***Research Topic #1:*** Nanoparticle-Decorated Suspended-Graphene Membrane for Hydrogen Sensing
***Faculty Mentor:*** Uche Wejinya (PI), Ph.D., Associate Professor of Mechanical Engineering
***Graduate Student Mentor:*** Yomi Omolewu
***Problem Statement:*** The need to reduce the dependence on fossil fuel is fostering research toward the realization of the hydrogen economy, and hydrogen sensors are integral part of this economy. Incorporating nanomaterials with carbon-based materials as graphene is been explored to improve the "4s" of sensors - sensitivity, selectivity, speed (response and recovery time), and stability. This project seeks explore the electrical properties of nanoparticle decorated suspended graphene membrane with the application directed toward hydrogen gas sensor.
***Objectives and Research Plan:*** The objective is to fabricate suspended graphene membrane and decorate the membrane with Palladium/Platinum nanoparticles. The research plan consists of three major tasks: Fabricate the suspended graphene membrane, decorating the graphene membrane with nanoparticles, and electrical characterization of the nanoparticle-decorated graphene membrane.
***Training Plan:*** Weeks 1-3: Fabrication of suspended graphene membrane; Weeks 4-6: nanoparticle decoration of suspended graphene membrane; Weeks 7-9: Electrical characterization of nanoparticle suspended graphene membrane decorated with nanoparticles; Week 10: Report writing and final presentation.
***Research Facilities:*** Micro and Nano Systems Engineering Laboratory, Arkansas Nano-Bio Materials Characterization Facility, and High Density Electronics Center.

***Research Topic # 2:*** Quantum Interfaces of Dissimilar Materials
***Faculty Mentor:*** Gregory J. Salamo, Ph.D., Distinguished Professor of Physics
***Graduate Student Mentor:*** Mr. Samir Kumar Saha
***Problem Statement:*** Coupling nanoscale materials with dissimilar properties creates the exciting opportunity to explore their extraordinarily rich interaction, unknown bonding at their interfaces, and expected novel properties, particularly those in which the coupling itself plays a key role. In many cases, one may expect to find the resulting material properties to be the sum of the properties of each material. However, this situation changes when the layers of each material are only a few atoms thick. In this, we can obtain a new material with its own unique properties. If we can develop growth techniques to meet this challenge, we can open a new door to new material properties.
***Objectives and Research Plan:*** The objective of this research is to investigate the growth and properties of semiconductor/transition metal oxide interfaces. This objective will be achieved using layer-by-layer growth by molecular beam epitaxy (MBE), with characterization capability for carrier mobility and density and piezoelectric force microscopy.
***Training Plan:*** Student will in Week 1 be introduced to the physics of semiconductors and ferroelectrics. Weeks 2-5: Using Hall apparatus, student will measure, investigate, and understand the electron mobility and carrier density of the semiconductor/transition metal oxide interface of monolayers of GaAs (001) on $BaTiO_3$ (110) grown on $SrTiO_3$ (110) substrates. Weeks 6-9: Investigate and understand the ferroelectric properties of the same sample using Piezoelectric Force Microscopy. Both investigations will be on several samples grown by MBE from single monolayer to 4 monolayers to understand the role of the interface thickness. Week 10: Report writing and final presentation.
***Research Facilities:*** MBE growth facility, Hall measurement facility, and piezoelectric force microscopy

***Research Topic #3:*** Nanostructured Materials for Advanced Rechargeable Battery Systems Using Atomic Layer Deposition
***Faculty Mentor:*** Xiangbo (Henry) Meng, Ph.D., Assistant Professor of Mechanical Engineering
***Graduate Student Mentor:*** Qian Sun and Jiyu Cai

***Problem Statement:*** The quick depletion of fossil fuels (oil, gas, and coal) is posing a series of challenges to our modern society. Renewable clean energies (e.g., solar and wind power) are expected to take dominance for our future energy supplies. To widely implement these new energies, electrical energy storage devices are essential and rechargeable secondary batteries (e.g., lithium-ion batteries) are among the most promising candidates. Although lithium-ion batteries are dominant in portable electronics, their further applications in transport and grids are still facing a series of issues in energy density, cost, safety, and long-term stability.
***Objectives and Research Plan:*** The objective of this project is to boost battery performance with nanostructured materials and explore new battery systems, featuring cost-effectiveness, long-term stability, high energy, and reliable safety. The resultant nanomaterials are expected to provide multiple benefits in achieving high-performance battery systems.
***Training Plan:*** The REU student will be trained to utilize atomic layer deposition for synthesizing a variety of nanostructured materials, characterize the resultant nanomaterials using electron microscopy and X-ray instruments, assemble battery cells, and investigate their electrochemical performance using a Neware battery cycler. Weeks 1-2: Training on operations of atomic layer deposition; Weeks 3-4: Synthesis of nanostructured materials; Weeks 5-6: Characterization of nanomaterials; Weeks 7-8: Assembly of battery cells and investigation of battery performance; Weeks 9-10: Drafting research report and presenting experiment results.
***Research Facilities:*** Meng's Nano & Energy Laboratory, Arkansas Nano-Bio Materials Characterization Facility, and High Density Electronics Center.

