2007 NSF RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU) IN NANOMATERIALS AND NANOMECHANICS

May 20 – July 27, 2007

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: Fundamental Nanomanufacturing Processes for High Precision NanoEDM
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: In nanoEDM, scanning nano tool tips are placed within 10nm of a substrate. A train of electric pulses is applied between the tool and substrate, immersed in dielectric oil medium. Developing a predictive manufacturing process for application specific high precision nano tool tips of various geometries is challenging though vital for nanoEDM.
Objectives and Research Plan: The objective is to understand and develop advanced multi-electrode electrochemical etching methods for manufacturing patterned tungsten and platinum-iridium nano-EDM tool tips. The intern will develop advanced etching tool shapes and sizes critical to the intended applications of nanometer scale machining for applications such as DNA detectors, nano-jets, etc. The intern will experiment with different rings shapes such as rectangular, triangular and trapezoidal to modify the electric field during tool etching.
Training Plan: Weeks 1-3: electrochemical etching; 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: Influence of Porosity on the Mechanical Behavior of FCC Metals
Faculty Mentor: Douglas Spearot, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Nikhil Joshi
Problem Statement: It is well established that vacancies and other point defects can serve as preferential sites for dislocation nucleation; however, the precise influence of vacancy distribution on mechanical properties is not well understood.
Objectives and Research Plan: The objective is to study the influence of nanoscale porosity on the mechanical properties of FCC metals. Material failure will be modeled using molecular dynamics simulations with interatomic potentials appropriate for nickel, copper and aluminum. This research is are designed specifically to strengthen the interns understanding of stress-strain and the role of imperfections in crystalline solids.
Training Plan: Weeks 1-2: computer code function; Week 3: atomic visualization.
Research Facilities: Multiscale Modeling Laboratory

Research Topic #7: Carbon Nanotube Based Microsensor
Faculty Mentor: Steve Tung, Ph.D., Associate Professor
Ph.D. Graduate Student Mentor: Jason Clendenin
Problem Statement: The development of micro and nanoscale biomedical sensors has become increasingly important in recent years due to concerns of homeland security and rising health care costs. Carbon nanotubes, with their naturally small size and remarkable material properties, provide an ideal building block for manufacturing ultrasensitive sensors at the nanoscale.
Objectives and Research Plan: The objective is to design and fabricate a carbon nanotube based flow sensor. The research plan is composed of two main tasks: nanotube alignment between two micro electrodes and sensor testing in a microscale wind tunnel.
Training Plan: Weeks 1-2: microfabrication; Weeks 3-4: carbon nanotube processing; Week 5: flow experiments.
Research Facilities: Micro and Nano Systems Laboratory

Research Topic #8: Atomistic Fracture Simulations of Monolayer Graphene Sheets
Faculty Mentor: Sulin Zhang, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Tao Mo
Problem Statement: Graphene sheets are an attractive alternative for polymer reinforcement since they are less costly than carbon nanotubes, but have comparable mechanical properties. This research will study the fracture strength of monolayer graphene sheets using atomistic simulations.
Objectives and Research Plan: The objective is to calculate the fracture strength of monolayer graphehe sheets using atomistic simulations. The reduction in the fracture strength of the graphene sheet due to the defects will be determined.
Training Plan: Weeks 1-2: Linux; Week 3: visualization software; Weeks 4-5: molecular dynamics/mechanics code.
Research Facilities: Multiscale Modeling Laboratory

Research Topic #9: Mechanical and Tribological Properties of Nano-textured Surfaces
Faculty Mentor: Min Zou, Ph.D., Assistant Professor
Ph.D. Graduate Student Mentor: Hengyu Wang
Problem Statement: Tribological issues affect the production yield and product reliability in nano-electro-mechanical systems due to the large surface-area-to-volume ratios. Our research effort focuses on surface nano-texturing to improve tribological performances in miniaturized systems.

Objectives and Research Plan: The objective is to study the mechanical and tribological properties of the nano-textured surfaces produced by aluminum-induced crystallization of amorphous silicon. The intern will perform surface topography and morphology characterizations using Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) and identify appropriate samples for mechanical and tribological study. The intern will then study the mechanical and tribological properties of these surfaces using nanomechanical and tribological characterization equipment.
Training Plan: Week 1: sample preparation; Weeks 2-3: AFM and SEM; Weeks 3-4: TriboIndenter.
Research Facilities: Nanomechanics and Tribology Laboratory

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DEADLINE FOR APPLICATION IS MARCH 16, 2007