Coatings for Biomedical and Healthcare Applications
Room Golden State Ballroom - Session DP-ThP

Coatings for Biomedical and Healthcare Applications (Symposium D) Poster Session

DP-ThP-1 Antibacterial Properties of Ag Doped Tetrahedral Amorphous Carbon Coatings Synthesized Using Hybrid Filtered Cathodic Vacuum Arc and Magnetron Sputtering System*, **SangYul Lee**, K. Oh, J. Park,* Korea Aerospace University, Republic of Korea*; D. Kim, J. Kim,* KIMS, Republic of Korea

Tetrahedral amorphous carbon (ta-C) coating is a hydrogen-free carbon coating with the remarkable properties comparable with those of diamond film, such as high hardness, optical transparency and chemical inertness. In this study, as silver (Ag) is known to be a potent antibacterial agent, silver (Ag) doped ta-C coatings with different Ag concentrations were synthesized on the AISI 316Land Ti64 coupons using an hybrid filtered cathodic vacuum arc (FCVA) and magnetron sputtering system. The doping effects of Ag concentration in ta-C coatings on the bacteria biofilms formed on the surface of medical products were examined. Surface condition and its physicochemical properties were investigated using SEM, AFM and XPS and also studied was their antibiofilm efficacy against a multi-drug resistant nosocomial pathogen *Pseudomonas aeruginosa*. In addition the antibacterial activity of Ag doped ta-C was evaluated by bacterial eradication tests with *Escherichia coli (E. coli)* at different incubation times.The result revealed that the synthesized Ag doped ta-C coatings inhibited the biofilm formation of *P. aeruginosa*and the antibacterial activity against *E. coli*in a concentration-dependent manner. Hence, this study demonstrated the possible use of Ag doped ta-C coatingsagainst the biofilm-related infections out of *P. aeruginosa* and antibacterial activity against *E. coli.* Experimental details will be discussed.

DP-ThP-2 Adhesion, Corrosion Resistance, and Blood Compatibility of Mao- Pretreated Magnesium Alloy Coated with Graphene Oxide and Pyrolytic 1,8-Diaminooctane-Incorporated Oxidized Polydopamine*, **Chau-Chang Chou**, S. Chang, H. Lee,* National Taiwan Ocean University, Taiwan*; W. Chen,* Cheng Gung Memorial Hospital, Keelung, Taiwan

Surface treatment and functional coating can effectively reduce the degrading status and promote the blood compatibility of magnesium implants. This study applied micro-arc oxidation (MAO) treatment to improve the corrosion resistance of magnesium alloy. The electrolyte was prepared by using sodium silicate, sodium hydroxide, and sodium citrate. The MAO process was performed by adjusting voltage which was determined by observing the completeness of the ceramic films. Then, Layer-by-layer assembly technique was implemented by dipping the substrates with graphene oxide, oxidized polydopamine mixed with pyrolytic 1,8-diaminooctane sequentially to provide their corrosion resistance, adhesive strength, and anti-clotting capability. The composition of substrate was confirmed by inductively coupled plasma mass spectrometry. Microstructural morphologies and crystallography of the MAO coatings were characterized using X-ray diffraction. Optical microscopy was implemented to observe the topographies of coatings. The samples' surface transition was revealed by water contact angle. Their surface topographies and element were observed by scanning electron microscopy and energy-dispersive X-ray spectroscopy. The cross-sectional morphology and the film thickness were evaluated by dual-beam focused ion beam microscopy. The function groups contained in composite multilayers were examined by Fourier transform infrared spectroscopy. The degradation resistance was measured by corrosion polarization curve. The combination of the multilayers was investigated by conducting scratch tests.The hemocompatibility of composite films for original, 7 days, and 15 days were studied according to the activated partial thromboplastin time and the platelet adhesion experiment. The results indicated that the coatings with multilayers of graphene oxide, oxidized polydopamine mixed with pyrolytic 1,8-diaminooctane layers after micro-arc oxidation had the best adhesion strength, corrosion resistance, and anticoagulant ability which can sustain more than 7 days under theorbital shaking tests.

