Coatings for Biomedical and Healthcare Applications
Room California - Session D1-2

Surface Coatings and Surface Modifications in Biological Environments

Moderators: Kerstin Thorwarth, Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland, Mathew T. Mathew, University of Illinois College of Medicine at Rockford and Rush University Medical Center, USA

1:30pm **D1-2-1 Optimisation of Antimicrobial Silver Nanocomposite Coatings on Orthopaedic Grade Cobalt Chromium Alloys and the Related Simulator Analyses in Knee Surgery*, Liuquan Yang,*** Wallwork Cambridge Ltd, UK*; L Richards,* MatOrtho Limited, UK*; J Shelton,* Queen Mary University of London, UK*; H Hothi,* University College London, UK*; S Collins,* MatOrtho Limited, UK*; J Housden,* Wallwork Cambridge Ltd, UK*; A Hart,* University College London, UK*; L Espitalier,* Wallwork Cambridge Ltd, UK

Hard wearing PVD silver nanocomposite coating has shown the antimicrobial effect in previous research and a good ion barrier for the release of heavy metal ions from the conventional orthopaedic grade cobalt chromium (CoCr) alloy. Therefore, such a coating family may be considered as a promising candidate in orthopaedic applications with bearing surfaces and in particular may lower the risk of post-operation infection. The control of silver release and the overall tribological friction/wear performances are critical for the safety and longevity of the orthopaedic implant research. This is study focuses on optimisation of four the electron beam physical vapour deposition (EBPVD) coatings deposited on the medial rotation knee (MRK^{TM}) surface with different levels of silver contents in the coating structure. The overall coating assessments are carried out on simulator testing in vitro for antimicrobial effectiveness, i.e., silver ion and particle release, and wear characterisations against ultra-high molecular weight polyethylene (UHMWPE). The proposed optimised coating structure will be subject to biocompatibility tests and clinical trials.

1:50pm **D1-2-2 Structure and Properties of Novel Hydrophobic Cr-Ag Antibacterial Coatings Deposited by Closed-field Unbalanced Magnetron Sputtering*, MohammadSharear Kabir,*** University of New South Wales, Australia*; A Karami,* University of Adelaide, Australia*; P Munroe,* University of New South Wales, Australia*; Z Zhou,* City University of Hong Kong, Hong Kong*; Z Xie,* University of Adelaide, Australia

Antibacterial coatings are defined as surface coatings that can repel or resist the attachment of bacteria by exhibiting bactericidal or anti-biofouling effects. They are emerging as a primary component in surface applications to mitigate problems related to bacterial pathogens. In this study, we have investigated the structure and properties of Ag-doped Cr coatings. These coatings were deposited by closed-field unbalanced magnetron sputtering method using pure (99.99 %) Cr and Ag targets. The structure and mechanical properties of the coatings were investigated using X-ray diffraction (XRD), transmission electron microscopy (TEM), focused ion beam microscopy (FIB) as well as nanoindentation. XRD analysis revealed Cr (110) as the dominant texture with the emergence of Ag (111) as the Ag content increases. TEM analysis revealed that the coatings were composed of distinct columnar grains several hundred nanometres in length. Furthermore, the coatings exhibited a hardness of around ~8 GPa with significant abrasion resistance and hydrophobic behaviour with a contact angle of ~114^{0}. Ongoing work is investigating the behaviour of these coatings under conditions of bacterial colonization.

2:10pm **D1-2-3 Thin Film Metallic Glass : A Lubricated Coating on Medical Needle for Reducing Fracture Toughness and Damage of Phantom Materials*, Berhane Gebru,*** *J Chu, C Yu,* National Taiwan University of Science and Technology (NTUST), Taiwan

A two successive insertion of bare and thin film metallic glass (TFMG) coated needles was used to measure the fracture toughness of polyurethane rubber block and porcine skin. We found that the TFMG coating reduced the fracture toughness of polyurethane rubber block and porcine tissue by more than 10 % compared to a bare needle. In both testing materials, a reduction in the cutting and frictional force is observed for insertion of TFMG-coated needle. The reduced cutting and frictional force can be ascribed to the low coefficient of friction (COF) of TFMG measured by nano-scratch tests. In addition, compared with bare needle, the crack area created on polyurethane rubber and porcine tissue for insertion of TFMG-coated needle is noticeably reduced. The results imply that by employing TFMG coating on the medical needle is capable of reducing the trauma of human tissue.

