Coatings for Biomedical and Healthcare Applications
Room California - Session D1-1

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

10:00am **D1-1-1 Highly Porous Scaffolds on TNZT Alloys for Bone Implant Applications***, **Samir Aouadi**, E Blackert, S Murguia, M Kramer, S Bakkar, M Young,* University of North Texas, USA

TNZT alloys with compositions of Ti-35Nb-7Zr-5Ta are materials that are more biocompatible than the more widely used Ti-6Al-4V alloy since each of its constituent elements is biocompatible. In addition, it has the lowest Young's modulus of all the titanium-based alloys created so far (50-60 GPa). This property allows for a greater transfer of functional loads, which ultimately leads to bone growth stimulation. TNZT alloys were produced by arc melting of pure elements and were forged into rods. Oxide nano-scaffolds were grown on TNZT using the hydrothermal method to investgate the potential of these nanostructured surfaces to improve osseointegration. The alloys with and without nano-scaffolds were characterized using top-view and cross-sectional scanning electron microscopy equipped with an energy dispersive x-ray spetrometer to investigate the structure, morphology and chemistry of the resulting nanostructures. Finally, the formation of hydroxyapatitite on the modified surfaces was investigated upon immersion in simulated body fluid (SBF).

10:20am **D1-1-2 Improving Cellular Proliferation on the Ti-6Al-4V Alloy by the Formation of Crystalline Nanotubes of Titanium Oxide***, **ItzelPamela Torres-Avila**,* Instituto Politecnico Nacional-Upibi, Mexico*; E Hernández-Sánchez, J Castrejón-Flores,* Instituto politécnico Nacional-UPIBI, Mexico*; J Velazqez,* Instituto Politécnico Nacional-ESIQIE, Mexico*; R Carrera-Espinoza,* Universidad de las Américas Puebla, Mexico*; U Figueroa-López,* Tecnologico de Monterrey, Campus Estado de México, Mexico

This work is about the formation of crystalline nanotubes of titanium oxide at the surface of the Ti-6Al-4V alloy and the evaluation of their effect on the cellular proliferation. The formation of nanotubes was performed by the anodic oxidation technique. The work potential was established in 60 V. The anodizing process was performed at times of 10, 20, 30, 40 50 and 60 min, in order to evaluate the effect of treatment time on the characteristics of the nanotubes and thus, on the cellular proliferation. A mixture of ethylene glycol, water and ammonium fluoride was used as electrolytic fluid. Scanning electron microscopy (SEM) and X ray diffraction (XRD) were applied to determine the morphology and the crystalline nature of the nanotubes. SEM examination showed a well-defined matrix of nanotubes of titanium oxide with crystalline structure and diameter in the range of 60 to 80 nm. The XRD patterns showed more and more defined picks as the treatment time was increased. The results also revealed a clear influence of the treatment time on the structure of the titanium oxide nanotubes, especially on the adherence to the substrate, where the best adherence was observed with 60 min of treatment. The cellular assays showed that the cells attach to the nanotubes and proliferated.

10:40am **D1-1-3 Effects of Nb and Ti on the Corrosion and Biocompatibility Behavior of Zr-based and Fe-based Thin Film Metallic Glasses***, **Jhong-Bo Wang**, Y Yang,* National Taipei University of Technology, Taiwan*; J Lee,* Ming Chi University of Technology, Taiwan

Recently, thin film metallic glasses (TFMGs) have drawn lots of attention from researchers due to their potential applications in the biomedical fields. In this work, a series of Zr-based and Fe-based TFMGs were prepared by a pulsed DC and RF magnetron co-sputtering system. TFMGs were deposited on 316L stainless steel and P-type (100) Si wafers. For the Zr-based and Fe-based TFMG, Nb and Ti elements were added, respectively. The amorphous structures of coatings were determined by a glancing angle X-ray diffractometer. The surface and cross sectional morphologies of thin films were examined by a scanning electron microscopy (SEM). The surface roughness of thin films was explored by an atomic force microscopy (AFM). A nanoindenter, HRC-DB adhesion test were used to evaluate the hardness and adhesion properties of thin films, respectively. The bio-corrosion properties were tested by an electrochemical polarization measurements. The biocompatibility of TFMGs was examined using MG63 cell and the MTS assay. Effects of Nb and Ti addition on the corrosion resistance and biocompatibility behavior of TFMGs were discussed.

11:00am **D1-1-4 Tribological Behavior of Nanotubes Grown on Ti-35Nb Alloy by Anodization***, A Luz,* UFPR, Brazil*; **Carlos Lepienski**,* Universidade Tecnológica Federal do Paraná, Brazil*; C Siqueira,* Universidade Federal do Paraná, Brazil*; G Souza,* Universidade Estadual de Ponta Grossa, Brazil*; N Kuromoto,* Universidade Federal do Paraná, Brazil

