Biological Materials Science Symposium: Poster Session
Sponsored by: TMS Structural Materials Division, TMS: Biomaterials Committee
Program Organizers: Kalpana Katti, North Dakota State University; Rajendra Kasinath, DePuy Synthes Products, LLC; Michael Porter, Clemson University; Francois Barthelat, McGill University

Monday 6:30 PM
March 16, 2015
Room: Atlantic Hall
Location: Dolphin

Session Chair: Francois Barthelat, McGill University; Rajendra Kasinath, DePuy

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F24: The Investigation of Wear Resistance of Hydroxyapatite-chitosan Bio Composite Coating on Stainless Steel 316L : *Sajjad Falaki*[1]; Rana Sabouni Tabari[1]; Seyyed Khatiboleslam Sadrnezhaad[1]; [1]Sharif University of Technology

The use of man made joint is always dealt with a certain amountof wear. In order to increase wear resistance, bio composite coatings which were made of hydroxyapatite(HA)and chitosan on stainless steel 316L by electrophoretic deposition (EPD) method developed. Using of Chitosan lead to room temperature composite materials processing.Wear resistance of coatings were examined by pin on disc wear testing and it was shown that modification of mechanical and abrasive properties achieved. Moreover scanning electron microscope(SEM) tests showed that appropriate porosity and acceptable distribution of particles were obtained.

F25: Toughening Mechanisms in Nacre: *Sina Askarinejad*[1]; Nima Rahbar[1]; [1]Worcester Polytechnic Institute

In this study, mechanical behavior and toughening mechanisms of abalone nacre-inspired multilayered materials are explored computationally and experimentally. In nacre's structure, the organic matrix, pillars and the asperities play important roles in its overall mechanical performance. A micromechanics model for multilayered biological materials is proposed to simulate their mechanical deformation and toughening mechanisms. The fundamental hypothesis of the model is that nano-scale pillars and asperities have near theoretical strength. It has previously shown that organic matrix behaves stiffer in proximity of mineral platelets. Moreover, short molecules in organic matrix behave stiffer than long macromolecules. The proposed model assumes that pillars and the asperities confine the organic matrix to the proximity of the platelets and hence increase their stiffness. The modeling results are in excellent agreement with the experimental results for abalone nacre. Toughness of multilayered samples with different layer thicknesses is also studied experimentally.

F26: Microstructural Analysis of Aristotle's Lantern in Sea Urchins: *Michael Frank*[1]; Kirk Sato[1]; Jennifer Taylor[1]; Lisa Levin[1]; Joanna McKittrick[1]; [1]University of California, San Diego (UCSD)

Regular sea urchins (Phylum Echinodermata; Class Echinoidea) use a complex of muscles and calcareous teeth, known as Aristotle's lantern, to scrape, cut, and chew food and bore holes into rocky substrates along the ocean floor. The calcite crystal orientation of its five teeth has magnesium concentrated (40-45 mol% Mg) in a polycrystalline matrix at the grinding tips of each tooth. A simultaneous incision, when open, protruding outwards, followed by enclosure, when retracting inwards, characterizes the feeding mechanism. A recent bioinspired application, which takes advantage of the cut off and enclose feeding mechanism, is a spring-loaded biopsy harvester that can precisely capture a tumorous tissue sample while safely minimizing the spread of cancerous cells. The morphology and microstructure of Aristotle's lantern was analyzed with a focus on other possible bioinspired applications.

F27: Surface Magnetized Colloidal Particles Aligned by Magnetic Freeze Casting: *Michael Frank*[1]; Michael Porter[1]; Steven Naleway[1]; Tsuk Haroush[1]; Joanna McKittrick[1]; [1]University of California, San Diego (UCSD)

Recent work has shown the potential of the freeze casting process to be a powerful tool for bioinspired design. However, enhancement of strength along multiple axes in these porous ceramic materials is a significant challenge due to the complexity of colloidal particle manipulation. Magnetic freeze casting provides a potential solution by combining two perpendicular forces: magnetic fields to align surface magnetized particle orientation and ice crystal growth to segregate particle aggregation. This strengthens the porous ceramic along both axes. We present that, through surface magnetization with charged ferrofluids, colloidal particles with a variety of material properties and morphologies (e.g. sub-micron powders, nanowires and nanotubes) can be magnetically freeze cast. We show that electrostatic interactions between colloidal particles with surface charge opposite to that of the ferrofluids imparts superparamagnetic properties onto every type of colloidal particle tested. Future focus on bone tissue engineering applications will be discussed.

