Coatings for Biomedical and Healthcare Applications
Room Grand Exhibit Hall - Session DP

Symposium D Poster Session

DP-2 Bone-like Nano-hydroxyapatite Coating on Low-modulus Ti-5Nb-5Mo Alloy Using Hydrothermal and Post-heat Treatments*, H Hsu, S Wu, S Hsu,* Central Taiwan University of Science and Technology, Taiwan*; C Hsu,* Da-Yeh University, Taiwan*; **Wen-Fu Ho,*** National University of Kaohsiung, Taiwan

Titanium and its alloys have been widely used as biomaterials for orthopedic and dental implants because of their excellent biocompatibility and mechanical properties. However, they are considered to be bioinert, such that when they are inserted into the human body these implants cannot bond directly to the surrounding living bone. This study aimed to improve the bioactivity of a low-modulus Ti-5Nb-5Mo alloy with a hydroxyapatite (HA) surface coating using eggshells as a Ca source through hydrothermal reaction and heat treatment. The results showed that the whole alkali-treated alloy surface was covered with amorphous calcium phosphate nanoparticles after hydrothermal reaction at 200 °C for 48 h. When subsequently heat-treated at various temperatures (400, 500 or 600 °C) for 48 h, the surface coating of Ti-5Nb-5Mo alloy was transformed into crystalline rod-like HA nanoparticles. Also, heat treatment enhanced the adhesion between the HA coating and the Ti alloy substrate. Additionally, FTIR analysis confirmed the production of HA containing mixed AB-type carbonate substitutions. To evaluate bioactivity of the bone-like HA-coated Ti-5Nb-5Mo alloy, the capability of calcium phosphate apatite formation on the alloy surface was assessed by immersion in a simulated body fluid (SBF). Dune-like apatite layer was observed to densely deposit on the surface of HA-coated Ti alloy after 6 h of immersion in the SBF. Notably, the ability of Ti-5Nb-5Mo alloy subjected to sequential process with alkali, hydrothermal, and heat treatments to form bone-like HA nanoparticle coating was obviously greater than that of its counterpart without HA coating.

DP-3 Niobium Oxide Scaffolds on Nb and on TNZT for use in Bone Implants*, **Madelyn Kramer,*** University of North Texas, USA*; E Leveque,* University of Rouen, France*; J Barclay, S Aouadi, M Young,* University of North Texas, USA

In this study, a TNZT alloy composed of Ti-35Nb-7Zr-5Ta in at.% and pure niobium were comparatively tested for their ability to grow nano-scaffolds on the surface for biomedical applications such as implant devices. The TNZT alloy was made by vacuum arc melting; and then rolled into a plate where it was subsequently sectioned and cut. The TNZT and niobium samples were polished flat, ultrasonically cleaned, and underwent hydrothermal treatments to grow nano-scaffolds of oxides on the surface. The TNZT and niobium produced Nb_2O_5 nano-scaffolds from a hydrothermal reaction in varying alkaline solutions: KOH at 170°C and NaOH at 60°C. Oxide scaffolding was also created when samples were annealed in air at 900°C for 2 hours. The TNZT and niobium nano-scaffolds were characterized by scanning electron microscopy (SEM). The nano-scaffolds will be characterized by X-ray diffraction (XRD) and Raman spectroscopy and will be further examined in simulated body fluid to further assess their biocompatibility.

DP-6 Muti-functional Porous TaOxNy Film Deposited on Ta/TaN-Ag Layers Prepared by Co-sputtering and De-alloying Approach*, J Hsieh, **ChungChieh Hsu**, Y Lin,* Ming Chi University of Technology, Taiwan

The oxynitride of a transition metal is able to form a new grade of functional thin film. In this study, TaOxNy-Cu films were first prepared using reactive co-sputtering, with the variation of O/N flow ratios. After deposition, the films were annealed, and Cu was etched away to form porous oxynitride structures with various O/N ratio. These porous films were then built on Ta/TaN-Ag layers, in order to induce antibacterial behavior and improve biocompatibility. The films were characterized using nano-indentation, XRD, and SEM. The results showed that the porosity of these films could be varied depending on Cu contents and O/N ratios. The samples were then tested for their biocompatibility and viability using MG-63 cells, and for the antibacterial efficiency against E. coli. According to the results obtained from biocompatibility and MTT assay testing, it was found that the pore size (or roughness) played a major role in terms of biocompatibility and cell viability. The antibacterial efficiency depends on the temperature and time of the second rapid thermal annealing.