DP-ThP-3 Surface Alloying for Antibacterial Martensitic Stainless Steel Fabrication*, Z. Chen, B. Liu,* ***Wen-Ta Tsai,*** National Cheng Kung University (NCKU), Taiwan*; C. Huang,* Tung Mung Development Co., Ltd., Taiwan

Stainless steels (SSs) containing antibacterial elements, such as copper element, could be used as antibacterial structural materials. However, the traditional metallurgical processes for the fabrication of copper-containing SSs include melting, casting, rolling and many other steps, which are highly costive and inconvenient for final product manufacturing. Furthermore, for ferritic and martensitic stainless steels, the low copper solubility in these grades of stainless steels makes copper alloying more difficult. Therefore, this study aims to develop a novel method for preparing copper-containing martensitic SS (namely SS 440C) on its surface by incorporating electrochemical plating and thermal diffusion process.

Successful surface alloying of copper onto SS 440C surface was achieved with unique processes consisting proprietary copper electroplating and subsequent thermal diffusion treatment. It generally accepted that stainless steels (normally SS 304) containing 3 wt% copper exhibits effective antibacterial activity. The SEM images and the associated EDS results of the above treated samples reveal that a surface layer with copper concentration greater than 3 wt% and a thickness as high as tens of micrometer could be produced on SS 440C surface by employing the novel technique invented in this investigation, which meets the requirement for antibacterial applications. The effective antibacterial performance of the above mentioned product was confirmed by employing the standard test (JIS-Z2801) for antibacterial activity examination.

DP-ThP-4 Enhancing the Surface Properties of Polymethylmethacrylate (PMMA) by Functionalizing with Atomic Layer Deposited Titanium(Iv) Dioxide*, **Harshdeep Bhatia**, C. Takoudis,* University of Illinois, Chicago, USA

Polymethyl methacrylate (PMMA) is a widely used polymer in applications such as engineering structural plastics, energy storage materials, and biomaterials. However, its poor surface properties lead to fracture and deformation. Functionalization of the PMMA surface can make it more resistant to aggressive environments and prevent it from biodegradation, discoloration, and increased surface roughness. Here, atomic layer deposition (ALD) was used to deposit TiO_2 thin films from tetrakis(dimethylamido)titanium (TDMAT) and ozone on PMMA substrates to improve its surface properties without the need for plasma assistance or another interlayer. Spectroscopic ellipsometry was used for the first time to measure the metal oxide film thickness on thick PMMA substrates. Two different growth regimes were observed, one for initial and the other for later ALD cycles. Initially, the growth rate on PMMA was 1.39 Å/cycle, which is*3.5 times higher than that on stand-alone silicon (0.4 Å/cycle); this is attributed to cyclic chemical vapor deposition of TDMAT and moisture within PMMA concomitant with TiO_2 ALD from TDMAT and ozone. However, after the formation of about 30-nm-thick film on PMMA, the TiO2growth rate became similar to that on silicon. Moreover, our results revealed that the presence of PMMA in the deposition reactor affects the TiO_2 growth rate on silicon substrates as well. These findings are discussed and corroborated with residual gas analyzer and X-ray absorption near-edge structure data. The thermal stability of the PMMA samples was examined by thermogravimetric analysis. Chemical composition and surface roughness of coated PMMA were studied by X-ray photoelectron spectroscopy and optical profilometry, respectively. The TiO_2 coating increased wettability by ~ 70% and surface hardness by 60%

DP-ThP-5 Diffusion-Based Plasma Nitriding for Surgical Needle*, **Takao Yamauchi**, P. Abraha,* Meijo University, Japan

Surgical instruments require medical grade and biocompatible materials with good corrosion resistance and tensile strength. Austenitic stainless steels are appropriate materials that can provide a sharp edge for repetitive use in medical procedures. These surgical tools may be cutting and holding tools or closure and hemostatic tools such as suture needles.

This research aims to enhance suture needles for improved ease of use in the repetitive suturing of large incisions. The shape of the needle body and the sharpness of the needle tip determines the force acting on suture needles. Therefore, better ease of use in terms of a smaller resistance force, a smaller body diameter, and a sharper needle tip are preferable. However, as we reduce the body diameter and sharpen the needle tip, the needle strength tends to decrease, and bending of the needle tip and possibly the needle body occurs, resulting in a short useful life span. In this study, surgical suture needles are plasma nitrided to suppress the bending of the needle tip and body for applications in large incisions.

