THE OHIO STATE UNIVERSITY
INSTITUTE FOR MATERIALS RESEARCH

Spring 2015 IMR Facility Grants Awards

Thirteen new research projects were awarded by the IMR in July 2015, for a total investment of $26,000 in nascent materials research. The thirteen projects support faculty researchers from four different departments within the College of Engineering and College of Arts and Sciences.

Multiscale Characterization of Degradation Mechanism in $LiFePO_4$ Battery Cathodes with Prolonged Electrochemical Cycling

Marcello Canova, Mechanical and Aerospace Engineering; Collaborators: Frank Scheltens and Robert Williams, Center for Electron Microscopy and Analysis

The scope of the current research is to characterize aging mechanisms in $LiFePO_4$ battery cathodes at the nanometer length scale. For this purpose, we wish to use Electron Energy Loss Spectroscopy (EELS) in the low loss regime in the Transmission Electron Microscope (TEM) to identify and quantify the phases formed in the cathode as the battery is discharged. The above phase identification and quantification process will be performed on an unaged cell and a matrix of aged cells, providing insight into the aging process in these cathodes at the proposed length scale.

Intrinsic Radiation Detection Characteristics of Gallium Nitride

Lei Cao, Mechanical and Aerospace Engineering

Room temperature, radiation hard, solid-state detectors have remained an elusive yet popular subject of interest in the radiation detection community. Current solid-state radiation detectors require cryogenic cooling, hermetical sealing, or shielding from intense neutron and gamma fields. With a bandgap of 3.4 eV and relatively large atom displacement energy, the III-V compound semiconductor gallium nitride (GaN) is an excellent candidate for elevated temperature, high radiation dose spectroscopy applications. This work seeks to develop alpha and x-ray detectors from GaN to be used in high temperature, intense radiation environments typically found in advanced reactors and accelerator beamlines. Funding from this grant will be used to improve previous GaN detector fabrication processes by employing sulfide treatment and surface passivation steps.

Nanoparticle Actuators for DNA Nanomachines

Carlos Castro, Mechanical and Aerospace Engineering; Co-PI: Jessica Winter, Chemical and Biomolecular Engineering

This research seeks to create nanomachines constructed from deoxyribonucleic acid (DNA) origami structures that are actuated using gold nanoparticles (AuNPs). In particular, a hinge structure will be investigated. AuNPs will be used to close the hinge; and two potential actuation mechanisms will be explored: AuNP-induced heating and photo-induced dehybridization of chemically modified DNA.

Nanoscale Structure and Dynamics of Supercooled Glass Forming Liquids

Jinwoo Hwang, Materials Science and Engineering

We propose to investigate the nanoscale structural origins of the glass forming ability in bulk metallic glasses (BMGs) using in situ fluctuation electron microscopy (FEM). FEM is an electron nanodiffraction technique that determines medium range order (MRO) in disordered materials. FEM will be performed with in situ annealing above the glass transition temperature to determine the MRO structure of the supercooled liquid BMG. Connecting the structures of supercooled liquids and solid BMGs will provide critical information on the glass forming dynamics and optimal alloy compositions for BMGs.

Development and Characterization of Novel Ferromagnetic Transition Metal Dichalcogenides Grown through Chemical Vapor Deposition

Ezekiel Johnston-Halperin, Physics

The transition metal dichalcogenides (TMDs), with the generalized formula MX_2 (where M is a group 4-10 transition metal and X is one of the chalcogenides), are a class of two dimensional (2D) materials that are of increasing interest due to their relatively easy fabrication and widely varied electronic, optical, and thermal properties. Recently, several studies have predicted the presence of ferromagnetism in both single and multilayered VS_2. We propose to adapt the chemical vapor deposition (CVD) growth techniques developed for the related material MoS_2 to the growth of VS_2 in an effort to grow highly crystalline VS_2. Utilizing these growth techniques will allow us to grow both single- and multi-layered VS_2 and verify the existence of ferromagnetism in this material. The development of these novel magnetic properties in a 2D material would provide a much-needed building block for the creation of all 2D material heterostructures and devices such as spin-valves.

High-Resolution Valence-Loss EELS Mapping of Oxide Nano-heterostructure Interfaces

Patricia Morris, Materials Science and Engineering

This work will use valence-loss electron energy-loss spectroscopy (VEELS) to spatially map the band gaps of semiconducting oxide nano-heterostructures in the Image Corrected Titan3 S/TEM. This data will be a necessary complement to promising STEM-Cathodoluminescence (CL) data acquired in early 2015 as a result of a previous IMR Facility Grant. These materials have been heavily studied in the past few years primarily for gas sensing, catalysis, and photovoltaics. Specifically, this study will analyze widely-used n- type SnO_2 nanowires that are coated with a 5-30 nm layer of other n-type and p-type oxides. Many groups that use these types of heterostructures explain or model the behavior with bulk band theory which is an oversimplification that needs refinement for nanostructures. The earlier CL data has successfully mapped differences in mid-gap defect states and local values of the band gap in some of the materials. This study will use absorption (VEELS) rather than emission (CL) to study these same properties in the same materials. Correlating the two techniques will give a full picture of the electronic structure of these nanomaterials and reveal any deficiencies of either as a standalone technique. Correlating these two techniques in STEM has never been reported in oxides and will be especially useful in probing the local environment of each heterostructure interface, demonstrating the capabilities of the instruments for future external proposals.