DP-7 Increased Ag+ Dissolution Rate of TaN-Ag Nanocomposite Thin Films by Air Atmospheric Pressure Plasma Jet*, J Hsieh, **Yi-Zheng Yang**, C Lin,* Ming Chi University of Technology, Taiwan

The present study was aimed at activating nano-sized Ag particles emerged on TaN-Ag thin films by air atmospheric pressure plasma jet (APPJ). It was proved that the dissolution rate of Ag NPs could be accelerated, and bactericidal efficiency could be enhanced. In the experiment, TaN-Ag thin films were prepared by reactive co-sputtering, followed by rapid thermal annealing. The annealed films were then treated in either dry or wet (immersed in buffer solution) environments by APPJ. It is found, after activation, the dissolution rate of Ag ions could be increased significantly. Hence the antibacterial efficiency was increased tremendously.

DP-8 Tribocorrosion Behaviour of DLC-Coated Ti-6Al-4V Alloy Deposited by PIID and PEMS+PIID Techniques for Biomedical Applications*, **Andre Hatem,*** Pontifícia Universidade Católica do Paraná, Brazil*; J Lin, R Wei,* Southwest Research Institute, USA*; R Torres, C Laurindo, P Soares,* Pontifícia Universidade Católica do Paraná, Brazil

One of the main drawbacks observed from the usage of titanium alloys implants is premature failure due to excessive wear and corrosion. These often lead to a total revision arthroplasty and also may expose human body to noxious elements if they are present in the implant alloy composition. Recently, new deposition techniques and coating compositions have been emerged targeting higher mechanical, microstructural and tribocorrosion properties on the implant surfaces. Diamond-like carbon (DLC) appears as a considerable coating option in this case, since it has an amorphous structure chemically inert composed by two types of carbon hybridizations (sp^2 and sp^3) that provides an extreme hardness, low friction coefficient, biocompatibility and still is a solid lubricant. The tribocorrosion behaviour of DLC films are influenced by the fraction between sp^2 and sp^3 bonds contained in the coating microstructure. Nonetheless, not only the bonds fraction affects this behaviour, but also the adhesion between coating and substrate to avoid its detachment, which in turn is strongly related to the applied deposition technique. Moreover, carbide and nitride interlayers are often deposited over substrate to favoring the DLC coatings adhesion. Among the advanced DLC deposition techniques are the plasma immersion ion deposition (PIID) and the plasma enhanced magnetron sputtering (PEMS). Both are examples of the plasma enhancement during film vapor depositions that results in coatings with higher density and adhesion when compared to other conventional techniques. This work aims to investigate the tribocorrosion behaviour of DLC coatings with distinct carbide and nitride interlayers, obtained by PIID only and PEMS+PIID hybrid techniques, applied on Ti-6Al-4V alloy samples for biomedical applications. The tribocorrosion tests were performed under phosphate-buffered saline (PBS) solution on the DLC-coated samples and compared to a Ti-6Al-4V bare alloy sample. Besides tribocorrosion tests, it were performed X-ray diffraction (XRD) analysis, Raman spectroscopy, scanning electron microscopy (SEM), nanoindentation hardness and scratch tests to evaluate the microstructure, morphology, mechanical properties and adhesion of the DLC-coated samples. The tribocorrosion tests demonstrated that the applied deposition techniques and interlayers compositions affect not only the adhesion but also the main wear mechanism, which implies in significant wear rate disparities between the DLC-coated samples. Nevertheless, the results show that DLC coatings deposited by the plasma enhanced techniques could be promissory to improve tribocorrosion behaviour in Ti-6Al-4V alloy implants.

DP-9 Fluorine-Incorporated Hydrogen-free Amorphous Carbon Thin Film for Artificial Heart (Ventricular Assist Device)*, **Shunto Maegawa,*** Keio University, Japan*; T Hasebe,* Tokai university, Japan*; M Nakayama, K Bito, Y Yamato,* Keio University, Japan*; T Mine, T Matsumoto,* Tokai university, Japan*; A Hotta, T Suzuki,* Keio University, Japan

Advanced blood-contacting medical devices has been more intensive for reducing the mortality rate of cardiovascular diseases. Surface coating is one interesting method of improving the mechanical, physical and biocompatible properties of devices in direct contact with blood and tissue. Fluorine-incorporated hydrogenated amorphous carbon (a-C:H:F) has received much attention as a coating material because of outstanding blood compatible properties which suppress fatal failure of the devices. However, mechanical strength of a-C:H:F film is too low to apply for mechanical medical devices such as blood pump of ventricular assist device (VAD). Thus, fluorine-incorporated hydrogen-free amorphous carbon (a-C:F) films were newly synthesized with vacuum arc deposition method focused on both blood compatibility of a-C:H:F and excellent mechanical properties of hydrogen free tetrahedral amorphous carbon (ta-C). In this study, we evaluated the possible medical applications of new a-C:F films for frictional parts of blood pump in VAD.

