FIRE: Facilitating Inclusive Research Experiences

Mid-May – July 2023
Dept. of Mechanical Engineering and Materials Science
University of Pittsburgh
Application Link
Application Due: March 3rd, 2023

The list of potential projects for summer research is below. Please select your top three choices when submitting your application.

1) ***Laser Processing of Nanocomposite Magnetic Alloys for Electric Vehicle, Space, and Power Grid Applications* - Dr. Paul Ohodnicki**

   Soft magnetic alloys play a critical role for enabling higher efficiency, smaller, and lighter electric power conversion systems for electric vehicles, power grid, and space applications. In this project we will investigate how laser-based processing methods can allow for scalable and optimized control of microstructure in magnetic alloys by tailoring thermodynamics and kinetics of the amorphous to crystalline phase transformation. To pursue this question, we will simulate laser processing techniques with Ansys and will also experimentally apply newly developed laser processing facilities to several representative alloy systems followed by characterization of their structure and magnetic properties through techniques such as x-ray diffraction and vibrating sample magnetometry.

2) ***Anti-biofouling performance of textured oscillating membranes for artificial lung* - Dr. Sung Kwon Cho**

   Biofouling is a common and critical problem in many biomedical devices. Recently, we developed acoustically oscillating membranes that significantly enhance oxygenation for artificial lung devices. In addition, the membrane oscillations are expected to significantly reduce biofouling when in contact with blood. A selected undergraduate student will carry out to characterize anti-biofouling performance on oscillating micro-textured membranes. In this project, the student will learn how to fabricate micro devices, set up experimental measurement systems, and analyze data, while working with PhD students and faculty.

3) ***Materials Design for Renewable Energy Technology* - Dr. Guofeng Wang**

   The commercialization of renewable energy technology, such as proton exchange membrane fuel cells, requires the innovation, design and development of high-performance yet low-cost materials. In this project, the functionality of electrodes and membranes of the fuel cells will be predicted and categorized in a database for design of advanced materials. The proposed research will be performed using the first-principles density functional theory calculation method and machine learning techniques.

4) ***System-level Modeling of Next-generation Radioisotope Thermoelectric Generators (RTGs)* - Dr. Matthew Barry**

Motivation: NASA JPL currently does not have the tools or models to conduct system-level trade studies of existing and novel RTGs, considering the path of heat from the Pu238 pellets all the way to the heat exchange system, which limits their ability to demonstrate the efficacy of RTGs to be competitive for future deep-space and sub-surface missions.

Research Question: Can we use low-fidelity yet robust analytic models (iterative, multi-method codes) to not only construct system-level models of RTGs, but effectively use those in trade studies where hundreds of billions of configurations need analyzed.

Technical approach: Multi-method models of the RTG, which will consider thermal resistance networks for linear elements, constitutive equations for non-linear thermoelectric phenomena, experimentally-based correlations for other unique non-linear phenomena, GPU-accelerated ray-tracing codes for radiation heat transfer, and iterative solution schemes to handle temperature-dependent material properties, will be implemented in MATLAB to create a system-level model.

5) ***Testing capsules for direct ocean carbon captures* - Dr. Katherine Hornbostel**

Novel approaches to capturing CO2 from the air and ocean are necessary to combat climate change. In this project, we will explore a new approach to capturing CO2 from the ocean using microcapsules filled with CO2 solvents. This student will be responsible for synthesizing capsules using microfluidic chips and testing their CO2 removal rates from synthetic seawater.

6) ***Hydrogen Cracking of Additively Manufactured Nickel Superalloys* - Dr. Zachary Harris and Dr. Markus Chmielus**

Hydrogen can reduce the toughness of many structural materials by greater than 90%, but little is known about hydrogen effects on additively manufactured alloys. This project seeks to assess the hydrogen cracking behavior of additively manufactured nickel superalloys exposed to marine environments. Students on this project will get the opportunity to additively manufactured specimens, measure hydrogen-material interactions, fracture samples, and characterize the failure surface and microstructure with electron microscopy tools.

7) ***Feedback Control in Microcantilever Sensors* - Dr. Nikhil Bajaj**

Microcantilever sensors are microelectromechanical systems that can be used to detect small changes in mass – for example, they can be used for gas sensing applications. We seek to tune the response using feedback control and study the effect of time delay. The student will use a Laser Doppler Vibrometer and Probe Station to study the vibrations of a micro cantilever sensor and implement a feedback loop with adjustable delay, and characterize the corresponding response so we can use it to design better sensors.

8) ***Promoting Protective Scale Formation on Nickel-Based Superalloys* - Dr. Brian Gleeson**

Nickel-based superalloys are designed for high-temperature strength and microstructural stability; however, resistance to high-temperature corrosion is also an important property that may or may not be intrinsically achievable. This project will characterize two so-called alumina-scale forming superalloys, Haynes HR-224 and Haynes 233, to determine whether surface deformation/recrystallization can promote alumina-scale formation. This study with involve high-temperature oxidation testing followed by detailed microstructural characterization using optical and electron microscopies.

9) ***Porosity and melt pool variability in additive manufactured metals for high temperature applications* - Dr. Albert To**

The porosity and melt pool size vary spatially in an additive manufactured part depending on local and global geometric features. This research aims to understand the effects of local heat buildup and spattering on porosity and melt pool dimensions. The research will utilize a combination of printing experiments, optical microscopy, and image/data analysis to gain a deeper understanding on the associated effects.

