Surface Engineering of Biomaterials, Devices and Regenerative Materials: Health, Food, and Agriculture Applications
Room Palm 1-2 - Session MD1-1-MoM

Coatings and Surfaces for Medical Devices: Mechanical, Corrosion, Tribocorrosion, and Surface Processing I

Moderators: Hamdy Ibrahim, University of Tennessee at Chattanooga, USA, **Sangeeta Kale**, Defence Institute of Advanced Technology (DIAT), India

10:00am **MD1-1-MoM-1 NaOh Etching and Oxygen Plasma Treatments on Surface Characteristics and Their Potential to Activate Micro-Arc Oxidized TiO_2 Biomedical Coatings.**, ***Paulo Noronha Lisboa-Filho* [paulo.lisboa@unesp.br]**, UNESP, Brazil **INVITED**

Activation treatments such as NaOH etching or O_2 plasma can play an essential role in surface conjugation of titanium with biomolecules, providing a better interaction at the bone-implant interface. However, their application on complex titanium dioxide (TiO_2) surfaces is still not explored. In this contribution, bioactive and porous TiO_2 coatings produced by micro-arc oxidation (MAO) were treated with NaOH etching or O_2 plasma and then placed in contact with a reactive isocyanate test compound to evaluate the potential of molecule conjugation. Results suggested that O_2 plasma treatment has only changed the surface chemistry of the coating through carbon contaminants removal, plasma-driven oxidation and generation of functional OH species, including reactive carboxyl groups. This chemical modification by plasma has made the surface superhydrophilic. After NaOH etching, the coating became rougher and also superhydrophilic, containing titanate structures doped with sodium and calcium on its surface and inside the inner pores. Upon reaction with butyl isocyanate, the O_2 plasma-treated surfaces seem to better provide molecule conjugation, introducing characteristic conjugation bonds, and also making MAO coatings more hydrophobic due to the surface-terminated methyl chains from isocyanate. This proof-of-concept study has demonstrated the promising grafting potential given by O_2 plasma on complex TiO_2 surfaces.

10:40am **MD1-1-MoM-3 Sustainable Antifouling Coatings Based on Liquid-Like Solid Surfaces for Medical and Engineering Applications**, ***Jinju Chen* [j.chen4@lboro.ac.uk]**, Loughborough University, UK; *Yufeng Zhu,* Shanghai Jiao Tong University, China; *Hernan Barrio-Zhang,* University of Edinburgh, UK; *Rui Han,* Loughborough University, UK; *Gary Wells,* University of Edinburgh, UK; *Rodrigo Ledesma-Aguilar,* University of Edindburgh, UK; *Waldemar Vollmer,* Queensland University of Technology and CSIRO, Australia; *Nicholas Jakubovics,* Newcastle University, UK; *Glen McHale,* University of Edinburgh, UK

Microbial biofilms present a pervasive challenge across healthcare, food production, water, and energy sectors, contributing to an estimated global economic burden exceeding $5 trillion annually. Overcoming this persistent problem demands durable, non-toxic, and scalable antifouling strategies that inhibit biofilm formation without relying on biocides.

In this study, we present a novel surface-engineering approach for long-term biofilm prevention using slippery, covalently attached liquid-like coatings—a new class of solid surfaces that combine the mechanical robustness of solids with the interfacial mobility of liquids. These permanently tethered liquid-like layers, independent of surface hydrophobicity, exhibit ultra-low interfacial friction and exceptional slipperiness (contact angle hysteresis <3°), effectively suppressing bacterial adhesion and subsequent biofilm growth.

When tested against two clinically relevant pathogens—Pseudomonas aeruginosa (PAO1) and Staphylococcus epidermidis (FH8)—the coatings achieved a 3–5 log reduction in biofilm biomass compared to polydimethylsiloxane (PDMS), a common catheter material, under both static and dynamic flow conditions over 14 days. Importantly, these liquid-like surfaces outperformed silver-based antimicrobial coatings, which rely on biocidal action but suffer from rapid fouling by dead bacteria and loss of efficacy over time. They also surpassed the emerging antibiofilm surfaces such as liquid-infused surfaces, whose performance under flow conditions is limited by oil depletion. In contrast, our covalently anchored liquid-like layers remain mechanically stable and maintain slippery, non-fouling properties even under dynamic shear.

Mechanistic analysis revealed that ultra-low liquid–solid friction, quantified by ultra-low contact angle hysteresis, is a strong predictor of long-term antibiofilm performance—defining a surface-physics design rule for future scalable coating development. Overall, this work provides a scientific and translational framework for designing durable, non-toxic coatings with long-term antibiofilm efficacy for medical devices and other biofouling-prone applications.

11:00am **MD1-1-MoM-4 Synergistic Fretting–Corrosion Mechanisms in DLC Coatings**, ***Tomasz Liskiewicz* [T.Liskiewicz@mmu.ac.uk]**, Manchester Metropolitan University, UK; *Samuel McMaster,* Anglia Ruskin University, UK; *Michael Bryant,* University of Birmingham, UK; *Thawhid Khan,* University of Sheffield, UK; *Yu Yan,* University of Science and Technology Beijing, China; *Ben Beake,* Micro Materials Ltd, UK **INVITED**

This study investigates the synergistic interactions between fretting wear and electrochemical crevice corrosion in diamond-like carbon (DLC) coating systems on AISI 316L substrate under physiologically representative conditions. Particular emphasis is placed on understanding how albumin influences fretting–corrosion mechanisms, given their critical role in many engineering and biomedical environments. A combined experimental methodology is employed, integrating micro-mechanical characterisation (instrumented indentation and scratch testing) with fretting experiments employing in-situ electrochemical characterisation to assess coating durability, damage initiation, and interfacial degradation. Electrochemical techniques, including open-circuit potential monitoring, potentiodynamic polarisation, and electrochemical impedance spectroscopy, are applied in situ during fretting to capture the evolving interaction between mechanical and electrochemical degradation processes.

