Fall 2011 Facility Grants
Awarded by the OSU Institute for Materials Research (IMR)

Eleven new research projects were awarded by the IMR in December 2011, for a total investment of \$22,000 in nascent materials research. The eleven projects support faculty researchers from seven departments within the College of Engineering, College of Food, Agricultural, and Environmental Sciences, and the Division of Natural and Mathematical Sciences.

Detecting Iron-Bound Proteins with MFM and SQUID Magnetometry

Lead Investigator: Gunjan Agarwal, Biomedical Engineering

It is well known that iron is an essential element in human physiology; yet too much or too little iron can be quite detrimental. For instance, an increase in body iron stores, termed as iron overload, is a consequence of several pathologies including hemochromatosis, chronic anemia and cirrhosis. When left untreated, iron overload can cause heart arrhythmias and can even lead to cardiac injury and congestive heart failure. The lack of sensitive techniques capable of *directly* measuring *iron* content is a major limitation in detecting iron overload. We propose here to adapt bioengineering techniques like SQUID magnetometry and magnetic force microscopy to exploit the magnetic properties of iron-bound proteins for direct evaluation of iron concentration in the blood.

Self Patterning of Zirconia Substrate Surfaces for Biological Applications

Lead Investigator: Sheikh Akbar, Materials Science and Engineering; Co-Investigator: Jessica Winter, Chemical & Bio-molecular Engineering

We have recently discovered a unique nanobar morphology on yttria-stabilized zirconia (YSZ) (110) single crystal surfaces by doping with gadolinia-doped ceria (GDC). Our objective is to understand the mechanism by which these nanobars form and align parallel to certain crystallographic directions on the YSZ substrate surface. This work would involve microstructural characterization of the nanobars which would require use of focused ion beam (FIB), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) facilities.

Steep Sub-Threshold Si/SiGe and III-V Quantum Tunneling Transistors

Lead Investigator: Paul R. Berger, Electrical and Computer Engineering

The goal of this project is to rapidly prototype 3-terminal quantum tunneling transistors for steep subthreshold slopes by extending the PI's extensive work on resonant interband tunneling diodes (RITD). A paradigm shift with future device scaling from standard MOSFET topologies, where temperature effects limit the slope to 60 mV/decade, towards tunneling based incarnations, where tunneling is virtually temperature independent, is envisioned. The PI's past collaborative work with the Naval Research Laboratory on 2-terminal Si/SiGe tunneling devices has created a library of understanding of tunneling devices and the materials growth and processing necessary to shape well defined degenerately doped quantum wells with active doping above 10^{20} cm^{-3} and with a waist of only 1 nm! This know-how will now be applied towards the demonstration of SiGe and III-V tunnel FETs with concurrent high ON currents, low OFF currents and subthreshold slopes below 60 mV/decade.

Nanoscale Tribocharging Mechanism and Mechanical Properties Investigation of Novel Organic and Inorganic Nano-Object-Petroleum Hybrid Lubricants

Lead Investigator: Bharat Bhushan, Mechanical and Aerospace Engineering

The investigation of the effects of tribocharging and scale on mechanical properties of nano-objects, such as nanotubes, nanobuds and nanohorns from compounds such as molybdenum disulfide, tungsten disulfide and carbon and their incorporation into petroleum-based lubricants, is proposed in this research. Incorporating these known solid lubricants into petroleum-based oils may lead to enhanced lubricity, however, as sliding progresses over time, an increase in attractive electrostatic forces could lead to greater adhesion. During sliding, nano-object aggregation may occur, leading to changes in morphology of the adhered nano-objects and change in the mechanical properties. The use of atomic force microscopy (AFM), electrostatic force microscopy (EFM) and environmental scanning electron microscopy (ESEM) provides the mechanism for the characterization of morphology and charge density. Initially, nano-objects will be deposited on metal and ceramic substrates either as dry nano-objects or as dispersions in petroleum-based oils using a spincoater, then tribocharging studies will be performed using AFM and EFM to correlate adhesion and electrostatic attraction and finally, mechanical properties will be evaluated using the Hysitron nanoindenter. This research will lead to an enhanced understanding of the properties of inorganic nanotube, nanobuds and nanohorns, and will lead to the creation of next generation petroleum-based oils with enhanced properties.