2:30pm **D1-2-4 Biocompatibility and Antimicrobial Performance of a Durable Super-hydrophobic Surface Modified Stainless Steel*, Cheng-Wei Lin,*** Feng Chia University; Central Taiwan University of Science and Technology, Taiwan*; C Chou,* Taichung Veterans General Hospital; National Yang-Ming University, Taiwan*; C Chung,* Central Taiwan University of Science and Technology, Taiwan*; J He,* Feng Chia University, Taiwan

For orthodontic application, a durable super-hydrophobic surface has been developed on AISI 304 stainless steel by sandblasting, electrochemical treatment and fluorocarbon plasma polymerization (SEP). The hybrid surface possesses nano/micro coexisting structure and present super-hydrophobicity (water contact angle 154°) and good abrasion durability. In this study, the *in vitro* tests for cell compatibility and antimicrobial behavior were performed by using fibroblast cell culture and bacterial cell culture, respectively.

The results reveal that the obtained hybrid surface exhibit better cell proliferation in comparison with the bare AISI 304 stainless steel (SS). In the antimicrobial test, the SEP surface also exhibit a comparatively lower level of bacterial adhesion than SS. These results suggest that the hybrid SEP treated AISI 304 stainless steel present good cell compatibility and antimicrobial performance, which are essential for orthodontic application.

2:50pm **D1-2-5 Immobilization of Carboxylic Acid Groups on Polymeric Substrates by Plasma-enhanced Chemical Vapor or Atmospheric Pressure Plasma Deposition of Acetic Acid*, Wei-Yu Chen,*** *A Matthews,* University of Manchester, UK*; F Jones,* University of Sheffield, UK*; K Chen,* Tatung University, Taiwan

Low-pressure plasma-enhanced chemical vapor deposition (PECVD) is a process that activates the precursor in the plasma state to deposit films on the surface. Introducing carboxylic acid functional groups via PECVD has been widely applied in various applications, such as the enhancement of interfacial adhesion between fillers and matrices in composite materials, molecular grafting for biosensors and biocompatibility improvement. To develop a compatible surface for cell adhesion, polymeric substrates, poly (lactic-co-glycolic acid) (PLGA) and polyethylene terephthalate (PET), were modified by a low-pressure acetic acid plasma to improve surface hydrophilicity and biocompatibility. The acetic acid plasma deposited film maintained stability on a hydrophilic surface for long-term aging and possessed good biocompatibility. If the acetic acid film can be deposited by process using atmospheric pressure plasma (APP), a more rapid, economic and power-saving method can be achieved. In this study, a remote APP system using a bespoke Pyrex APP chamber was utilized to deposit acetic acid film onto the surfaces of polymeric substrates. The wettability, stability of hydrophilicity and surface elemental composition of the APP-deposited film will be reported and compared with that prepared via low-pressure acetic acid plasma.

3:10pm **D1-2-6 Coatings Deposition by RF Magnetron Sputtering of Loosely Packed Hydroxyapatite Powder Target*, Laurynas Lukosevicius,*** The University of Manchester, UK*; S Mráz, J Schneider,* RWTH Aachen University, Germany*; A Matthews,* The University of Manchester, UK

It is well known that hydroxyapatite (HA), which is the major mineral compound of bone tissue, promotes orthopedic implants osteointegration when applied in a mixture or composite material compound. HA target preparation can be difficult and target cracking can occur. Therefore, many different target preparation techniques such as sintering, mixing HA with additional materials, HA plasma spraying copper discs prior the deposition or directly sputtering from the powder have been employed during previous research. Also, the deposition of HA is complicated due to the target and grown film decomposition as well as low bonding strength of the coating to the substrate.

In this study, amorphous HA coatings were deposited on Titanium, Magnesium and Silicon substrates from three different loosely packed powder target electrodes arrangements by radio frequency magnetron sputtering in an argon environment pressure of 5–50 mTorr and magnetron power of 30-381 W (1.5-6 W/cm^{2}). Deposition from solid and powder target materials has been evaluated and compared. Furthermore, the influence of the deposition parameters on the coating phase and elemental composition has been investigated.

The Ca/P ratio has been evaluated by means of EDS and XPS. FTIR and Raman analysis revealed that deposited coatings contain a typical calcium phosphate structure. The analysis showed that coatings of a multiphasic mixture containing HA, TCP, pyrophosphate and CaO have been formed.

Furthermore, pyrophosphate was the major compound of the coating deposited at 50 mTorr process pressure. Heat treatment of the HA and titanium composites at 550 °C in air medium led to the crystallization of the coating.

