

Spring 2013 IMR Facility Grants

Awarded by the OSU Institute for Materials Research (IMR)

Eight new research projects were awarded by the IMR in June 2013, for a total investment of \$16,000 in nascent materials research. The eight projects support faculty researchers from seven different departments within the College of Engineering, College of Veterinary Medicine, and the College of Arts and Sciences.

Indirect Magnetic Force Microscopy

Gunjan Agarwal, Biomedical Engineering

This project aims to develop a novel indirect magnetic force microscopy (MFM) technique for identifying presence of iron in biological samples. Novel silicon nitride platforms will be employed to achieve analytical electron microscopy and MFM on the same samples.

Bio-tolerant and Biocompatible in vivo Biosensors and Implantable Bioelectronics

Paul Berger, Electrical & Computer Engineering; Co-Investigator: Thomas Rosol, Veterinary Sciences

Leveraging our recent report of enhanced and drift-free silicon (Si) based electronics in an in vivo simulated environment [Electronics Letters, vol. 49, pp. 450-451 (March 28, 2013)], we propose to extend this platform from “bio-tolerant” to “biocompatible”. Essentially, the ionic barrier [USPTO pending (filed Sept. 2012)] developed for these Si-based electronics should permit drift-free biosensor operation for the time needed to perform a clinical test (i.e. less than 10 minutes) up to the reported 24 hours. Phase 1 of this proposal is the maturation of our ion tolerant biocapacitor reported in Electronics Letters to realize the fully functionalized field effect transistor as shown in Fig. 1 and improve sensitivity (Phase 2). Monies requested will defray fabrication and limited raw materials costs. In Phase 3, our group also proposes to extend these bio-tolerant Si-based devices to explore the usage of biocompatible conjugated polymers, which are organic based semiconductors. The carbon-carbon bonding of this class of electronic materials make them excellent candidates for in vivo usage. Lessons learned in Phase 1, such as shortening receptor length and adjusting the dielectric gate thickness to boost biosensor sensitivity, will be directly applied to enhance the lower mobility organics. To aide in material downselection, such as polar vs. non-polar molecules, we propose to quantify the immune response of various candidate materials using in vivo mouse studies. In liaison with Prof. Rosol, a pathologist in the Veterinary School, candidate materials will be implanted and their longterm exposure quantified. The Si-based versions will be used as a baseline comparison. Monies requested here will defray the costs of buying and maintaining a candidate mouse colony.

Ohmic Contacts to 2-D Semiconductors

Wu Lu, Electrical and Computer Engineering

Transition metal dichalcogenides (TMD) have attracted considerable research interests for their great potential of next generation electronic and optoelectronic devices. One critical bottleneck preventing the development of high performance TMD MOSFETs is to form ohmic contacts with low contact resistance on these 2D semiconductors. This IMR Facility Grant project is to develop low resistivity ohmic contacts on TMD thin films using a variety of metal schemes, and plasma and thermal processing techniques.

Novel 3D Oxide Heterojunctions Scaffolds Using High-Surface Area Aerogel

Patricia Morris, Materials Science and Engineering

This project will create high-surface area materials with unique functionalities using TiO₂ aerogels as the main active component, and nanorods or nanowires of other materials to enhance performance. The nanorods can help facilitate easier charge movement, and the band gap bending at the interface between the nanorods and aerogel can be engineered based on the type of materials to enhance charge carrier lifetime and improve photocatalytic activity. These materials should help improve performance in dye-sensitized solar cells, photocatalytic water-splitting, and may have analogous benefits in chemoresistive gas sensors.

Auto-Redox Reactions in Iron-bearing Perovskite

Wendy Panero, School of Earth Sciences

Ferrous iron (Fe²⁺) minerals dominate the Earth's upper mantle. At great depths, the dominant iron-bearing silicate perovskites contain predominantly ferric iron (Fe³⁺). A well-mixed mantle requires pressure-induced oxidation of iron, likely through an auto redox reaction in the Earth's deep mantle according to $3 \text{Fe}^{2+} \rightarrow 2 \text{Fe}^{3+} + \text{Fe}^0$. This proposal tests that the auto redox reaction predicted in the Earth's deep interior is independent of the partial pressure of oxygen through quantifying the oxidation state of iron in perovskite and resulting iron metal precipitates.

Magnetic Domain Study in Low Loss Ferrites

Henk Verweij, Materials Science and Engineering

Materials that have high permeability and low loss at high frequency (~1 GHz) are currently not available. This is caused by the occurrence of domain related resonance at 500 MHz – 1 GHz. The objective of this project is to observe ferrite magnetic domains that resonate near 1 GHz. We will fabricate and characterize initially BaFe₁₂O₁₉ (BaM) samples with a hexagonal structure

and high anisotropy, subsequently $\text{Co}_2\text{Ba}_3\text{Fe}_{24}\text{O}_{41}$ (Co_2Z) which has a similar but more complex structure with higher permeability at high frequency. The domain wall structure will be studied with electron microscopy, combined with magnetic force microscopy. This work will prepare for in-situ observation of domain wall resonance using magneto-optical Kerr effect (MOKE) microscopy with femto-second (fs) laser illumination.

An Integrated Micro Heater/Sensor and Graphene Coating Design and Fabrication for Rapid Heating and Cooling for Micro and Nano Plastic and Glass Molding Applications

Allen Yi, Integrated Systems Engineering

The ultimate goal of this project is to develop a novel molding system capable of rapid heating and cooling for micro/nano plastic and glass molding. To achieve this goal, this novel molding system will be equipped with an embedded micro heater matrix for high efficiency local heating during the molding process. Integrated micro thermal and strain sensors will be used for precision process control. Multiple isolation layers and a carbide-bonded graphene layer will be used to improve thermal efficiency and temperature uniformity. This plan is partially based on the latest research in that it was discovered that the carbide-bonded graphene coating could greatly improve the micro/nano filling and demolding process with its very low friction coefficient and high thermal conductivity.

Cracking Mechanisms of Primary Water Stress Corrosion (PWSCC) Using Multi-Dimensional Materials Characterization Technologies

Jinsuo Zhang, Mechanical and Aerospace Engineering; Co-Investigator: Prasad Mokashi, Mechanical and Aerospace Engineering

The research goal is to identify the mechanisms and important factors/processes driving PWSCC of Ni-base alloys. The research will be performed by conducting detailed examinations of specimens with well-defined crack tip conditions of Ni-base alloys tested in simulated primary water using multi-dimensional materials characterization techniques and extensive comparisons of the results among different alloys and the same alloy with different pre-treatment conditions. As an initial study, the proposed proposal focuses on characterization of Alloy 690 and 52M using transmission electron microscopy (TEM) and field emission scanning electron microscopy (FESEM).