High Temperature Irradiation Effects on Optical Fiber Dopant Migration

Lead Investigator: Thomas Blue, Mechanical & Aerospace Engineering; Co-Investigator: Wolfgang Windl, Materials Science and Engineering

We propose to quantify the migration of dopants in silica optical fibers subjected to high temperature operation in a nuclear reactor radiation environment. The results of this work are generally applicable to existing optically based instrumentation and specifically relevant to development of optically based instrumentation for nuclear reactor environments. Optical instrumentation is already commercial-off-the-shelf technology for mundane environments and the purpose of this research is to determine the feasibility of extending the technology to the harsh environments of future high temperature reactors. When optical fibers are heated beyond 400°C, optical attenuation increases even in the absence of radiation. The attenuation increase is a result of several effects including diffusion of dopants within the fiber, diffusion of impurities into the fiber, mechanical stresses, and crystallization of the fiber. Irradiation by neutrons and gamma rays will cause additional damage to the fiber. The effects of these damage mechanisms are difficult to separate and quantify based on optical attenuation data alone. Quantifying the dopant migration and correlating those results with optical attenuation data will enable the separation of the effects and will establish bounding thermal and radiation conditions for long term use of optical instrumentation at high temperatures and in high temperature radiation environments.

Ant Neck Joint Testing and Characterization

Lead Investigator: Carlos Castro, Mechanical and Aerospace Engineering; Co-Investigator: Blaine Lilly, Mechanical and Aerospace Engineering

This research seeks to characterize the micromechanical structure-function relation of several species of ants. We hypothesize that the ant's ability to carry extremely large loads relative to its body mass is the result of a highly integrated system comprised of composite materials, internal muscle mechanisms, and surface microstructure. This work will employ a combination of scanning electron microscopy, microCT imaging, stress-strain experiments, and computational modeling to examine the exoskeleton and underlying tissues in the critical loadbearing regions where the head, thorax, and abdomen join. The results of this research will elucidate composite materials-based mechanisms that facilitate ants' extraordinary load-carrying capabilities. Future work will apply this knowledge to the design and fabrication of bio-inspired lightweight innovative joints and mechanisms for micro- and macro- scale robotics applications.

Evaluation of Nano, Micro and Macro Biobased Fillers in Elastomeric Applications

Lead Investigator: Katrina Cornish, Horticulture and Crop Science

We intend to substitute conventional mineral particulate and fibrous fillers and reinforcing agents used in elastomers with biobased materials made from agricultural byproducts and food processing wastes. We will prepare cellulosics, polysaccharides, proteins, plant-produced minerals and other bio-materials at macro, micro and nano scales, capitalizing on natural chemical and physical diversity. These materials will be incorporated into elastomeric films and compared with commercially-available materials. Applications may include (1) substrates and probiotic films with nutritional cues for controlled cellular adhesion, growth and proliferation, (2) medical gloves and balloons, (3) building materials, and (4) will explore environmental products for wastewater treatment, and oil and gasoline spills.

Mechanistic Study of TIO2 Nanowires Grown by Thermal Oxidation of Titanium Alloys

Lead Investigator: Suliman Dregia, Materials Science and Engineering; Co-Investigator: Sheikh A. Akbar, Materials Science and Engineering

Titanium dioxide nanowires have been grown on titanium alloy substrates by a straightforward one-step heat treatment process. The Ti alloy substrates used contain a mixture of Ti-α and Ti-β phases. The nanowires produced by this method exhibit a strong preference for growth on the β phase. The objective of this proposed study is to use high resolution electron optics and compositional analysis tools to investigate the role alloying elements play in the growth of nanowires in both the α and β phases. With this information we hope to develop a better understanding of the underlying growth mechanism.

An Oxygen Release System to Improve Neural Stem Cell Survival During Transplantation

Lead Investigator: Jianjun Guan, Materials Science and Engineering

NSC transplantation holds a great potential to treat brain diseases, but experiences a high rate of cell death during transplantation. One of the major causes is low oxygen condition at the transplantation site. The goal of this proposal is to create a novel oxygen release system capable of continuously supplying oxygen to NSCs to improve their survival under low oxygen condition.

Proposal to Fabricate and Characterize Nanochannel Electroporation Devices Using Semiconductor/Cleanroom Technologies

Lead Investigator: Gregory Lafyatis, Physics

Nanochannel electroporation (NEP) refers to a *very* recently developed technique in which a controlled amount of a substance --- e.g. a drug, or targeted RNA, or DNA sample --- is electrically injected through the cell membrane of a biological cell and into the cytoplasm. In contrast to other transfection techniques, such as viral vectors, chemical agents, or even other electrical methods ("electroporation"), NEP enables *precise control over the amount or dosage* of the transfection agent introduced into the cell with virtually no cell mortality. To date, all devices used to effect NEP have been fabricated using polymer replication processing. Fabricating similar devices using semiconductor processing techniques should allow us to extend the capabilities of NEP beyond the technical limitations of the replication processing. In particular, we will work to make devices that, comparatively, a) are more dimensionally stable b) are specially suited to investigating the science behind NEP c) allow transfection of larger numbers of cells.

Transformation Optics from Focused Ion Beams

Lead Investigator: Ronald M Reano, Electrical and Computer Engineering

In this research project, the use of focused ion beams to achieve large index of refraction gradients required for transformation optics will be investigated. Techniques to reduce and quantify optical losses will be established. The resulting fabrication fidelity will be compared with refractive index requirements from simulated designs.