The ta-C (control) and a-C:F films were deposited by filtered cathodic vacuum arc (FCVA) method using a graphite target and introducing C_3F_8 gas into the chamber. We synthesized these films by varying the pressure of C_3F_8 gas to control fluorine content in the films. The fluorine content of the film surfaces was measured by X-ray photoelectron spectroscopy. Carbon bonding structure was analyzed with Raman spectroscopy. Blood compatibility was evaluated by human platelets adsorption tests, and ball-on-disc tests were used to measure friction coefficient (f) for evaluating wear resistant properties. Finally, we applied a-C:F film on blood pump of ventricular assist device.

The fluorine content rate increased from 10 to 50 at.% with increase of C_3F_8 gas pressure. The shift of G peak position in the Raman spectra became lower with increase of fluorine content, and no peaks was identified at 50 at.% fluorine content as usual in a polymer-like film. The a-C:F films containing fluorine content reduced platelets adhesion than ta-C films. On the other hands, much fluorine doping in ta-C simultaneously degrade wear resistant ability. However, friction coefficient of a-C:F films with fluorine content of 10 and 30 at.% (f = 0.121, 0.138, respectively) were greater than or equal to ta-C (f = 0.138). We applied 10 at.% a-C:F on frictional parts of VAD, and consequently improved driving of VAD without frictional wear.

In conclusion, the fluorine-incorporated hydrogen-free amorphous carbon (a-C:F), which we newly developed by using FCVA method, is a promising candidate for frictional parts of blood-contacting medical devices.

DP-10 A Sustainability Investigation on the Hemocompatibility of Heparin/Dopamine and Heparin/Collagen Self-Assembled Multilayers Coated on a Titanium Substrate*, W Cherng,* Chang Gung Memorial Hospital, Taiwan*; **Chau-Chang Chou**, Y Pan,* National Taiwan Ocean University, Taiwan*; C Yeh,* Chang Gung Memorial Hospital, Taiwan*; T Wu, Z Dong, J Ho,* National Taiwan Ocean University, Taiwan

This work used self-assembly technology to build a heparin/collagen and a heparin/dopamine multilayers on a titanium substrate. Both the coatings' hemocompatibility and adhesion were investigated. The substrate was commercial pure grade 2 titanium which was electropolished for 48h. The oxidation condition of the dopamine interlayer was achieved by being treated treating in a 2 mg/ml dopamine solution under an atmospheric environment for 8 h. After the pretreatment, the samples were immersed in a poly-L-lysine solution for 30 minutes. Then they were alternatively dipped in a heparin and a collagen solutions for 30 minutes . On the other hand, in a heparin and a dopamine solutions to for 30 or 60 minutes until the desired number of layers were achieved. The hydrophilicity, chemical composition, and surface topography of the films were investigated by water contact angle measurement, Fourier transform infrared spectroscopy, and scanning electron microscopy. The film thickness was evaluated by the cross-sectional technique of a focused ion beam microscopy. The amount of the heparin that attached to the samples was measured by toluidine blue O test. The hemocompatibility was verified by the hemolysis ratio, platelet coverage area, and activated partial thromboplastin time (APTT) in vitro. The adhesion of the multilayers was studied by conducting micro-scratch tests. To investigate the performance under dynamic fluid contact, an orbital shaker was implemented. At dynamic environment state, the heparin quantity which was derived by the toluidine blue O test and APTT were assessed after dynamic test. Experiment results show that, the blood compatibility of heparin/dopamine sample is not superior than heparin/collagen one. Moreover, heparin/dopamine multilayers have stronger binding between multilayers and the substrate while not be capable of improving blood compatibility of titanium substrate. However, the extend of coating time are not conducive for the improvement of the related performance. After the dynamic tests, basing on the comparison of residual heparin content, dopamine is capable of resisting physiological fluid shearing stress, but the capability of anticoagulation are no more significantly enhanced from the original Ti substrate, which is worthy of more extensive investigation in the future.

