Biological Materials Science: Bioenabled Materials and Systems
Sponsored by: TMS Functional Materials Division, TMS Structural Materials Division, TMS: Biomaterials Committee
Program Organizers: Rajendra Kasinath, DePuy Synthes (Johnson and Johnson); Steven Naleway, University of Utah; Vinoy Thomas, University of Alabama at Birmingham; Jing Du, Pennsylvania State University

Tuesday 2:00 PM
March 12, 2019
Room: 217A
Location: Henry B. Gonzalez Convention Center

Session Chair: David Restrepo, University of Texas San Antonio; Jing Du, Penn State University

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2:00 PM Keynote
Functional Hybrid Material Systems Designed by Guided Biofabrication: *Candan Tamerler*[1]; [1]University of Kansas

Non-covalent biomolecular self-assembly has become a prominent strategy in biofabrication for multi-functional materials and systems with a wide range of applications, ranging from reparative and regenerative medicine to biotechnology. Nature provides bioinspired design strategies to develop innovative materials that simultaneously self-assemble and self-organize, two design characteristics that are essential to man-made purely synthetic systems. Proteins play an essential role in fabrication of biological materials owning to their functional range, from structural to biochemical. Our group has focused on mimiking protein's abilities in the design of functional materials and devices that are self-guided and undergo co-assembled through engineered biomolecular building blocks. This presentation will provide an overview on the guided co-assembly design approaches demonstrated to repair defective tissue interfaces, create antimicrobial coatings, target diseased cells, as well as enhance biocatalytic performance and thermal stability of enzyme catalysts.

2:40 PM
A Nacre-like Glass that Surpasses the Impact Resistance of Tempered Glass: *Zhen Yin*[1]; Florent Hannard[1]; Francois Barthelat[2]; [1]McGill University; [2]Mcgill University

Glass is widely used in architecture, transportation or electronics because of its high transparency, chemical stability and hardness. Two main strategies are available to improve its fragility. Tempered glass uses compressive stresses near the surface to increase strength and impact resistance, but it shatters catastrophically. Laminated glass contains debris, but it has moderate impact resistance. Here we report a nacre-like glass that outperforms current glass designs. Hexagonal patterns were laser-engraved in thin borosilicate glass plates and then assembled in multilayered glass to form a brick and mortar architecture. For the interlayer we used ethylene-vinyl acetate which is transparent and highly deformable. Impact tests revealed that the resistance of our nacre-like glass panels is double that of tempered glass. MicroCT scans revealed that nonlinear tablet sliding occurs over large volumes, absorbing a tremendous amount of impact energy. Heavier damage is confined to the impact site which makes our material damage tolerant.

3:00 PM
Nanoscale Toughening Mechanisms in the Cell Walls of Wood: Mona Maass[1]; Holger Militz[1]; *Cynthia Volkert*[1]; [1]University of Goettingen

Wood is an ideal structural material mainly due to its high toughness. In order to understand what kind of nanoscale toughening mechanisms cause the high toughness, in-situ scanning electron microscope fracture tests on the tracheid cell walls of pine latewood were performed. Since intracellular failure predominantly occurs at the interface between the secondary cell wall layers S1 and S2, the crack was created and propagated at this interface in longitudinal direction. Crack arresting accompanied by crack deflection was observed which resulted in a wave-like crack path. Crack bridging was rarely observed. We suggest that the crack is channeled by the microfibrils. Consequently, the abrupt change in microfibril angle at the S1/S2 interface leads to the observed toughening mechanisms which contribute to the high toughness of bulk wood. In addition, we propose that the "channeling effect" is the reason for the predominant failure at S1/S2 interface.

3:20 PM
Discrete Element Models of Crack Propagation and Toughness in Idealized, Enamel-inspired Composites: *John Pro*[1]; Francois Barthelat[1]; [1]McGill University

This work examines the effect of non-planar prism decussation and prism-to-interface stiffness mismatch on crack resistance (R-curves) in enamel-like structures using a beam-spring network discrete element model. Macroscopic crack growth is modeled directly through rupture of the cohesive zones in a virtual fracture specimen with an initial notch. It is illustrated that the fracture resistance increases indefinitely as the crack advances due to decussation, while the maximum prism stress appears to reach steady state due to the limited interfacial strength. Decussation is shown to simultaneously increase the rate of crack resistance but decrease the composite longitudinal modulus (parallel to the prisms), which suggests a mechanism for the enamel modulus to approach that of the dentine-enamel junction. It is illustrated that the primary contributor to the toughness amplification is the large inelastic zone that develops ahead of the crack, similar to what has been shown in nacre-like structures.