β-type titanium alloys have been proposed to replace the Ti–6Al–4V alloy due to the V and Al toxicity for long term use. Such β alloys with Nb, Mo, Zr, Sn or Ta additions are considered nontoxic, presenting lower elastic modulus than other conventional biomaterials. However, the tribological behavior of Ti and its alloys are unsatisfactory, featured by high wear rates and friction coefficients that limit applications in the biomedical area. Surface treatments can be employed to improve the surface properties while maintaining the bulk properties. Nanotubes can be produced through anodization, composed of oxides with elements from the substrate, such as TiO_2. Structure and morphology of nanotubes grown on Ti and its alloys can improve the surface biocompatibility, wettability and corrosion resistance as compared to untreated materials. However, there are few studies on the tribological properties of these films. The purpose of this study was to investigate the friction coefficient and wear rate of nanotubes grown on Ti-35Nb alloy, using a linear reciprocating tribometer. Results were compared with Ti and polished Ti-35Nb alloy. Hardness and elastic modulus of the substrates were measured through instrumented indentation. The produced coatings were also characterized by X-ray diffraction, scanning electron microscopy and metallographic analysis with optical microscopy. Nanotube layers were grown in an electrolyte containing 1 M H_3PO4 + 0.8 wt.% NH_4F, at 20 V for 160 minutes. The nanotubes were annealed at 530 ºC for 3 h. The Ti-35Nb alloy comprises α and β phases. The Ti-35Nb alloy presented higher hardness (3.7 GPa) and lower elastic modulus (96 GPa) than the pure Ti, a consequence of the β phase-containing microstructure. The nanotubes exhibited random diameters and approximately 2 µm thick. The crystal structure of the nanotube layers was a mixture of TiO_2 and Nb_2O_5 oxides. Friction coefficient of the nanotube layers was in the 1.0-1.1 range, lower than that of the polished Ti-35Nb (1.3) and the Ti surfaces. Likewise, wear rate of these coatings was $(0.06 \pm 0.01).10^{-3}$ $mm^3/N.m$, which was much lower than the value obtained for Ti-35Nb alloy $[(1.66 \pm 0.13).10^{-3}$ $mm^3/N.m]$. The wear mechanisms were adhesive and abrasive on Ti and Ti-35Nb alloy. However, the surface coated by the nanotube layers disclosed nor adhesive neither abrasive characteristics, in contrast to the reference surfaces. The low wear rates suggested a good adhesion between layer and substrate.

11:20am **D1-1-5 Designing Hydrogels to Enhance Biomedical Implant Performance***, **Stephanie Bryant**,* University of Colorado, Boulder, USA, United States of America **INVITED**

The foreign body response (FBR) occurs ubiquitously to nearly all implanted non-biological materials and is characterized by fibrous encapsulation. The primary orchestrators of the FBR are macrophages, but efforts to control macrophage phenotype and subsequently the FBR have been challenging. This observation is in part due to the fact that macrophages have highly disparate functions ranging from inflammation to wound healing. It is well accepted that macrophages sense a biomaterial through the adsorbed proteins, but the nature by which adsorbed proteins mediate macrophage phenotype and ultimately the FBR remains poorly understood. While traditional efforts focused on creating 'bioinert' biomaterials as a means to prevent protein adsorption, recent evidence demonstrates that even hydrophilic materials readily adsorb proteins and elicit a FBR. This has led to a shift from 'bioinert' to 'bioactive' materials as means to control macrophages and subsequently the FBR. To this end, our group designs synthetic-based hydrogels to which bioactive molecules (e.g., extracellular matrix (ECM) analogs, small molecules, etc.) are introduced in a highly controllable and tunable manner to create tissue-like mimetic materials. We use poly(ethylene glycol) (PEG) hydrogels as the base structural component to control the bulk properties. Proteins, glycosaminoglycans, peptides, or other small molecules that are functionalized with polymerizable groups are then tethered into the PEG. Our group has characterized the FBR to PEG hydrogels, in the absence of any bioactive signals, and demonstrated through *in vitro* and *in vivo* experiments, a robust FBR with macrophage recruitment, macrophage activation, and the formation of a fibrous capsule. Incorporating bioactivity, as simply as, a cell adhesion peptide sequence, is sufficient to attenuate the response, but not abrogate the response. Using knockout mice models, we have identified that the initial inflammatory response mediates the long-term fibrotic response suggesting that targeting the early stages of the FBR may be critical to the long-term prevention of the FBR. In addition, we have identified that prostaglandin E2, a molecule that is secreted by stem cells to control inflammation, can significantly reduce the inflammatory macrophage phenotype and the associated FBR *in vivo*. Current efforts are focused on creating biomimetic and anti-inflammatory hydrogels as a means to dynamically control macrophage phenotype at an implant surface and improve the long-term performance of implantable biomaterials.

12:00pm **D1-1-7 Fabrication and Properties of Ca, P Containing Coating on Magnesium Alloy by Micro-arc Oxidation***, **Hui Tang**,* University of Electronic Science and Technology of China, China

As a novel metallic bio-absorbable implant material, magnesium alloy has drawn tremendous interest recently. However, relatively poor corrosion resistance in an environment of physiological fluids restricts their broad applications. In this study, Ca, and P containing coating were prepared on the surface of AZ31 magnesium alloy by micro-arc oxidation. The morphologies, composition, wettability, mechanical properties and corrosion resistance of the coatings were investigated. The corrosion mechanism was studied by long-term immersion in Hank's solution. And the formation mechanism of hydroxyapatite in SBF solution was also studied by combining the ICP and SEM. The results demonstrate that the Ca, P coating could improve the corrosion resistance of magnesium alloy in Hank's solution, and increase the bioactive of the magnesium alloy. The morphologies, composition, wettability and corrosion resistance could be controlled by the composition of the electrolyte and power parameters.

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