DP-11 Wear Characteristics of Total Ankle Joint Prosthesis with Their Surface Roughness*, Y Jeong, **Jae-Woong Yang**, K Park, S Lee, T Jung,* Osong Medical Innovation Foundation, Republic of Korea

The ankle joint consists of the tibia and fibula above, and the talus below. In the disabling conditions, total ankle replacement (TAR) is becoming an alternative to arthrodesis, i.e. fusion of the tibio-talar articulation, which implies long immobilization, loss of function, and a variable rate of success. This short comings of ankle fusion have led to the development of numerous ankle joint replacements. The conventional type of prosthesis is the three component prosthesis, have a free gliding core and give multi-axial motion, which designs the upper articulation allows for gliding and rotation and the lower articulation allows for flexion/extension. In spite of the increasing interest in TAR, the high failure rate associated with wear of the PE component that has related with their material property and surface roughness. The aim of this study was to verify the wear characteristics of total ankle joint prosthesis with their surface roughness.

The wear specimen of total ankle joint prosthesis was prepared with Ti-6Al-4V alloy and UHMWPE (ultra-high molecular weight polyethylene) for tibia-talus and bearing component, respectively. A wear test was carried out using a Force 5 (AMTI, Massachusetts, US) wear simulator which can be allowed to move in three axis to flexion-extension, internal-external axial rotation, as well as sinusoidal compressive load. All tests were performed following standard ISO 14243, wear rate was calculated with weight loss of UHMWPE bearing while the specimen has tested at certain cycles. The surface roughness by wear simulation cycles was measured using a SJ-411 surface roughness tester (Mitutoyo, Yokohama, Japan).

As based on the preliminary results, wear rate of UHMWPE bearing was 7.9 $\times 10^{-6}$ mg/cycles. The surface roughness (Ra) of tibia-talus increased (0.05 to 0.1) with accumulation of simulation cycles while that of bearing component decreased (1.0 to 0.65).

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Keywords: Total Ankle Joint Prosthesis, Wear, Simulation, Surface Roughness, Biomaterials

DP-12 2D Materials for Bioelectronic Sensing*, W Lai,* University of Dayton/Sensors Directorate, Air Force Research Laboratory, USA*; A Stroud,* Institute for Micromanufacturing/Physics Program, Louisiana Tech University, USA*; R Berry,* Materials and Manufacturing Directorate, Air Force Research Laboratory, USA*; P DeRosa,* Institute for Micromanufacturing/Physics Program, Louisiana Tech University, USA*; R Naik,* Human Effectiveness Directorate, Air Force Research Laboratory, USA*; **Christopher Muratore**,* University of Dayton, USA

Detection of compounds in liquids (such as sweat or saliva) and vapors (such as air in a workplace, a packaged food container, or the cockpit of a fighter jet) has broad reaching applications in industry, home, and battlefield. Analytical devices such as mass spectrometers or gas chromatographs can be used in these applications but they lack portability and the ability to operate continuously yet unobtrusively. Flexible sensor materials could be wearable or otherwise easily integrated into any of the environments suggested above. Mono- and few-layer TMDs are known to demonstrate extreme mechanical flexibility, accommodating up to 10% strain prior to rupture. In addition to convenient form factors afforded by their flexible nature, the high surface to volume ratio of ultrathin semiconducting materials allows detection of very low concentrations of adsorbed molecules via a measurable alteration of their electrical response (e.g., their current-voltage (IV) curve) as if they are "doped" by the presence of surface adsorbates. While the effects on adsorbate-surface relationships in graphene could be understood in context of decades of studies of p-based interactions dictating nanomaterial behavior, 2D TMD interactions are based on d-electron interactions and therefore respond much differently than carbon-based low-dimensional structures to adsorption events and other interactions with molecules. Non-covalent bonding on 2D TMD is only understood qualitatively. Measuring the response in materials with controlled densities of defects introducing localized metallic-like regions of exposed Mo plane-edge atoms and changing the 2D MoS_2 electronic band diagram systematically as predicted by simulations.will provide insight on charge transfer or redistribution in analyte-functional molecule-2D semiconductor interactions. We have demonstrated attachment of a binding peptide to a functional MoS_2 transistor, and observe a significant response in the I-V characteristic curve. Sensitivity to adsorbed molecules for semiconducting 2D TMDs such as MoS_2 is approximately two orders of magnitude higher than graphene based on the predicted minimum subthreshold swing (SS), defined as the inverse of the slope of a transistor IV curve in its steepest part (for a field effect transistor (FET), $SS=d(V_{gate\text{-}source})/d(I_{drain})$. Smaller values of SS suggest higher sensitivity as a small change in surface potential gives rise to a significant change in current, thus enhancing sensitivity. For 2D MoS_2, the SS is around 60 mV/decade in contrast to 1000-5000 mV/decade minimum for graphene, suggesting >100 X higher sensitivity for TMD-based 2D sensors in comparison to graphene.