Currently, silicone-coated or metallic glass-coated modified surfaces are the available methods that enhance the durability of surgical tools. However, delamination of the coating while in use may cause an undesirable medical problem for the subject and compromise the sharpness of the needle tip. This study aims to determine the insertion-retraction characteristics of untreated, silicone-coated, and plasma-nitrided suture needles. The results of our experiments show the measured insertion-retraction characteristics curves of plasma nitrided suture needles were superior to those of the silicon-coated and untreated samples tested. Furthermore, since plasma nitriding is a diffusion process, the dimensional changes are minimal and no danger of delamination. The presentation will show the performance of plasma-nitrided stainless steel surgical suture needles.

DP-ThP-6 Development of TiO_2/Ag Multilayer Antibacterial Coatings Using Magnetron Sputtering Technique for Potential Applications in Non-Permanent Implants, ***Sebastián Rodríguez Maya**, M. Restrepo Posada, F. Bolívar Osorio, G. Bejarano Gaitán, J. Lenis Rodas,* Universidad de Antioquia, Colombia

The development of ideal surfaces to be used in metal implants and osseus stabilization devices require the consideration of different phenomena such as the formation of a bacterial biofilm on the surface followed by the usual appearance of infections or the total rejection of the device. On the other hand, the overgrowth of bone material around these devices constitutes a barrier when it comes to removing them when their function has been fulfilled. Due to this, the development of multilayer antibacterial coatings of TiO2/Ag on Ti6Al4V substrates by means of the Magnetron Sputtering technique for its potential use in non-permanent implants were studied. The coatings obtained using this technique exhibit a uniform and densely packed, columnar growth profile and it also offers significant control over the microstructural features. Consequently, the properties of the developed systems were characterized using scanning electron microscopy (SEM), X-ray diffraction (XRD), tribologic assays and surface properties such as rugosity and contact angle.

DP-ThP-8 Evaluation of Biocompatibility and Corrosion Resistance of Strontium-Calcium Phosphate Coated Magnesium by Electrodepositon, ***Jung-Eun Park**, J. Ji, Y. Kim, S. Byeon, M. Lee,* Chonbuk National University, Korea

This study aims to improve the initial corrosion and biocompatibility of biodegradable magnesium by coating the magnesium surface with calcium phosphate containing strontium by electrodeposition. In this study, calcium phosphate coatings doped with Sr of various concentrations were electrodeposited on the magnesium surface at an applied voltage of 4 V for 1 h. The corrosion behavior and biocompatibility of the modified magnesium surfaces were evaluated.

The surface of the magnesium coated with strontium-calcium phosphate showed a dense dendritic shape and became denser as the strontium content increased. strontium-calcium phosphate coated magnesium showed improved corrosion resistance and lower pH change than pure magnesium. In vitro strontium-calcium phosphate coated magnesium showed enhanced bioactivity. strontium-calcium phosphate coated magnesium showed excellent osteoblast proliferation and differentiation.

Therefore, the strontium-calcium phosphate developed in this study inhibited the initial corrosion of magnesium and effectively formed corrosion products and bioactive materials on the surface. In addition, excellent biocompatibility was confirmed.

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DP-ThP-9 Improvement in Corrosion Resistance and Biocompatibility of Biodegradable Mg Surface with Combination of Calcium Phosphate and Chitosan, ***Seo-young Kim**, Y. Jang, T. Bae, M. Lee,* Jeonbuk National University, Republic of Korea

Metallic implants for bone fixation have been used for healing a fractured bone. For success of implantation, the superior bearing capacity and biocompatibility is needed. Magnesium, which is biodegradable metal, has great mechanical properties than other biodegradable materials, and its biocompatibility can be improved by functional polymer or ceramic coating. in this study, Mg surface was modified with bio-ceramic (apatite) containing chitosan to improve its corrosion resistance and biocompatibility.

