NanoWestern

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Dear Nanoscale Scientists,

The new year is starting with the installation of a new electron beam deposition tool that will be replacing the well utilized "Hoser" system that was used for chromium, titanium, silver and gold deposition. This instrument was acquired through an NSERC-RTI grant along with our own resources and should be ready for training and use this early February. Electron beam deposition produces a pristine thin film with excellent control over the thickness and surface roughness from small substrates up to 6" wafers. The instrument from Angstrom Engineering has been designed to handle multiple users and operates automatically through a Windows based software package.

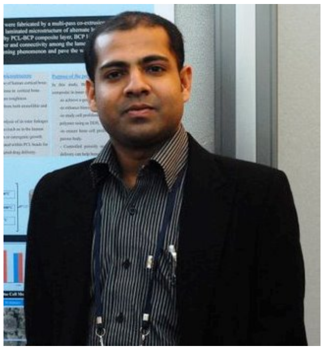
What's more for the coming year, is the upgrade and addition of new instrumentation that were successfully funded through a CFI led by David Shoesmith. These include; upgrades to our etching equipment, a new nanoimprint lithography system for large surface patterning and a new high precision stage and software package for electron beam lithography. All are in the process of being acquired and should be operational before the end of the year. We hope that these additions will meet your needs to assist your research projects. Please do not hesitate to contact us if you would like to know more about these new fabrication capabilities.

Lastly, I would like to congratulate the winners of the Western Nanofabrication Facility award, Sina Martin, Ali Feizabadi and Michael Zylstra who will all receive $2000 in support in the form of instrument time and Nanofab access to complete their research projects that involve nano and microscale fabrication.

Sincerely yours,

Francois Lagugné-Labarthet

Scientific Director, Western Nanofabrication Facility



Organic/Inorganic Hybrid Biomaterial Scaffolds for Bone Tissue Engineering

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Organic-inorganic hybrid materials have domain sizes at molecular level and chemical bonding between the organic and inorganic phases [1]. As the extracellular matrix of bone is primarily collagen and hydroxyapatite with molecular interactions between them, a logical strategy for bone tissue engineering is to develop hybrid biomaterials. We have synthesised a set of hybrid biomaterials by varying the organic and inorganic components [2,3]. Ideally, scaffolds for bone tissue engineering are bone-biocompatible, porous and biodegradable, properties that will support the attachment and proliferation of bone cells, and enhance bone formation and angiogenesis [4]. Conventional bioactive composites, made of organic and inorganic components, could be good candidates for this application. However, conventional composites consist of distinct phases, resulting in non-uniform physical, chemical, mechanical and biological properties, making them unsuitable as bone biomaterials [5]. In contrast, chemically crosslinked hybrid biomaterials act as a single-phase material at the molecular level, yielding a material that can be uniformly tailored for specific applications.

We have utilized several techniques to fabricate scaffolds with optimized pore size, interconnective pores and adequate porosity using hybrid biomaterials. Figure 1A represents hybrid scaffolds prepared through solvent-free casting and particulate leaching. This hybrid biomaterial consists of polycaprolactone as organic moiety and borophosphosilicate glass as inorganic component, crosslinked at molecular level by covalent bonding among phases. Figure 1B represents another hybrid biomaterial scaffolds prepared by 3D printing. This hybrid material was prepared by in situ co-polymerization of organic polyvinylpyrrolidone and calcium-silica-phosphate tertiary glass system.

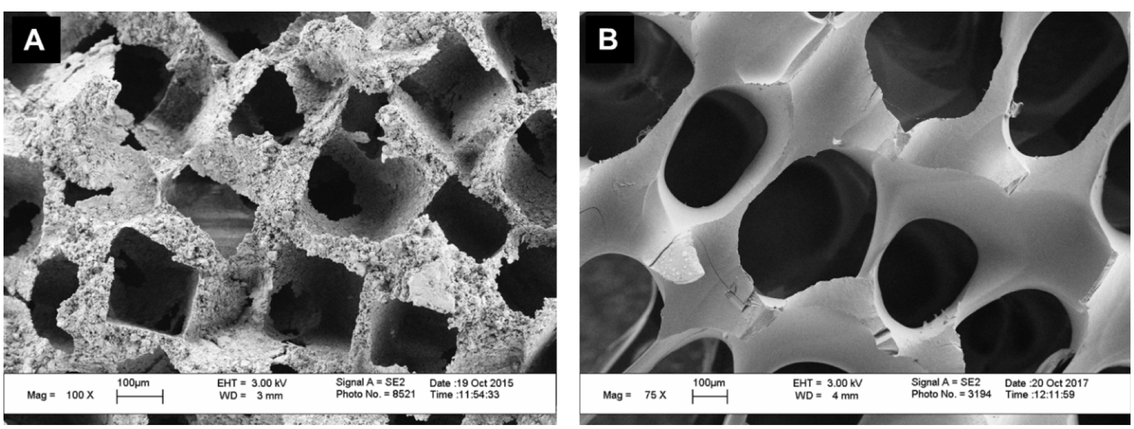
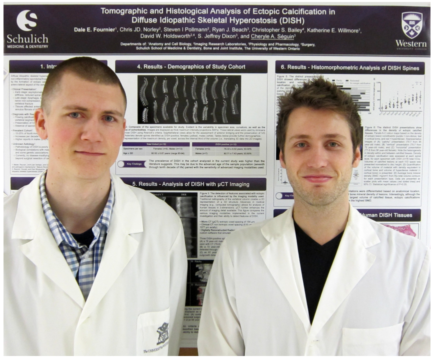