DP-13 Study of TiO_2-MgO Composites to Improve the Corrosion Resistance of Mg for Development of Biodegradable Orthopedic Implants*,* ***EricNoé Hernández-Rodríguez****, C Vicencio-Acosta, C Íñiguez-Contreras, A Balvantín-García, J Diosdado-de la Peña,* DICIS, University of Guanajuato, Mexico*; R Mis-Fernández, J Peña-Chapa,* CINVESTAV-IPN Mérida, Mexico*; M Zapata-Torres,* CICATA-IPN Legaria, Mexico*; A Márquez-Herrera,* DICIVA, University of Guanajuato, Mexico

In this work we report the study of TiO_2-MgO composites as anticorrosive coatings on Mg substrates. Mg has been extensively studied in order to develop biodegradable implants, however, the fast degradation in the physiological fluid is its main disadvantage. Here, we propose the use of the biocompatible TiO2-MgO composite as a protective coating in order to modulate the corrosion resistance of Mg pieces. TiO_2-MgO composites were deposited on Mg substrates by the RF-sputtering technique, and the TiO_2/MgO ratio was changed through the sputtering power. XRD analysis showed that coatings with a high content of MgO present a cubic crystalline structure, while a decrease on the crystallinity was found as the TiO2 content is increased; finally, coatings with the highest content of TiO_2 are amorphous. XPS analysis showed the formation of Ti-O, Mg-O and Ti-Mg-O bonds; the rate between this bonds is related to the resistance against corrosion of the samples. Corrosion experiments were conducted by using the Hank´s solution as the corrosive media and Tafel curves were obtained by employing a potentiostat in the three electrode configuration. Values of corrosion current (i_{corr}) demonstrate that it is possible to improve the corrosion resistance of Mg by employing the TiO_2-MgO composite; even more, the TiO_2/MgO rate on the coatings permits to modulate the corrosion resistance, with the lowest resistance when the coating is only composed by MgO, and the highest resistance when only the TiO_2 is present.

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DP-15 Fabrication and Characterization of Magnesium Incorporated Hydroxyapatite on the Titanium Substrates via Electrochemical Deposition*, Y Chor,* National Taipei University of Technology, Taiwan*;* ***Chien-Ming Lei****,* Chinese Culture University, Taiwan*; S Chen, K Huang, P Chen,* National Taipei University of Technology, Taiwan

Titanium and its alloys have been widely used for biomedical implant due to their desirable mechanical properties, corrosion resistance, and excellent biocompatibility. However, titanium and its alloys have an issue of their insufficient bioactivity. Recently, studies have shown that hydroxyapatite coated metal surface can improve both biocompatibility and bioactivity.

Hydroxyapatite is the major composition in tooth and bone. Compared to synthetic hydroxyapatite, natural bones have various trace elements which play important roles for cell growth. Magnesium incorporated hydroxyapatite stimulate the proliferation of osteoblast during the early stage of implantation. It has a significant effect in bone metabolism. In this study, magnesium ion was added into the electrolyte which composed of P and Ca ions, and then MHA coatings on titanium substrate were prepared by electrochemical deposition. We carried out characterizations to identify the phase composition, the changes of surface morphology, surface roughness and corrosion resistance of coatings in the simulating body fluid. Results show that magnesium incorporated hydroxyapatite has higher surface roughness and corrosion current density. Moreover, the magnesium incorporated hydroxyapatite can induce nucleation and growth of the new apatite on the surface where $Ca_3(PO_4)_2$ precipitates can be found after immersion test. As a result, the magnesium incorporated hydroxyapatite shows better biocompatibility and bioactivity.

