluated through abrasive wear tests, which demonstrated that all coatings enhanced wear resistance compared to the uncoated glass substrate. The coatings containing copper oxide nanoparticles demonstrated the highest resistance and were the most effective in terms of antimicrobial performance, achieving a 3log (99.9%) reduction in microbial count after a 24-hour contact period.

Finally, a critical evaluation on the potential industrial scale-up of the proposed coating solutions is presented.

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

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**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**, 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<sub>2</sub>) 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*, 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<sup>-3</sup> M for creatinine/uric acid, 10<sup>-4</sup> 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, 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 (μAcm<sup>-2</sup>mM<sup>-1</sup>) and 37.02 (μAcm<sup>-2</sup>mM<sup>-1</sup>) 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, 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*, 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

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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.

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