F28: MoS2-Ceria Hybrid Nano-composite Based Electrochemical Biosensor: *Ankur Gupta*[1]; Soumen Das[1]; Sudipta Seal[1]; [1]University of Central Florida

Recently developed MoS2 nanoparticles have find applications in H2 evolution and H2O2 detection at nanomolar scale. This is attributed to the catalase activity of MoS2 nanoparticles. On the other hand, cerium oxide nanoparticle (CNP) exhibits superoxide and H2O2 scavenging property. Therefore, in this attempt MoS2-CNP hybrid nanocomposite based biosensor has been developed. It has been hypothesized that CNP will help to regenerative surface thus improve the detection limit as well as recovery of the surface. Biosensing capability of hybrid sensor has been analyzed by both glucose oxidase and xanthine oxidase. Electrocatalytic activity of hybrid sensor has been measured using cyclic voltammetry. Sensitivity, response time and detection limit of hybrid sensor has been compared with MoS2 and CNP sensors.

F29: Advances in the Understanding of the Effects of External Treatments on the Subcellular Structure and Composition of Plant Cell Walls: *Mikhael Soliman*[1]; Laurene Tetard[1]; [1]University of Central Florida

The need for nanoscale, non-invasive physical and chemical characterization of materials has become more significant in recent years with advances in nano-biotechnology and other related fields. One particular area that can benefit from innovative nanoscale characterization is biomaterials in plant biology. Studying the ultrastructures of plant cell walls emerges as a great challenge with direct implications in environmental and health science, biofuel research and derived carbon materials. With cell wall thicknesses in the micrometer range and core components in the nanometer range, a multi-scale approach at the interface between optics and force microscopy is necessary. We will show that tailoring confocal Raman micro-spectroscopy, force spectroscopy, and multi-frequency atomic force microscopy can improve the understanding of cell wall structure and composition in order to expand the fundamental knowledge of the effects of external treatments on plant cell walls.

F30: Amperometric Detection of Hydrogen Peroxide and Dopamine by Ceria Nanoparticle-Functionalized Self-Assembled Monolayer Biosensor: *Craig Neal*[1]; Shashank Saraf[1]; Sanghoon Park[2]; Soumen Das[1]; Hyoung Cho[2]; Sudipta Seal[1]; [1]AMPAC; [2]University of Central Florida

Ceria nanoparticles (CNPs) have been demonstrated in literature to modulate reactive oxygen species concentrations and undergo redox changes in the presence of biomolecules. Using catalytic CNPs as an analyte detector, we have produced a self-assembled monolayer (SAM)–based biosensor that displays enzyme-level sensitivity/selectivity. The electrochemical analysis techniques cyclic voltammetry and chronoamperometry were implemented to demonstrate CNP-SAM sensor detection of hydrogen peroxide and dopamine, to model sensor function in central nervous system-mimetic conditions. The sensor is able to detect nanomolar concentrations of peroxide and dopamine with greater selectivity compared to bare gold electrode; resulting from CNP surface, chemical activity. Additionally, passivation of electrode surface by SAM prevents bio-fouling experienced by most in situ biosensors. The sensor was produced by dip-coating bare gold electrode in mercaptododecanoic acid, base-treating to charge carboxyl groups of SAM layer, followed by electrostatic complexation of CNPs. Detection was performed in phosphate-buffered saline solutions.

F31: Regenerative Nanoporous Gold Biosensor in Harsh Biofouling Conditions: *Shashank Saraf*[1]; Craig Neal[1]; Sangoon Park[1]; Soumen Das[1]; Sudipta Seal[1]; Hyoung Cho[1]; [1]University of Central Florida

In this study the nanoporous gold (NPG) and plain gold (PG) electrodes are compared for possible use as a sensing electrode to be used in physiological conditions. We have demonstrated that the NPG is far superior in sensitivity and resistance to biofouling as compared to the PG. The PG surface becomes biofouled within minutes resulting in complete loss of signal. NPG on the other hand, retained almost 95% signal in the same environment. NPG has been explored in biosensor and catalysis applications; however its behavior in physiological conditions has not been very well studied. In this report PG and NPG were exposed to high concentrations of Bovine serum albumin (BSA) protein to test their resistance towards biofouling. An unexpected result was obtained where the biofouled NPG electrode exhibited signal regeneration under incubation in BSA solution for longer times.

F32: Dynamic Modeling Approach to Follow Adsorption Kinetics of Engineered Proteins that Self-assembles Through Biomolecular Recognition: *James Meyer*[1]; Viraj Singh[1]; Banu Taktak Karaca[1]; Paulette Spencer[1]; Anil Misra[1]; Candan Tamerler[1]; [1]University of Kansas

The intrinsic ability of proteins to interact with inorganics has inspired widespread interest into the biological assembly and patterning of solid materials. Lately many inorganic binding peptides were biocombinatorially selected and then utilized in diverse applications requiring oriented assembly of functional peptides and/or proteins. Many studies focused on the applications; however, their adsorption kinetics dictates their wide-spread utilization. The modified Langmuir adsorption models have proven useful, to some degree, to derive kinetics related parameters. As our understanding of molecular recognition based biomolecular interactions with solid materials grows, establishing an adaptable kinetics model to follow individual binding steps relevant to their bio-self-assembly process becomes a necessity. We developed an integrative computational approach to analyze experimental protein adsorption studied by quartz-crystal-microbalance spectroscopy with dissipation. The model was tested on genetically engineered red fluorescence protein with gold binding ability to follow several distinct regions that may be relevant to different surface binding events.