3:40 PM Break

4:00 PM Invited
Using Biomineralization Routes to Build Cancer Testbeds: *Kalpana Katti*[1]; MD Shahjahan Molla[1]; Sumanta Kar[1]; Dinesh Katti[1]; [1]North Dakota State University

Biomineralization of hydroxyapatite inside nanoclay galleries though use of interlayer modifications with amino-acids has led to development of bone-mimetic tissue engineering scaffolds. The unique nanoclay scaffolds enable proliferation and differentiation of human mesenchymal cells to form hierarchical mineralized collagen and ECM mimicking bone. Bone is a popular niche for prostate and breast cancer cells' migration and colonization, leading to metastasis, at which point the cancer incurable. We have developed a humanoid testbed using tissue engineered bone to create breast and prostate cancer tumors in vitro. This test-bed duplicates last stage of cancer metastasis as indicated by the gene expression and immunocytochemistry. Nanoindentation experiments are used to obtain elastic properties of tumors. FTIR experiments conducted during progression of tumor at metastasis indicate unique signatures of DNA and protein contents during cancer progression. The engineering test-bed can be used for personalized medicine as well as a screening tool for new anti-cancer drugs.

4:30 PM
In Vivo Evaluation of Electrochemically Deposited Collagen Biomaterial for Soft Tissue Healing: *Xingguo Cheng*[1]; [1]Southwest Research Institute

Here we described an electrochemical process which can be used to deposit collagen-based biomaterials into densely packed biomaterials. The key advantages of electrochemically deposited collagen over traditional collagen gels are robust mechanical strength, various alignment, various topography, and various composition through co-deposition with micro/nanoparticles or biomolecules. Several collagen biomaterials deposited using this electrochemical process were investigated for various soft tissue healing applications in vivo. In a rat tendon gap defect model, implantation of electrochemically deposited collagen fiber restore the strength and integrity of tendon defect after 16 weeks. In a porcine deep partial thickness burn model, collagen biomaterial demonstrated the support of keratinocytes migration, fibroblast invasion, and neo blood vessel formation. In a diabetic skin wound model, implantation of pure collagen biomaterial or collagen biomaterial with adipose-derived stem cell result in improved wound healing. These results demonstrated the great potential of electrochemically deposited collagen biomaterial for soft tissue healing applications.

4:50 PM
Processing of a Formable Bioactive Glass Composite for Bone Tissue Scaffolding: *Caitlin Guzzo*[1]; John Nychka[1]; [1]University of Alberta

Bone defects are treated with bone grafts, which replace damaged bone with either natural bone or bone substitute. Synthetic materials, such as bioactive glasses, have been developed to overcome immunological and structural limitations of natural bone. Bioactive glasses are osteoconductive—when implanted, they simultaneously degrade and encourage the formation of new bone. However, when sintered to form scaffolds, these glasses devitrify, resulting in low strength and reduced bioactivity. This work details the processing of a particulate composite which self-cures to form a 3D scaffold. This composite consists of 45S5 bioactive glass and aqueous sodium silicate, forming a paste which can be molded to fill unique geometries of bone defects before curing. Optical characterization showed the structure to be an open porous network, which is designed to promote tissue in-growth during wound healing. Additional characterization included chemical and mechanical analysis, and further development will involve in vitro behavior and property studies.

5:10 PM

3D Printed Nanocomposite for Interstitial Hyperthermia of Cancer Cells: *Kwabena Kan-Dapaah*[1]; John Obayemi[2]; Ali Salifu[2]; Nima Rahbar[2]; Wole Soboyejo[2]; [1]University Of Ghana; [2]Worcester Polytechnic Institute

Implantable ferromagnetic metallic thermoseeds have some desirable features suitable for hyperthermia, however, issues associated with biocompatibility and corrosion limit their efficacy. Stimuli-responsive polymeric nanocomposites offer the opportunity to design smart and efficient systems capable of overcoming these challenges. In this work, a potential strategy based on biocompatible plasmonic nanocomposite thermoseeds is explored. First, material properties of the nanoparticles and nanocomposite materials were studied. Second, the hyperthermic properties of 3D printed thermoseeds during exposure to near-infrared laser were tested in different. Last, *in-vivo* performance was investigated using a 3D finite element method (FEM) model, which was validated with *ex-vivo* experiments. Structural properties of component materials did not change after forming nanocomposite and were not affected by nanoparticle concentration. In aqueous solution, the thermoseeds showed adequate heating powers. They effectively suppressed cell viability. The experimental and FEM results suggest that these plasmonic nanocomposite thermoseeds are capable of achieving hyperthermic temperatures *in-vivo.*
