2008 NSF Research Experiences for Undergraduates (REU) in Nanomaterials and Nanomechanics

May 18 – July 25, 2008

UNIVERSITY of ARKANSAS
1871

Department of Mechanical Engineering

Project Descriptions

Research Topic #1: Plasma Diagnostics for the Deposition of Nano-materials
Faculty Mentor: Matt Gordon (PI), Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Aditya Aryasomayajula
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: Percolation Phenomena in Nano-Particle Composites
Faculty Mentor: Adam Huang, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: TBD
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: Aerospace Miniaturization Technologies Laboratory

Research Topic #4: Engineering of Nano-Bio Materials and Manufacturing Processes
Faculty Mentor: Ajay P. Malshe, Ph.D., Professor and 21st Century Chair of Materials, Manufacturing and Integrated Systems
Ph.D. Graduate Student Mentor: Kumar Virwani
Problem Statement: The field of bio/nano manufacuturing 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 the human body.
Objectives and Research Plan: The objective is to study bio-integrated systems and bio mimetic surfaces to expose students to the emerging area of bio-nano manufacturing and integrated materials, and their applications. The project will involve such topics as cell assisted synthesis of nanostrucures and intra-cellular interactions for integrated systems like organs. The student will design, fabricate and test scientific hypotheses through systematic engineering. The student will analyze the results and prepare a systematic report and present it to peers.
Training Plan: Weeks 1-3: bio-integrated systems; Weeks 2-3: SEM.
Research Facilities: Materials and Manufacturing Research Laboratories

Research Topic #5: Role of Oxidation in Time-Dependent Crack Growth in Ni Base Superalloys
Faculty Mentor: Ashok Saxena, Ph.D., Dean, Distinguished Professor and 21st Century Graduate Research Chair of Materials Science and Engineering
Ph.D. Graduate Student Mentor: Jeffery Evans
Problem Statement: New and accurate models are needed to predict the dwell-time effects on the fatigue crack growth behavior in turbine disk materials at elevated temperatures. Damage effects include creep, fatigue, environment and microstructure.
Objectives and Research Plan: The objective is to separate the role of a variety of time-dependent damage mechanisms in Ni base alloys by conducting experiments. The test material chosen for the study will be an aircraft turbine disk alloy Rene'88. These tests will be incorporated into physically based models for predicting high temperature time and cycle dependent crack growth in a nonlinear fracture mechanics framework.
Training Plan: Week 1: fracture mechanics; Weeks 2-4: laboratory equipment (servo-hydraulic test systems, creep machines, extensometers and furnaces).
Research Facilities: Mechanical Properties Research Laboratory

Research Topic #6: Mechanical Behavior of Metallic Nanolaminate Composite Materials
Faculty Mentor: Douglas Spearot, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Rahul Rajgarhia
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 nanolaminte 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.
Research Facilities: Multiscale Modeling Laboratory

Research Topic #7: Nanoscale Biomedical Sensors
Faculty Mentor: Steve Tung, Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Jason Clendenin
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: Gold Nanoparticle-induced Crystallization of Amorphous Silicon
Faculty Mentor: Min Zou, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Hengyu Wang
Problem Statement: Stiction/adhesion and friction are issues that affect the reliability of magnetic hard disk drives (HDD). 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 develop a novel nanoscale surface-texturing technique that has the potential to be applied to miniaturized systems such as HDD for generating nano-textured surfaces to reduce stiction/adhesion and friction forces. Gold nanoparticles will be utilized to induce crystallization of amorphous silicon (a-Si) and thus to 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

<u>Research Topic #9:</u> Applying Nanosensor Technolgies to HVAC Systems
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 years, but what have changed are the control of the system and the monitoring of conditions within the space. What if we could place even more sensors with the building and system? The next level of HVAC system improvement may come from applying economically feasible nanosensor technologies to our homes and office buildings.
Objectives and Research Plan: The objective is to evaluate the applicability of nanosensors in the field of heating, ventilating, and air-conditioning (HVAC) systems.
Training Plan: Weeks 1-2: HVAC systems; Weeks 3-4: nanosensor fundamentals
Research Facilities: Laboratory for Energy Systems Studies

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DEADLINE FOR APPLICATION IS MARCH 3, 2008