F33: Single Step Biofabrication of Self-Organized Hybrid Molecular Assemblies: *Banu Taktak Karaca*[1]; Ryan Maloney[1]; Dwigth Deay[1]; Brandon Tomas[1]; Mark Richter[1]; Candan Tamerler[1]; [1]University of Kansas

The functional integration of biologically active components to next generation fabrication methods are growing rapidly due to emerging opportunities for engineered novel devices and systems. Yet, biological and material interfaces are among the critical challenges to address. One of the key interests is to maintain the biomolecular orientation and consequently the activity of the biomolecule when it is at a close proximity to the material surface. Here, we studied biomimetically designed biofunctional interfaces by incorporating biocatalysis into our fabrication protocols. Here we take the initial steps toward designing chimeric enzyme-based hybrid assembly platforms by genetically integrating the engineered material selective peptide tags for tethering oxidoreductase enzymes onto electrode surfaces. We genetically inserted material selective molecular recognition domains into the oxidoreductases. While self-organization of hybrid assemblies were demonstrated to be achieved under different material and buffer combinations over a single step process, their biocatalytic activity at different material interfaces were followed.

F34: Towards Amperometric Sensors via Self Assembled Metal-specific Enzymes: *Dwigth Deay*[1]; Brandon Tomas[1]; Ryan Maloney[1]; Candan Tamerler[1]; Mark Richter[1]; [1]University of Kansas

Immobilization of enzymes on surfaces for the development of amperometric biosensors has traditionally been accomplished with nonspecific covalent chemistry such as EDC/NHS coupling or aldehyde crosslinking. These methods possess several drawbacks such as the inactivation of the enzyme by structural perturbation, reliance on reactive amino acids on the enzyme surface, and the inability to simultaneously functionalize bundled sensors with different enzymes. Here, the putrescine oxidase gene from rhoddococcus erythropollis was cloned with either an N-terminal gold or an N-terminal platinum binding peptide derived through phage display selection. The engineered proteins were over-expressed in Escherichia coli and purified by metal affinity chromatography. The constructs were analyzed using a quartz crystal microbalance, nanoparticle pulldown of enzyme activity, and nanoparticle agarose gel electrophoresis. Their selective adsorption onto patterned metal surfaces, i.e. Pt and Au were shown by fluorescently labeling the constructs. The conversion of polyamines were monitored on the designed electrode surfaces.

F35: Easing the Fabrication of Bioinspired Composites Through the use of Clathrate Hydrates in Freeze Casting: *Steven Naleway*[1]; Yi-Husan Hsiao[1]; Michael Porter[1]; Marc Meyers[1]; Joanna McKittrick[1]; [1]University of California, San Diego

Ubiquitous throughout nature are two phase ductile-brittle composites (e.g. collagen-hydroxyapatite in bone, aragonite-chitin in abalone shell). This has given rise to a number of techniques to fabricate bioinspired composites consisting of brittle (e.g. ceramic) and ductile (e.g. polymeric, metallic or glassy) phases. A commonly employed technique is freeze casting, where a ceramic scaffold is templated by growing ice crystals, then can be infiltrated with a second phase. While this has shown a great deal of potential, the pores created by freeze casting tend to be small which impedes the infiltration process, especially when dealing with high temperature or high viscosity infiltration. We present a simple method for the creation of enlarged pores during the freeze casting process which eases infiltration. This method employs the chemical tools of hydrophobic hydration and non-stoichiometric solids called clathrate hydrates. We propose this as a new tool to simplify the creation of bioinspired composites.

F36: Microstructure, Mechanical Property of Porous Hydroxyapatite-ß TCP Biomaterial Consolidated by Rapid Sintering using Space Holder : *Kee-Do Woo*[1]; Tack Lee[1]; Hae-Cheol Lee[1]; Seong-Tak Oh[1]; [1]Chonbuk National University

Abstract; Space holder method can easily control Young's modulus due to control the pore size, distribution and shape. In this study, porous hydroxyapatite(HA)-beta TCP biomaterial which is not included poison elements was successfully fabricated by powder metallurgy using space holder of NH4HCO3 and foaming agent of TiH2. The consolidation of powder was conducted by spark plasma sintering process (SPS) at 1000°C under 50MPa conditions. The effect of space holder contents on pore size and distribution of HA-beta TCP biomaterial was observed by optical microscope (OM) and scanning electron microscope (SEM). As a result of microstructure observation, a lot of pore was uniformly distributed in the sintered HA- beta TCP biomaterial. Young's modulus of porous HA fabricated by space holder method is lower than sintered HA- beta TCP.