For coating, $chitosan_{(sol)}$ was prepared by dissolving 1% chitosan powder in 1% acetic acid (pH 6.0). Calcium phosphate $_{(sol)}$ was prepared by mixing 0.25mol/L Ca-EDTA and 0.25mol/L KH_2PO_4 in DW (pH 5.9). The surface of pure Mg was thermally treated in the different ratio of mixture [Calcium phosphate $_{(sol)}$: chitosan $_{(sol)}$] for 1 h at 90℃. The morphology and composition of the surface were examined by SEM with EDS. The precipitated crystal structure and chemical bonding was analyzed using XRD and FT-IR. The electrochemical corrosion resistance of surface was measured by potentiodynamic polarization. The cytocompatibility on MC3T3-E1 osteoblastic cells was conducted.

After thermal treatment, porous and fine particles were formed on the Mg surface. The particles were uniformly covered on the surface. Increasing the mixing ratio of chitosan contributed to miniaturization of the particles and improvement of the density of the coating layer. The particles in coating layer were composed of Mg, C, O, P, and Ca components, and it was an apatite-based compounds with octacalcium phosphate (OCP) and hydroxyapatite (HA) crystal phase. FT-IR analysis results demonstrated the presence of chitosan in the coating layer. The bio-ceramic (apatite) layer increased the potential of the Mg surface, which improved corrosion resistance. It was effective on the increase of cell's proliferation.

The surface coating technique can form the uniform film consisted with chitosan-apatite particles. The dense apatite layer was effective in improving the corrosion resistance of magnesium and enhancing cytocompatibility.

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DP-ThP-10 Influence of Plasma-Enhanced Chemical Vapor Deposition Associated with Different Finishing Procedure on the Degradation of CAD/CAM Dental Ceramic, ***Aldiéris Alves Pesqueira**, L. Scaion Silva,* São Paulo State University (Unesp), School of Dentistry, Araçatuba, Brazil*; V. Adelino Ricardo Barão,* (University of Campinas (UNICAMP), Piracicaba Dental School, Brazil*; K. Henrique Cruz, V. Alves Nascimento, J. Pedro Justino de Oliveira Limírio,* São Paulo State University (Unesp), School of Dentistry, Araçatuba, Brazil*; B. Egumi Nagay,* University of Campinas (UNICAMP), Piracicaba Dental School, Brazil*; E. Cipriano Rangel,* Sao Paulo State University (UNESP), Laboratory of Technological Plasmas (LaPTec), Engineering College, Sorocaba, Brazil

Acid erosion is common in patients with gastroesophageal reflux disease or eating disorders (nervous bulimia and/or anorexia). Such condition can degrade the mechanical strength of oral restorative materials such as ceramics. Surface treatments have been used to protect or improve the mechanical properties of ceramic materials. In this context, plasma-enhanced chemical vapor deposition (PECVD) is a promising technique for depositing a thin film on ceramics. Therefore, we aimed to evaluate the structural and mechanical characteristics of zirconia/silica ceramic in a CAD-CAM interpenetrating resin matrix (Shofu Block HC) as a function of different finishing procedures associated or not with PECVD after erosive challenge. A total of 120 specimens were divided into 4 groups of surface finishing: only mechanical polishing (MP), only application of light-curing sealant (S), association of MP or S with PECVD (MP+PECVD and S+PECVD). A steel reactor was used for PECVD application and a thin-film was deposited under an atmosphere of 85% hexamethyldisiloxane monomer (HMDSO) and 15% argon (Ar). The erosive challenge was performed with 5% HCl (pH = 2.0) for 273 h. The surface roughness (Ra), surface free energy, Vickers microhardness, flexural strength, and elastic modulus of ceramic material as a function of surface finishing were investigated before and after the erosive challenge. A homogeneous silicon-based thin film was successfully deposited on ceramic surface. The PECVD thin film was able to reduce the surface roughness and increase flexural strength of ceramic when associated with mechanical polishing, even after erosive challenge, while the other groups had an increase in roughness ($p<0.05$). In general, PECVD increased the ceramic surface hardness, and reduced the surface free energy when associated with mechanical polishing or sealant application before and after erosive challenge ($p<0.05$). In conclusion, the PECVD thin film effectively enhanced the roughness, hardness, surface energy, flexural strength, and elastic modulus of zirconia/silica ceramic in an interpenetrating resin matrix, mainly when associated with mechanical polishing. The creating of silicon-based thin films might be a good strategy to reduce ceramic degradation in the oral environmental.

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