Figure 1. SEM images of porous bone tissue engineering scaffolds. A) Scaffolds made of polycaprolactone/(borophosphosilicate glass) hybrid through solvent-free casting and particulate leaching; B) 3D printed scaffolds of plyvinylpyrrolidone/(calcium phosphosilicate glass) hybrid materials.

1. Kickelbick, G., Introduction to Hybrid Materials. In Hybrid Materials, Wiley-VCH Verlag GmbH & Co. KGaA: 2006; pp 1-48.
2. Mondal, D.; Rizkalla, A. S.; Mequanint, K., Bioactive borophosphosilicate-polycaprolactone hybrid biomaterials via a non-aqueous sol gel process. RSC Advances 2016, 6 (95), 92824-92832.
3. Mondal, D.; Dixon, S. J.; Mequanint, K.; Rizkalla, A. S., Mechanically-competent and cytocompatible polycaprolactone-borophosphosilicate hybrid biomaterials. Journal of the Mechanical Behavior of Biomedical Materials 2017, 75 (Supplement C), 180-189
4. Zhang, X.; Chang, W.; Lee, P.; Wang, Y.; Yang, M.; Li, J.; Kumbar, S. G.; Yu, X., Polymer-ceramic spiral structured scaffolds for bone tissue engineering: effect of hydroxyapatite composition on human fetal osteoblasts. PLoS One 2014, 9 (1), e85871.
5. O'Brien, F. J. Biomaterials & Scaffolds for Tissue Engineering. Mater. Today 2011, 14 (3), 88-95



Pathological Calcification in Diffuse Idiopathic Skeletal Hyperostosis

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Diffuse idiopathic skeletal hyperostosis (DISH) is a vertebral column pathology characterized by the formation of bony bridges that connect adjacent vertebral segments. The estimated prevalence of DISH is 15-25% in North Americans over the age of 50 years, with a greater prevalence in males than in females (2:1). Symptoms of DISH include back pain and stiffness, but can be more severe if lesions impinge on surrounding anatomy. Despite this high prevalence, the pathophysiology of DISH is poorly understood and there are no disease-modifying treatments. The present study aims to characterize the pathological features associated with ectopic calcification in human spine tissues that meet the diagnostic criteria for DISH.

Collaboration with Western's Nanofabrication Facility allows us to use techniques such as scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) to characterize pathological calcification in DISH. Thus, producing an unprecedented insight into characteristics of human tissues (**Figure 1**). SEM analysis allows for the interpretation of structural organization as it relates to features of bone. While, assessment of the elemental composition of tissues further explain structural features. Together, this information fosters an improved understanding of the pathobiology of calcification in human tissue, such as DISH.