DP-16 Electrochemical Characteristics of RF-sputtered Zn and Si Coatings on HA Coated Ti-6Al-4V by PEO Treatment*,* ***InJo Hwang****, H Choe,* Chosun University, Republic of Korea

Commercially pure titanium (cp-Ti) and Ti alloys (typically Ti-6Al-4V) display excellent corrosion resistance and biocompatibility. Ti and its alloys are not bioactive. Therefore, they do not chemically bond to the bone, whereas they physically bond with bone tissue. Their poor surface biocompatibility, the surface of Ti alloys has to be modified to improve the surface osteoinductivity. Among various surface modification methods, the electrochemical deposition process provides an effective surface for biocompatibility because large surface area can be served to cell proliferation. Plasma electrolyte oxidation (PEO) enables control in the chemical composition, porous structure, and thickness of the TiO_2 layer on Ti surface. In addition, previous studies have concluded that the presence of Ca^{+2} and PO_4^{3-} ion coating on porous TiO_2 surface induced adhesion strength between Hap and Ti surface during electrochemical deposition.

Radio frequency(RF) magnetron sputtering in the various PVD methods has high deposition rates, high-purity films, extremely high adhesion of films, and excellent uniform layers for depositing a wide range of materials, including metals, alloys and ceramics like a hydroxyapatite. The aim of this study is to research the Zn and Si ions coatings on the micro-pore formed Ti-6Al-4V alloys by RF-magnetron sputtering for dental applications.

Silicon (Si) in particular has been found to be essential for normal bone and cartilage growth and development. Zinc (Zn) plays very important roles in bone formation and immune system regulation, and is also the most abundant trace element in bone. The objective of this work was to study electrochemical characteristics of RF-sputtered Zn and Si coatings on HA coated Ti-6Al-4V by PEO treatment.

The coating process involves two steps: 1) formation of porous TiO_2 on Ti-6Al-4V at high potential. A pulsed DC power supply was employed. The sparking energy also will affect the size of micro pores and the ions concentrations. 2) Electrochemical tests were carried out using potentiodynamic and AC impedance methoeds. The morphology, the chemical composition, and the micro-structure analysis of the sample were examined using FESEM, EDS, and XRD. The enhancements of the Hap forming ability arise from Si/Zn-TiO_2 surface, which has formed the reduction of the Si/Zn ions. The promising results successfully demonstrate the immense potential of Si/Zn-TiO_2 coatings in dental and biomaterials applications (Supported by NRF: 2015H1C1A1035241 & NRF: No.2008-0062283 ; hcchoe@chosun.ac.kr).

DP-18 Nucleation and Growth of Bone-like Apatite Formation on Ti-6Al-4V in Solution Containing Mn, Mg, and Si Ions after Plasma Electrolytic Oxidation*,* ***SangGyu Lim****, H Choe,* Chosun University, Republic of Korea

Titanium and its alloys that have a good biocompatibility, corrosion resistance, and mechanical properties such as hardness and wear resistance are widely used in dental and orthopedic implant applications. They can directly connect to bone. However, they do not form a chemical bond with bone tissue . Plasma electrolytic oxidation (PEO) that combines the high voltage spark and electrochemical oxidation is a novel method to form ceramic coatings on light metals such as titanium and its alloys . This is an excellent reproducibility and economical, because the size and shape control of the nano-structure is relatively easy.Silicon (Si), m anganese (Mn), and magnesium (Mg) has a useful to bone. Particularly, Si has been found to be essential for normal bone, cartilage growth and development. Manganese influences regulation of bone remodeling because its low content in body is connected with the rise of the concentration of calcium, phosphates and phosphatase out of cells. Insufficience of Mn in human body is probably contributing cause of osteoporosis. Pre-studies have shown that Mg plays very important roles in essential for normal growth and metabolism of skeletal tissue in vertebrates and can be detected as minor constituents in teeth and bone.

The objective of this work was to study nucleation and growth of bone-like apatite formation on Ti-6Al-4V in solution containing Mn, Mg, and Si ions after plasma electrolytic oxidation. Anodized alloys was prepared at 270V~300V voltages. And bone-like apatite formation was carried out in SBF solution for 1, 3, 5, and 7 days. The morphologies of PEO-treated Ti-6Al-4V alloy in containing Mn, Mg, and Si ions were examined by FE-SEM, EDS, and XRD (Supported by NRF: 2015H1C1A1035241 & NRF: No.2008-0062283 ; hcchoe@chosun.ac.kr).

DP-19 Ion Release of Zn, Si, Mn-doped Hydroxyapatite Films Formed on the Ti-6Al-4V Alloy by Plasma Electrolytic Oxidation*,* ***MinGyu Park****, H Choe,* Chosun University, Republic of Korea

Titanium and its alloys have been used in the fields of orthopedics and dentistry due to their abilities to exhibit high specific strength, high corrosion resistance, and chemical inertness particularly in biological circumstances. Despite these attractive properties, their passive films were somewhat bioinert in nature so that sufficient adhesion of bone cells to implant surface was delayed after surgical treatment. Recently, the Plasma electrolyte oxidation (PEO) of titanium metal has attracted a great deal of attention.