3:30pm **D1-2-7 Advanced Medical Biosensing Systems with Soft/Stretchable Materials and Assemblies***, J Rogers,* ***Roozbeh Ghaffari,*** Northwestern University, USA **INVITED**

Unusual classes of electronics and electrochemical sensors enabled by recent advances in materials science and mechanics have been designed with 'skin-like' physical properties. These systems are highly conformal and wearable by virtue of their soft mechanics compared to conventional packaged electronics and sensors. In this talk, we present an overview of recent advances in novel materials, mechanics and designs for emerging classes of fully-integrated soft bio-electronics. These devices incorporate microfluidics and microfabricated arrays of sensors configured in ultrathin, stretchable formats for monitoring of hydration and (electro-)physiology. Quantitative analyses of strain distributions and electronics performances under mechanical stress highlight the utility of these advanced medical systems in the clinical and remote environments. We will conclude with representative examples of epidermal systems being tested in clinical studies and sports field trials.

4:10pm **D1-2-9 Cyclic Voltammetry Study of Electrolytic Plasma Processing of Porous Ti***, M Shbeh,* University of Sheffield, UK*;* ***Aleksey Yerokhin,*** University of Manchester, UK*; R Goodall,* University of Sheffield, UK

Titanium is one of the most commonly used materials for biomedical applications. However, there are two issues associated with the use of it, namely its bio-inertness and high elastic modulus compared to the elastic modulus of the natural bone. Both of these hurdles could potentially be overcome by introducing a number of pores in the structure of the Ti implant to match the properties of the bone as well as improve the mechanical integration between the bone and implant, and subsequently coating it with a biologically active ceramic coating to promote chemical integration. This study has investigated the utility of cyclic voltammetry to understand processes that occur during electrolytic plasma surface treatments of porous Ti parts with different amounts of porosity produced by Metal Injection Moulding. Anodic behaviour of the porous Ti substrates was studied in aqueous solutions of disodium hydrogen phosphate in the voltage range 0 to 500 V. The shapes of the cyclic voltammograms for the relatively dense samples were relatively steady and not sensitive to the change in the scan rate, with more distinctive peaks indicating occurrence of complex multi-electron transfer processes observed. In contrast, for more porous samples the voltammogramms had hump-shaped start and less distinctive peaks. The treatment of porous samples with higher porosity and open pores resulted in much thicker surface oxide layers that penetrate through the inner structure of the samples forming a network of surface and subsurface coatings. The results are of potential benefit in producing surface engineered porous samples for biomedical applications which not only address the stress shielding problem, but also improve the chemical integration with the bone matrix.

4:30pm **D1-2-10 Corrosion and Degradation Behavior of dahp pre-treated PCL Composite Coatings on Pure Magnesium***,* ***Yuyun Yang,*** Institute for Corrosion Science and Surface Technology, China*; K Zheng,* Institute of Biomaterials, Germany*; G Jin, X Cui,* Institute for Corrosion Science and Surface Technology, China*; S Virtanen,* Institute for Surface Science and Corrosion, Germany*; A Boccaccini,* Institute of Biomaterials, Germany

Application demands for magnesium have increased dramatically recently due to its favorable mechanical properties. However, the poor corrosion resistance of magnesium under corrosive environment strongly impedes numerous applications, particularly in the biomedical field. Numerous efforts have been made to improve the anticorrosion property of magnesium, such as increasing purity level, modifying composition, and altering the microstructure by heat treatments. Surface modification has been proved to be an efficient and cost-effective approach in enhancing corrosion resistance and degradation behavior of magnesium. Polymeric coatings are attracting increasing attention because of their pronounced protective effect on magnesium matrix. Polycaprolactone (PCL) has been employed in a series of composite coating systems developed in our group to control the dissolution of magnesium. However, the main weakness of polymeric coatings is the unsatisfied adhesion to the bulk matrix. Therefore, pretreatment of magnesium is required to enhance the interaction between the magnesium matrix and polymeric coatings. Di-ammonium hydrogen phosphate (DAHP) is commonly used to synthesis hydroxyapatite in the hydrothermal method as an essential compound. In this study, DAHP was used to pre-treat magnesium under hydrothermal condition prior to PCL coating for enhancing the adhesion. It is also expected that DAHP pretreatment would facilitate the phosphate deposition and induce hydroxyapatite formation in further. In addition, nanoscaled bioactive glass particles (BGN) that were synthesized by a modified Stöber method were incorporated in the PCL coating to improve biological activities of the coated magnesium. The results showed that DAHP/PCL composite coatings offer magnesium significant protection against corrosion in comparison to the DAHP pre-coating and PCL composite coating. The DAHP/PCL composite coating shows great potential in improving corrosion resistance of magensium for biomedical applications.

Author Index

Bold page numbers indicate presenter