10) ***Demonstrate a New Multi-Material 3D Printing Process based on Wavelength Selective Photopolymerization (WSP)* - Dr. Xiayun Zhao**

Traditional photopolymerization-based 3D printing technologies fabricate complex parts by exposing a photoreactive resin to one-wavelength light in a spatially-selective manner but require material switch-over and tedious re-alignment and cleaning to print practical multi-material components. The research question is how to harness the wavelength selective photopolymerization (WSP) mechanisms to realize rapid, continuous multi-material photopolymer based 3D printing. In this project, we will develop a feasible material system, embody design a sample part for a chosen application (e.g., soft robot/sensor, microfluidic, circuitry) and create corresponding projection masks, and experimentally print samples with demonstrated performance.

11) ***In-situ Interferometric Monitoring of Photopolymer 3D Printing* - Dr. Xiayun Zhao**

Understanding material properties during photopolymer 3D printing is crucial to attaining optimum processes and high-quality parts, but current in-situ monitoring methods are costly, intrusive, and interruptive. The research question is how to develop an in-situ optical interferometry system and method that that can monitor voxel-resolved part-scale profiles of three dimensions, density, and DoC (degree of curing) during a novel photopolymer 3D printing process. In this project, we will design a co-axial interferometer on top of a lab-designed photopolymer 3D printer and develop a physics measurement model as well as a machine learning based sensor data analytics method.

12) ***In-situ Ultrasonic Monitoring of Photopolymer 3D Printing*** **- Dr. Xiayun Zhao**

Knowledge of material properties during photopolymer 3D printing is crucial to attaining optimum processes and high-quality parts, but current in-situ monitoring methods are costly, intrusive, and interruptive. The research question is how to develop an in-situ ultrasonic system and method that that can measure depth-resolved elastic modulus, loss factor, and degree of curing (DoC) during a novel photopolymer 3D printing process. In this project, we will design an in-situ ultrasonic sensor array on top of a lab-designed photopolymer 3D printer and develop a time-of-flight method and/or a wave dispersion method (preferred) to extract the wave velocity as well as the viscoelastic properties.

13) ***Use Fiber-reinforced hydrogel to mimic tissue mechanical properties*** **- Dr. Qihan Liu**

Engineers have long been trying to synthesize soft materials mimic the mechanical properties of biological tissues. The nanofiber reinforcement is one of the key factor that differentiate tissue from common synthetic soft material, yet the mechanics of fiber-hydrogel interaction cannot be systematically studied without an efficient manufacturing platform to systematically control the fiber arrangement. We will use our custom-made manufacturing platform to systematically change the fiber arrangement and test the mechanical properties of the resulting hydrogels.

14) ***Wire arc additive manufacturing of an enclosed impeller*** **- Dr. Albert To**

Manufacturing of enclosed impeller involves multiple steps involving 5-axis machining and welding which limit the design freedom and increase lead times. The proposed research is to discover design rules involved in toolpath planning necessary to manufacture an enclosed impeller using a 5-axis wire-arc additive manufacturing (WAAM) successfully. The student researcher will learn how to operate the WAAM system and use the CAM software to design toolpath.

15) ***Utilizing Measurements for Personalized Stroke Rehabilitation*** **- Dr. William Clark**

Stroke affects hundreds of thousands of people each year in the United States, leaving many with difficulty moving one arm or hand and making stroke the leading cause of permanent disability. Rehabilitation for stroke patients involves directing the patient to practice repeated motions but there are currently no methods that individualize the therapy for each patient. This project will contribute to ongoing research that is investigating the use of wearable sensors to develop methods for defining personalized rehabilitation treatments for stroke patients.

16) ***Additive manufacturing of gradient materials*** **- Dr. Jung-Kun Lee**

Engineering of graded composites of hard ceramics and strong metals is a very important topic, since they can provide advantages of both ceramics and metals. The objective of the proposed research to develop a new processing technique for metal-ceramic composites using the reaction of transient liquid. Binder-jet printing and subsequent metal infiltration will be combined to material processing, which will be followed by extensive microstructure analysis.

17) Measurement of Anterior Cruciate Ligament (ACL) Graft Strengths - **Dr. Patrick Smolinski**

Motivation: The best graft for ACL reconstructions is not known and the grafts may be torn. This research will investigate which tissue source is best for ACL tissue grafts. To accomplish this, different ACL grafts will be constructed and tested to failure.

18) Electromagnetic Field Processing of Functional Magnetic Ceramic Ferrites for Electric Vehicle and Power Grid Applications - **Dr. Paul Ohodnicki**

Magnetic ceramic ferrites are an important class of materials for high frequency applications in inductors and transformers, of critical importance for electric vehicle power electronics and renewable grid integration applications. This project will seek to theoretically model and experimentally explore potential for thermal processing of ferrites using electromagnetic field assisting processing. Analytical models using tools such as Matlab and experimental thermal processing of ferrite samples will be explored to develop an understanding of structure - processing - property relationships.

19) *Understanding the biomechanical function of bladder* - **Dr. Anne Robertson**

The bladder is an amazing organ that has the capacity to fill under very small changes in pressure due to its high compliance during filling. The focus of this research project is to understand some of the structural and geometric properties that make this high compliance possible. In order to answer this question, we will use a combination of whole organ mechanical testing combined with micro-Ct analysis and sophisticated microscopy to explore the bladder filling process and role of wall components in determining its mechanical properties.