2009 NSF RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU) IN NANOMATERIALS AND NANOMECHANICS

May 17 – July 24, 2009

UNIVERSITY of ARKANSAS
1871

Department of Mechanical Engineering

PROJECT DESCRIPTIONS

Research Topic #1: Plasma Diagnostics for the Deposition of Nanomaterials
Faculty Mentor: Matt Gordon (PI), Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Sam Mensah
Problem Statement: Millions of dollars are spent in the development of advanced coatings, but experience has shown that scale-up is often difficult due to significant, unpredictable variations. Plasma diagnostics will thus be performed in an inverted cylindrical magnetron sputtering system used to deposit nano-films on cutting tools to aid this scale-up process.
Objectives and Research Plan: The objective is to use state-of-the-art plasma diagnostic systems – optical emission spectroscopy, residual gas analysis, and Langmuir probe – to quantitatively and spatially measure neutral and charged atomic and molecular ground state and excited state number densities and energy, and electron number density and energy. Critical parameters which will be investigated include pressure, power, gas composition, substrate bias voltage, magnetic field configuration, and pulsed versus alternating current power configuration. One specific task for the intern, spatially mapping the electron density, for example, will be determined when the intern arrives.
Training Plan: Weeks 1-2: plasma fundamentals; Weeks 2-3: plasma diagnostic.
Research Facilities: Surface Engineering and Advanced Materials Processing Laboratory

Research Topic #2: Molecular Dynamic Simulations to Minimize Stress Induced Curvature
Faculty Mentor: Joseph J. Rencis (co-PI), Ph.D., Professor and Head
Ph.D. Graduate Student Mentor: Sachin Terdalkar
Problem Statement: Stress induced during the fabrication of thin-film devices is the main cause of curvature in thin-films. Curvature affects the performance of thin-films used in Micro-Opto-Electro-Mechanical System devices. One way to reduce curvature is through argon ion bombardment on the silicon substrate. This causes the amorphization of the surface modifying the stress gradient through the film thickness. The simulation of the entire process is carried out using molecular dynamic simulation to asses the stress and curvature variation due to ion bombardment.
Objectives and Research Plan: The objective is to perform three-dimensional molecular dynamic simulations to study the stress generation mechanisms in free-stranding silicon thin-films induced by argon ion bombardments. From the simulations, the change in the curvature of the thin-film is correlated with the kinetic energy of the incident ions and the impact density. The Ames lab classical molecular dynamic code is used to carry out the simulations.
Training Plan: Weeks 1-2: atomistic simulation basics; Weeks 2-3: computer code and interatomic potentials; Week 3: atomic visualization training; Weeks 4-5: molecular dynamics.
Research Facilities: Multiscale Modeling Laboratory

Research Topic #3: Corrosion Process of Nanoparticles
Faculty Mentor: Adam Huang, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Cody Baxter
Problem Statement: Conductive nano-particle composites can provide new capabilities as sensing elements for micro/nano-devices. However, the non-linear electro-conductivity characteristics of the nano-particle composites are needed for successful application in micro/nano-devices.
Objectives and Research Plan: The objective is to study the percolation phenomena in nano-particle composites and the temperature sensitivities of such effects. This project also presents an opportunity for the intern to study, and appreciate the differences of, the physical behaviors between the nano-scale and bulk materials.
Training Plan: Weeks 1-3: electrode mask design and nano-particle composite fabrication; Week 4: test sample measurements.
Research Facilities: Engineered Micro-Nano Systems Laboratory

Research Topic #4: Behavior of Nanoparticle-based Lubricants for Energy Savings in Engines
Faculty Mentor: Ajay P. Malshe, Ph.D., Professor and 21st Century Chair of Materials, Manufacturing and Integrated Systems
Ph.D. Research Mentor: Dr. Demydov
Problem Statement: The field of sustainable manufacturing is expanding at a tremendous rate. However, there is much to be learned before the benefits from this area can be used. This fact is particularly true for applications involving green technologies.
Objectives and Research Plan: The objective is to study nanoengineering of multifunctional particles for energy savings. The project will involve design and testing of nanoparticle-based lubricant additives to oil to extend its durability and to save energy when using hydrocarbon fuels. The student will design, fabricate and test scientific hypotheses through systematic engineering in the areas of advanced materials and manufacturing using advanced analytical techniques. The student will analyze the results and prepare a systematic report and present it to peers.
Training Plan: Weeks 1-3: nano-based sustainable systems; Weeks 2-3: SEM.
Research Facilities: Materials and Manufacturing Research Laboratories (Table 4)