Silicon (Si) in particular has been found to be essential for normal bone and cartilage growth and development. Zinc (Zn) plays very important roles in bone formation and immune system regulation, and is also the most abundant trace element in bone. Manganese(Mn) is important in terms of protein synthesis, the manganese is insufficient, the generation of cartilage synthesis of the organic matrix is low is delayed, thickness and length decreased abnormal bone generation is performed. Si, Zn, and Mn has a beneficial effect on bone.

The objective of this work was research on i on r elease of Zn, Si, Mn-doped h ydroxyapatite f ilms f ormed on the Ti-6Al-4V a lloy by p lasma e lectrolytic o xidation. Anodized alloys was prepared at 270V~300V voltage in the solution containig Zn, Si, and Mn i ons. Ion release test was carried out using potentidynamic and AC impedance method in 0.9% NaCl solution. The surface characteristics of PEO treated Ti-6Al-4V alloy were investigated using XRD, FE-SEM, AFM and EDS(Supported by NRF: 2015H1C1A1035241 & NRF: No.2008-0062283 ; hcchoe@chosun.ac.kr [mailto:hcchoe@chosun.ac.kr]).

DP-20 Nanotube Shape Changes on Ti-30Nb-xTa Alloys with Continuously Changed Potentials*, Han-Cheol Choe,* Chosun University, Republic of Korea

CP-Ti and its alloys have over the past few decades become the premier choice as biocompatible dental and hip replacement implant materials. Although the Ti-6Al-4V alloy is an acceptable prosthetic biomaterial, recent studies indicated that the release and accumulation of Al and V ions could have harmful effects on the human body. In order to overcome these disadvantages of Ti-6Al-4V alloy, new β type Ti alloy made of non-toxic alloying elements such as Nb, Ta and Zr have been developed. Surface modification is generally essential to improve the chemical bonding between Ti implant and bone tissues. Thus, it has been shown that nano-scale porous as well as tubular oxide layers on titanium alloys can increase the bioactivity of an implant material. Also, it should be possible to control the nanotube size and morphology for biomedical implant use by controlling the applied voltage, alloying element, current density, anodization time and electrolyte. The aim of this study was surface modification of nanotube formed Ti-30Nb-xTa alloys with changes in anodization factors. The Ti-30Nb-xTa alloys with Ta contents of 0, 15 wt. % were melted by using a vacuum arc-melting furnace and, homogenized for 12h at 1000℃. The anodization was performed by changing of applied voltage from high to low (30 V to 10 V) and, from low to high (10 V to 30 V) for 1h. The electrolyte was composed of 1 M H_3PO_4 + 0.8 wt.% NaF. This study was evaluated the phase of Ti-30Nb-xTa alloys using an x-ray diffractometer (XRD), and the microstructure of the samples was investigated with field emission scanning electron microscopy (FE-SEM) and optical microscope (OM). For biocompatibility, fibroblast cell was cultured and contact angle was measured. (NRF: No.2008-0062283; hcchoe@chosun.ac.kr).

DP-21 Shapes of Bone-like Apatite Formation on Sr and Si-doped Hydroxyapatite Surface of Ti-6Al-4V Alloy after Plasma Electrolytic Oxidation*, Ji-Min Yu,* *H Choe,* Chosun University, Republic of Korea

Metallic biomaterials have been mainly used for the fabrication of medical devices for the replacement of hard tissue such as artificial hip joints, bone plates, and dental implants. Because they are very reliable on the viewpoint of mechanical performance. This trend is expected to continue. Especially, Ti and Ti alloys are bio- inert. So, they do not chemically bond to the bone, whereas they physically bond with bone tissue. For t heir poor surface biocompatibility, the surface of Ti alloys has to be modified to improve the surface osteoinductivity. Recently, ceramic-like coatings on titanium, produced by plasma electrolytic oxidation (PEO), have been developed with calcium- and phosphorus-enriched surfaces. A lso included the influences of coatings, which can accelerate healing and cell integration, as well as improve tribological properties. However, the adhesions of these coatings to the Ti surface need to be improved for clinical use.