F37: Silk Fibroin Bio-Polymer Integrated Nanostructures for Energy/Sensing Applications: *Swetha Barkam*[1]; Corey Rodas[1]; Anh Ly[1]; Rameech McCormack[1]; Sudipta Seal[1]; [1]University of Central Florida

Silk fibroin (SF) protein is a biocompatible and biodegradable polymer useful for in vivo and in vitro studies. It can be made into different biomedical nanostructures useful for in vivo and in vitro studies, tailored for biomedical application. Silk fibroin additionally displays controllable polymorphism and the pleated beta-sheet form is the source of its piezoelectric capabilities with unique mechanical properties. Polyvinylidene fluoride (PVDF) is a biocompatible polymer with high piezoelectric coefficient values. This study takes a novel approach in nano-architecture of combining the controllable mechanical properties, piezoelectricity, and biodegradability of SF with chemically resistant, ferroelectric, piezoelectric PVDF through electrospinning or making highly ordered polymer nanopillars. Ceria nanoparticles (CNPs) have been proved to change their surface chemistry in presence of H2O2, thereby rendering them sensitive towards H2O2. Additionally in this study CNPs are immobilized on the SF-PVDF nanostructures to make a piezoelectric sensor.

F38: The Ganoid Scales of Atractosteus spatula: Potential for Bioinspired Flexible Armor: *Vincent Sherman*[1]; Wen Yang[2]; Robert Ritchie[3]; Marc Meyers[1]; [1]Materials Science and Engineering Program, University of California, San Diego; [2]Complex Materials, ETH Zürich; [3]Lawrence Berkeley National Laboratory

The alligator gar (A. spatula) is covered with bony scales and an enamel-like surface layer. The scales form a tridimensional pattern in which neighboring scales overlap in such a manner that the thickness conforms and the sum of the overlaps is constant. The mechanical properties and structure are correlated and the tridimensional pattern revealed by computerized tomography is transferred by additive manufacturing to a magnified array of idealized, identical tiles. It is demonstrated that flexibility is maintained while protection is retained. This design is proposed as a model for bioinspired flexible ceramic composite personal armor. Research funded by AFOSR MURI.

F39: Response of Osteoblast-Like Cells to Titanium Alloying Elements: *Dongmei Zhang*[1]; Cynthia Wong[1]; Peter Hodgson[1]; Yuncang Li[1]; [1]Deakin University

Titanium alloying elements such as niobium and zirconium have been widely used in the design and fabrication of biomedical titanium alloys. However, the response of osteoblasts to these titanium alloying elements is not well understood. In this study, the response of osteoblast-like cells SaOS2 including initial cell adhesion, cell proliferation, cell morphology, alkaline phosphate activity and collagen secretion to the pure discs of titanium (control group), niobium, tantalum, silicon, zirconium, hafnium and chromium was comprehensively investigated. Results indicate that SaOS2 cells adhered, spread and proliferated well on all of discs and there was no significant difference in collagen secretion. SaOS2 cells seeded on tantalum and zirconium discs showed relatively higher alkaline phosphate activity compared with other elements. Niobium, hafnium, chromium and silicon inhibited the alkaline phosphate activity.

F40: Comparisons of Apetite Deposition on the Surface of Titanium and Ti6Al4V Alloy Powders: *Elif Yeni*[1]; Ziya Esen[2]; Servet Turan[1]; [1]Anadolu University; [2]Cankaya University

Titanium and its alloys have been used in a wide range of medical applications due to their biocompatibility and mechanical properties. Nevertheless, Ti and its alloys cannot provide sufficient osseointegration. In this study, the powders of metallic implant materials of titanium and Ti6Al4V alloy were alkali and heat treated to optimize the implant to bone contact and enhance the bone regenaration. Powders were soaked in 5 M NaOH aqeous solution at 60 oC for 24 hour and subsequently heat treated in 600 oC in muffle furnace for one hour. To investigate apetite formation on the surfaces, powders were immersed in simulated body fluid (SBF) (36.5±0.5) for 1, 5 and 15 days. The resultant surface coating layers after alkali treatment and apetite layers formed during in-vitro tests layers were characterized and compared by using scanning electron microscopy, energy dispersive X-Ray spectroscopy and X-Ray diffraction techniques Keywords: Biomaterials, apetite deposition