Research Topic #5: Carbon Nanotube Separation for Sensing and Biomedical Applications
Faculty Mentor: Uche Wejinya, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Zhuxin Dong
Problem Statement: Carbon nanotubes (CNTs) have been intensely studied, and are good candidates for many electronics and sensing applications. The interests in using carbon nanotubes to manufacture electronics and sensors have increased in recent years because of the increase need for making electronics smaller, and their excellent electrical and mechanical properties. These potentials cannot be achieved unless CNTs with semiconducting and metallic band structure can be successfully deposited and separated.
Objectives and Research Plan: The objective of this work is to study the electrical and mechanical properties of carbon nanotubes in order to determine the band structures. The research plan consists primarily of three main tasks: 1) Micro electrode design and fabrication, 2) Carbon nanotube deposition and verification using Atomic Force Microscopy (AFM), and 3) Measurement and testing.
Training Plan: Week 1: Project Overview, Introduction to Atomic Force Microscope; Weeks 2-3: Microchips fabrication, CNT deposition; Weeks 4-5: Measurements and Testing
Research Facilities: Micro and Nano Systems Engineering Laboratory

Research Topic #6: Mechanical Behavior of Metallic Nanolaminate Composite Materials
Faculty Mentor: Douglas Spearot, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Alex Sudibjo
Problem Statement: Metallic nanolaminate composite materials consist of many repeating layers of metallic or intermetallic constituents. For these nanostructured materials, it is well known that interfaces serve as the initiation sites for dislocations during plastic deformation. However, the precise role of the interface structure on dislocation emission is unknown. Such information is required to develop models for deformation in metallic nanolaminate composites.
Objectives and Research Plan: The objective is to study the plastic behavior of Cu-Ni and Ti-Al nanolaminate composite materials using computer simulations (molecular mechanics and molecular dynamics simulations with interatomic potentials appropriate for nickel, copper, aluminum and titanium). This research is designed specifically to strengthen the undergraduate students' understanding of plastic deformation and the role of interfaces in crystalline solids.
Training Plan: Weeks 1-3: computer code basics and atomic visualization; 4-5: nanolaminate model and initial testing; 6-8: analysis and additional simulations; 9-10: report and presentation.
Research Facilities: Multiscale Modeling Laboratory

Research Topic #7: Nanoscale Biomedical Sensors
Faculty Mentor: Steve Tung, Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Husein Rokadia
Problem Statement: Biomedical sensors are becoming increasingly important in recent years due to rising health care costs and concerns of homeland security. This is especially the case in DNA based analysis where the traditional testing equipment, although accurate, is expensive and requires a long testing time. Nanoscale biomedical sensors, due to their small size and precision design, provide a potential solution for this problem by allowing molecular-level measurements at a tremendous saving in time and cost.
Objectives and Research Plan: The primary objective is to design and fabricate a nanoscale biomedical sensor for DNA based analysis. The research plan consists of two main tasks: integrate DNA with nanoscale sensing material and evaluate sensor output using an atomic force microscope.
Training Plan: Weeks 1-2: microchip fab; Weeks 3-4: materials processing; Week 5: Sensor test.
Research Facilities: Micro and Nano Systems Laboratory

Research Topic #8: Aluminum-induced Crystallization of Amorphous Silicon
Faculty Mentor: Min Zou, Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Hengyu Wang
Problem Statement: Stiction/adhesion and friction are issues that affect the reliability of miniaturized systems. Our research effort focuses on surface nano-texturing to improve tribological performances in the miniaturized systems.
Objectives and Research Plan: The objective of the proposed research is to investigate a novel nanoscale surface-texturing technique that has the potential to be applied to miniaturized systems, such as micro-electromechanical systems (MEMS) for generating nano-textured surfaces to reduce stiction/adhesion and friction forces. Aluminum will be utilized to induce the crystallization of amorphous silicon (a-Si) and thus form silicon nano-textured surfaces on various substrates with good bonding strength and durability.
Training Plan: Week 1: overview of the project and literature search training; Week 2-3: sample preparation technique training.
Research Facilities: Nanomechanics and Tribology Laboratory

Research Topic #9: Utilizing Nanoparticles to Enhance Heat Transfer in Heating and Cooling Equipment
Faculty Mentor: Darin Nutter, Ph.D., P.E., Associate Professor
Ph.D. Graduate Student Mentor: Wei Guo
Problem Statement: The heating, ventilating, and air-conditioning (HVAC) system plays a vital role in maintaining comfort, health, and security within residential or commercial buildings. Surprisingly, the basic HVAC system has not significantly changed over the last 20-30 years, including the use of the vapor compression refrigeration cycle and the use of common refrigerants such as R-134a and R-410a. This project will begin to look at the use of nanoparticles in heat transfer media and the identification/quantification of potential efficiency gains in HVAC equipment.
Objectives and Research Plan: The objective is to evaluate the applicability of nanoparticles to increase heat transfer in the field of heating, ventilating, and air-conditioning (HVAC) systems.
Training Plan: Weeks 1-2: HVAC systems; Weeks 2-3: nanoparticle fundamentals
Research Facilities: Laboratory for Energy Systems Studies (LESS)

Contact Information for program:
Prof. Matt Gordon, Program Director
NSF REU Program in Nanomaterials and Nanomechanics
Department of Mechanical Engineering
University of Arkansas
Fayetteville, AR 72701
V-mail: 479-575-4458
Fax: 479-575-6982
E-mail: mhg@uark.edu *Electroinic submission prefered.*
REU Website: http://comp.uark.edu/~jjrencis/REU2007/

DEADLINE FOR APPLICATION IS MARCH 2, 2009