Particularly Silicon (Si) has been found to be essential for normal bone, cartilage growth and development. This hydroxyapatite, modified with the inclusion of small concentrations of silicon has been demonstrating to improve the osteoblast proliferation and the bone extracellular matrix production. Strontium-containing hydroxyapatite (Sr-HA) was designed as a filling material to improve the biocompatibility of bone cement. In vitro, the presence of strontium in the coating enhances osteoblast activity and differentiation, whereas it inhibits osteoclast production and proliferation.

The objective of this work was to study shapes of bone-like apatite formation on Sr and Si-doped hydroxyapatite surface of Ti-6Al-4V alloy after plasma electrolytic oxidation. Anodized alloys was prepared at 270V~300V voltages with various concentrations of Si and Sr ions. Bone-like apatite formation was carried out in SBF solution. The morphology of PEO, phase and composition of oxide surface of Ti-6Al-4V alloys were examined by FE-SEM, EDS, and XRD(Supported by NRF: 2015H1C1A1035241 & NRF: No.2008-0062283 ; hcchoe@chosun.ac.kr [mailto:hcchoe@chosun.ac.kr]).

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DP-22 Chemical Bonding Characteristics of Biocompatible TiO2 Oxide Multilayer by the XPS Depth Analysis*, Jae-Myung Jang,* GwangJu Nambu University, Republic of Korea*; T Park,* Eco-Tech Korea, Republic of Korea*; H Choe,* Chosun University, Republic of Korea

Most recently, to improve the biocompatibility, various processes that aim at coating an implant material with a bioactive nanoparticles such as synthetic hydroxyapatite have been proposed[1]. For this purpose, barrier and porous/tubular type of anodic oxide films could be formed by electrochemical anodization using a set of specific conditions including optimized potential, electrolyte composition, and temperature. Also, the chemical component of the electrolyte is essential in determining the type of morphology that is eventually formed, and the geometric morphology of TiO_2 oxide film is mutually important in direct contact with biological tissue in dental or surgical implants. In addition, the specific ions in the contact surface with the bone site plays a critical role in terms of adhesion and stability for long periods in the living body.

Thus, in this work, the manufacture of the TiO_2 barrier-type multilayerwas accurately performed in a mixed electrolyte containing HAp, Pd, and Ag nanoparticles. The temperature of the solution was kept at approximatively 32℃and was regularly rotated by a magnetic stirring rod in order to increase the ionic diffusion rate. The manufactured specimens were carefully analyzed by XPS depth profile to investigate the result ofchemical bonding behaviors. From the analysis of chemical states of the TiO_2 oxide multilayer using XPS, the peaks are showed with the typical signal of Ti oxide at 459.1 eV and 464.8 eV, due to Ti 2p(3/2) and Ti 2p(1/2), respectively. The Pd-3d peak was split into Pd-3d(5/2) and Pd-3d(3/2)peaks, and shows two bands at 334.7 and 339.9 eV for Pd-3d3 and Pd-3d5, respectively. Also, the peaks of Ag-3d have been investigated. The chemical states consisted of the O-*1s*, P-*2p,* and Ti-*2p* were identified in the forms of PO_4^{2-} andPO_4^{3-}. Based on the results of the chemical states, the chemical elements into the TiO_2 oxide multilayer were also inferred to be penetrated from the electrolyte during anodic process. The structure characterization of the modified surface were performed by using FE-SEM, and from the result of biological evaluation in simulated body fluid(SBF), the biocompatibility of TiO_2 oxide multilayer was effective for bioactive property(Supported by NRF: 2016R1D1A1B01016542 & NRF: No.2008-0062283 ; hcchoe@chosun.ac.kr)

DP-25 Corrosion and Antibacterial Properties of Micro-Arc Oxidized Biodegradable Mg-Sr Alloys for Biomedical Applications*, Mehmet Yazici,* Ondokuz Mayis University, Turkey*; E Gulec,* Gebze Technical University, Turkey*; M Gurbuz,* Ondokuz Mayis University, Turkey*; Y Gencer, M Tarakci,* Gebze Technical University, Turkey

Despite magnesium has some advantages over the present biomaterials it has some handicaps for orthopedic applications, such as high corrosion rate, mechanical properties [1, 2]. To improve the corrosion resistance of magnesium a ceramic layer was produced on the Mg alloys by micro-arc oxidation (MAO) method. To provide a better corrosion resistance Ag ions added antibacterial HA nano particles were added to the electrolyte in the range of 1-15 g/lt. The coated alloys were characterized by using scanning electron microscopy and X-ray diffractometer. Also immersion tests, corrosion tests and anti-bacterial tests were done to compare the coatings.

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