Novel Plasma Synthesis of Heteroatom Doped Carbon Nanostructures for Highly Active Oxygen Reduction Reaction Catalysts for PEM Fuel Cells

Umit Ozkan, Chemical and Biomolecular Engineering; Co-PI: Nicholas Brunelli, Chemical and Biomolecular Engineering

Heteroatom doped carbon nanostructures have shown great promise as catalysts in fuel cells for the highly challenging oxidative reduction reaction (ORR), demonstrating longer life-times than platinum. These materials can be challenging to synthesize, requiring a high temperature batch process that produces a variety of structures. We will use a novel approach using a continuous plasma process to reduce the reaction temperature while allowing us to tune the conditions to produce uniform and active carbon nanostructures.

Dissimilar Materials Joints Exploration through TKD and Nanoidentation

Antonio Ramirez, Materials Science and Engineering; Co-I: Boian Alexandrov, Materials Science and Engineering

The new technique Transmission Kikuchi Diffraction (TKD) in combination with Nanoidentation, will be used to study dissimilar metallic interfaces associated to structural joints produced using different welding processes, including conventional arc welding, friction stir welding and impact welding. The join use of these two techniques will make possible to fully characterize the nano and micro scale inter-diffusion and intermetallic phases precipitation on these interfaces, minimizing the use of TEM/STEM, which is conventionally the used technique to approach this problem.

Imaging Skyrmions in Low-Dimensional Chiral Magnets with Image-Corrected Lorentz Microscopy

Mohit Randeria, Physics; Co-I: Robert Williams, Center for Electron Microscopy and Analysis

Skyrmions have been the focus of some exciting new research in magnetic materials over the past 5 years because their topological spin textures have been predicted to have potential for novel applications. These magnetic phases can be directly observed by using Lorentz microscopy, with significant increases in resolution with the use of image corrected microscopy. This research seeks to provide initial experimental observations of these interesting topological spin textures in real space for materials that have already been the focus of theoretical work.

Quantification of 3-D Extracellular Matrix Fiber Remodeling in a Microphysiological Model of Tumor Stroma Activation

Jonathan Song, Mechanical and Aerospace Engineering

The tumor stroma is the tissue surrounding the cancer cells of a solid tumor, and is comprised of extracellular matrix (ECM) proteins such as fibrillar collagen and noncancerous cells including fibroblasts. Recent studies have shown that activated cancer-associated fibroblasts (CAFs) can significantly remodel the collagen of tumor stroma to promote cancer invasion and metastasis. Yet, it remains poorly understood how the mechanical conditions unique to the tumor stroma, such as slowly moving interstitial flow through 3-D tissue, can help sustain the activation of CAFs. To address this important question, we will leverage our expertise in developing microphysiological systems that reconstitute the 3-D tissue-level function of the tumor stroma in vitro to systematically investigate how mechanical stimulation due to interstitial fluid flow promotes collagen matrix fiber remodeling by activated fibroblasts. We will quantify the orientation of matrix fibers using reflectance microscopy to ascertain a directional bias for collagen fiber alignment in relation to the direction of interstitial flow.

Spin Excitations Coupling with THz Metamaterials

Rolando Valdes Aguilar, Physics

Terahertz metamaterials have been studied for their promise as the basis for the creation of invisibility cloaks, perfect lenses that beat the diffraction limit, as well as the basis for future electronics/photonics. Because the response of the metamaterial to THz radiation depends on how the basic unit cell of the metamaterial reponds to the polarization of the THz wave, it is possible to tailor this response for applications. Some metamaterial units, known as split ring resonators (SRR), respond as small magnetic dipoles that resonantly absorb light with an electric dipole selection rule (known as LC resonance). This bianisotropic (or magnetoelectric) response has not been studied when it is coupled with other collective excitations in the substrate of the metamaterial (such as phonons or magnons). The purpose of this proposal is to study the coupling of the SRR LC resonance to the spin wave excitations in several magnetic materials, and through this response understand how to manipulate these magnetic excitations externally.

Study on Mechanistic Understanding of the Environmental Damage in a Ni-based Turbine Disk Alloy

Gopal Viswanathan, Center for Electron Microscopy and Analysis

This study focuses on formulating a detailed understanding on environmentally accelerated damage process on the structural and compositional instabilities in a turbine disk Ni base superalloy. The damage occurs at the nano-scale on locations that were normally inaccessible to the researchers in the past. But the availability of state-of-the-art facility in CEMAS at OSU has opened up the possibility to extract and probe a site-specific volume (<5 μm^3) of material from these locations to conduct research in a way that was unimaginable before.

Microstructure and Pitting Corrosion Resistance of Used Nuclear Fuel Welded Stainless Steel 304 Canisters

Jinsuo Zhang, Mechanical and Aerospace Engineering

The research goal is to identify the corrosion resistance and characteristics of welded canisters material, stainless steel 304 (SS304). The research will be performed by conducting detailed examinations of specimens of as-received and as-welded conditions with pitting corrosion under well-controlled operation conditions in a simulated canister surface environment. The proposed project focuses on characterization of post-tested SS304 using scanning electron microscopy (SEM) and dispersive X-ray spectrometer (EDS).