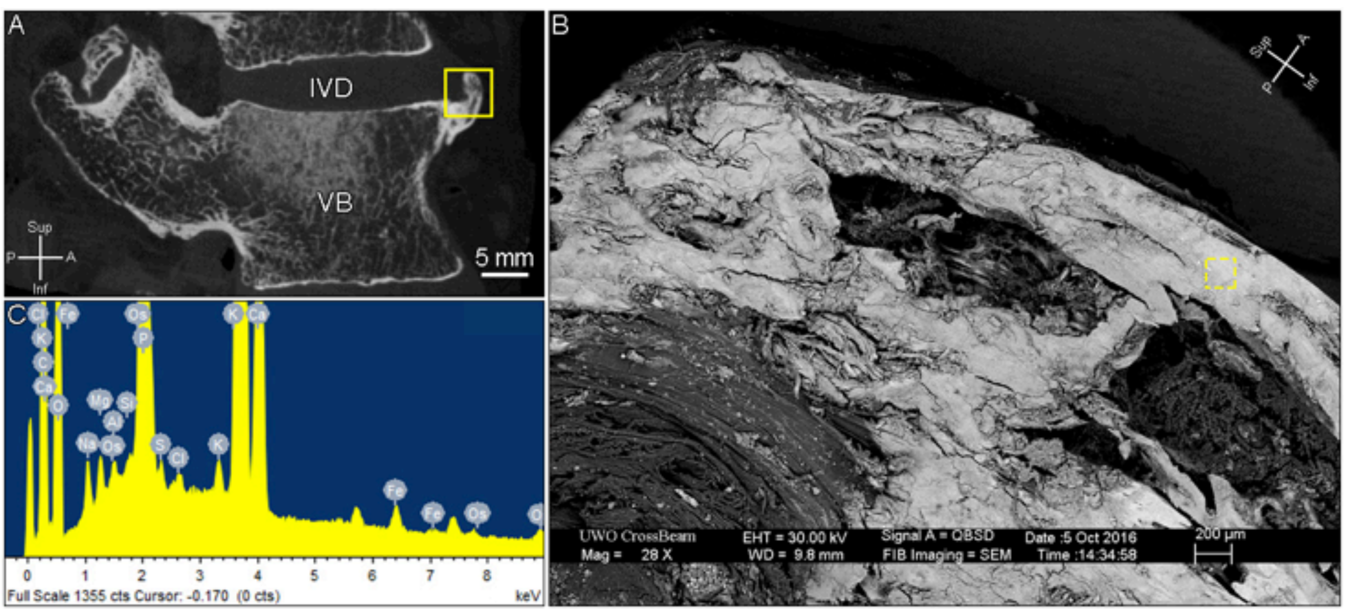

Figure 1. Analysis of human spinal tissue affected by ectopic calcification. (**A**) Micro-computed tomography sagittal slice from a thoracic segment (85 year-old male diagnosed as DISH-positive). (**B**) Scanning electron microscopy of region of interest (*yellow box* in A) at 28X magnification using the CrossBeam FIB Imaging system. (**C**) Abscissa of the EDX spectrum of ectopic calcification (*dotted yellow box* in B) displaying peaks of calcium and phosphorus. Acronyms: A - anterior; P - posterior; Sup - superior; Inf - inferior; VB - vertebral bone; IVD - intervertebral disc.

Notched Micro-Cantilever Bending Tests to Measure the Mechanical Properties of Grain Boundaries of Different Orientation in Ni^{+} and He^{+} Irradiated Inconel X750.

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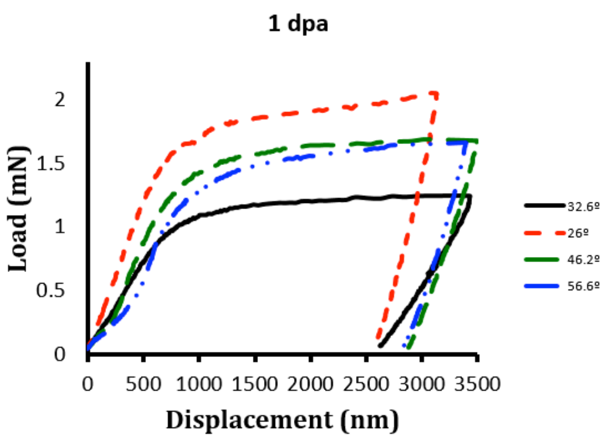
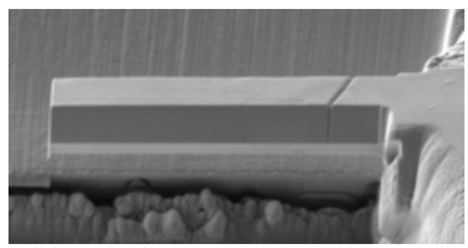
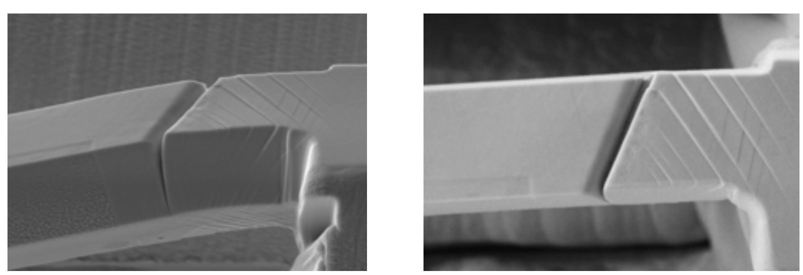
We present the results of bending tests performed on notched micro-cantilever beams made from ion-implanted Inconel X750 Ni super alloy material. The tests were performed to assess the strength of specific grain boundaries when exposed to varying amounts of implanted Ni^{+} and He^{+} used to simulate neutron-induced crystal damage and helium accumulation in this alloy when subjected to CANDU in-core conditions. Pentagonal cross-section micro-cantilever beams, 3µm wide by 20µm long, were milled using FIB. The base, maximum normal stress region, of each cantilever was positioned at individual grain boundaries, which was pre-characterized by EBSD and had a misorientation angle of 25º, 35º, 45º or 55º. The cantilevers were subjected to a bending load and the force-displacement response was recorded. The yield stress in bending was found to vary with grain boundary misorientation angle and boundaries with 25º misorientation yielded the highest yield stress. The increase in yield stress with increasing Ni^{+} and He^{+} implantation was also characterized and was correlated to the distribution of slip band features observed, post-test, around the grain boundaries.



Load-Displacement graph for 4 cantilevers tested in bending, all irradiated with 1 dpa Ni^{+}



Before Test



After Test