Fretting was replicated by applying micro-motion to the Al2O3 ball relative to the coated plate under a dead weight normal load. A maximum Hertzian contact pressure of 800 MPa was used for the tests, at a fretting displacement amplitude of 100 µm, giving a gross slip fretting regime. Each fretting test lasted 60 minutes resulting in 3600 cycles at a frequency of 1 Hz. Detailed surface and subsurface analyses using scanning electron microscopy, focused ion beam cross-sectioning, and energy-dispersive X-ray spectroscopy reveal progressive coating damage involving micro-cracking, interfacial delamination, and tribologically induced graphitisation of the DLC layer. Results demonstrate that fretting accelerates corrosion through mechanical disruption of the coating–substrate interface, while corrosion promotes further fretting damage via under-film attack and crack propagation, establishing a genuine fretting-corrosion synergy.

A mechanistic model is proposed in which mechanical defect initiation, electrochemical attack, and debris generation act in a feedback loop, driving progressive coating degradation. These insights highlight the importance of considering protein–surface interactions and combined degradation modes when designing DLC coatings for demanding fretting–corrosion service conditions in biomedical and engineering applications.

11:40am **MD1-1-MoM-6 Machine Learning Approach for Predicting the Corrosion Behavior of Coated Magnesium-Based Materials**, *Abdelrahman Amin,* University of Tennessee at Chattanooga, USA; *Ibrahim Awad,* Independent Researcher, USA; ***Hamdy Ibrahim* [hamdy.m.elsayed@gmail.com]**, Kennesaw State University, USA

One effective approach to control the fast corrosion of magnesium alloys is coating them with a micro-arc oxidation (MAO) layer, which significantly slows down the degradation process. Although experiments have proven the efficacy of this method in studying corrosion, there remains a need to identify more time- and cost-effective solutions. Finite element analysis offers a potential solution, but the complexity of the factors involved in the MAO process makes machine learning methods a more efficient and time-saving alternative for predicting corrosion behavior. This study aims to expand existing machine learning models from predicting corrosion in uncoated magnesium to innovatively forecasting the degradation of MAO-coated samples, focusing on predicting corrosion current density and corrosion potential based on electrochemical corrosion test data.

The key factors involved in the MAO coating process were identified, and relevant data was collected from the literature, with more focus on electrochemical corrosion test results, particularly potentiodynamic polarization (PDP) corrosion test. The primary predictive variables were derived from the parameters of the MAO process, while the response variables were the PDP corrosion potential and corrosion current density. To determine the most accurate predictive model, we evaluated and compared several machine learning algorithms using Python with 80% training and 20% testing data. Once the most effective model was identified, we applied two different predictive approaches for comparison: (i) Exact value prediction, and (ii) Logarithmic value prediction. The Random Forest prediction method identifies the stone related to corrosion current prediction due to its wide range. However, the log prediction method addresses the weaknesses observed in the exact prediction method. Moreover, the Mean Absolute Error (MAE) confirms the model's accuracy. Corrosion Current Density and Corrosion Potential predicted from the log approach were more accurate compared to the obtained values from the exact approach.

12:00pm **MD1-1-MoM-7 Fabrication of Bio-Active Aptes-Gold-Coated Strips for Nerve Agent Detection Using Resonant Sensors***, **Pranali Pandharpatte [pranali.pandharpatte@gmail.com]**, Piyush Shah,* Defence Institute of Advanced Technology (DIAT), India*; K.G. Girija, Chiranjib Mazumder,* Bhabha Atomic Research Centre (BARC), India*; Shaibal Banerjee, Sangeeta Kale,* Defence Institute of Advanced Technology (DIAT), India

Sarin (isopropyl methyl phosphono fluoridate) is an organophosphate ester with high potency as nerve agent, which is extremely dangerous and rapidly attacks the nervous system of human body and makes them incapable in merely few seconds. As direct experimentation with Sarin is highly restricted, dimethyl methylphosphonate (DMMP) serves as a widely accepted safe simulant to explore this biologically-hazardous molecule better.

Through this study, fabrication of active sensing surfaces on chromatography paper strips is discussed, which are coated with gold nanoparticles (AuNPs) and 3-aminopropyltriethoxysilane (APTES) via a dip-and-dry coating technique. These strips enable a rapid and selective chemical response towards DMMP, thereby changing their effective dielectric response.Such a strip is superimposed on a resonant sensor, which is a complementary split-ring resonator (CSRR) operating at 428 MHz. The compact and highly sensitive CSRR sensor is designed on an FR4 substrate with copper metallization, which are excited using RF signal to create electromagnetic field around. The coated strips superimposition on the sensor bed not only augments the electromagnetic near-field confinement of the sensor but also modifies the resonant frequency and signal power as the surface chemistry changes with DMMP interactions. Our studies show detection in the range of 100 to 500 ppm of DMMP, wherein the sensor demonstrates a frequency shift from 10 MHz to 18 MHz and a power variation of 1.98 dB to 4.7 dB. The CSRR–AuNPs–APTES hybrid system highlights the interdisciplinary relevance of surface-engineered coatings in biomedical and environmental sensing, offering potential solutions for nerve gas detections. A smart diagnostic platform with real-time monitoring for healthcare diagnostics is demonstrated.

Keywords- Organophosphorus compounds, Complementary split-ring resonator (CSRR), Surface engineering, Paper-based biosensor, RF sensor, Biocompatibility, Environmental monitoring, Real-time detection platform

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