***Research Topic #4:*** Nano-channel Based Two-Phase Separation
***Faculty Mentor:*** Adam Huang, Ph.D., Associate Professor of Mechanical Engineering
***Graduate Student Mentor:*** Morgan Roddy
***Problem Statement:*** To date there have not been any nano-satellites, or smaller, with the mobility to change its orbit, perform coordinate formation flight, or proximity maneuvers. Although the reason for this is from multiple fronts (scientific, technological, safety, budgetary, and inter-agency politics), the key criteria tends to be safety and asset risk assessment related. Questions regarding mobility relates to the propulsive technology available, hence the propellant safety (explosion), toxicity (ground crew exposure), corrosive effects (damage to other satellites and launch vehicle in case of leak), orbital performance (orbital collisions), and clean-up (space debris) are the leading inhibitors. The goal of the mentor's current propulsion research is to demonstrate a non-toxic, non-flammable, and non-pressurized propellant micro-propulsion technology for nano-satellites using nano-channel based phase separation of liquid propellants.
***Objectives and Research Plan:*** Weeks 1-2: Review of fluid mechanics, leading into nano-fluidics; Week 3-4: Introduction of relevant micro/nano-fabrication techniques (photolithography and nanolithography), Week 5-6: nano-channel fabrication, Week 7-8: test sample measurements. Training equipment includes basic micro/nano fabrication techniques and atomic force microscopy.7-9: Graphene characterization and integration with CNT; Week 10: Report writing and final presentation.
***Research Facilities:*** Engineered Micro/Nano-Systems Laboratory (ENRC-3915) and UA High Density Electronics (HiDEC) Facility.

***Research Topic #5:*** Developing graphene-based nanocomposites for sensing airborne chemicals
***Faculty Mentor:*** Z. Ryan Tian, Ph.D., Associate Professor of Chemistry and Biochemistry
***Graduate Student Mentors:*** Tom McKean (former REU intern) and Rudy Acosta
***Problem Statement:*** Detecting airborne chemicals and pathogens in real-time, high specificity and sensitivity at low-cost using a user-friendly mechanism is necessary in today's world. This has been an ongoing effort in Tian-lab for more than a decade. This work is indeed a low-risk, high-gain project covering two equally publishable pipelines of research progress in developing both sensory materials and devices in a lab.

***Objectives and Research Plan:*** The objective is to learn how to fine-tune the sensory functions of the new Graphene-based nanocomposites' surface-electronic properties when in contact with the airborne analysts at different concentrations (or partial pressures). The research plan is to conduct the lattice doping and surface coating or ion exchange in both nano synthesis and post-synthesis steps for optimizing the sensory materials' sensitivity and specificity and developing simple amperometric sensors.
***Training Plan:*** Weeks 1-2: Hand-on for the materials syntheses; Weeks 3-4: Hand-on for the materials characterizations; Weeks 5-6: Optimization of the materials syntheses based on the characterization data; Weeks 7-8: Hand-on for the sensor fabrication; Weeks 9-10: writing research report and presentation of results.
***Research Facilities:*** Nanostructures and Manufacturing Lab, Arkansas Nano-Bio Materials Characterization Facility, and High Density Electronics Center.

***<u>Research Topic #6</u>:*** Numerical Simulations of Particle Suspensions in Multi-Phase Fluids
***Faculty Mentor:*** Paul Millett (PhD), Associate Professor of Mechanical Engineering
***Graduate Student Mentor:*** Rosario Cervellere (former REU intern)
***Problem Statement:*** Multi-phase liquids such as oil-in-water (O/W) or water-in-oil (W/O) emulsions are commonly utilized in many scientific and industrial applications including materials processing, food sciences, skin-care products, thin-film coatings, and the extraction of fossil-fuels. Over time, the droplets in emulsions will coarsen due to droplet-droplet coalescence and other droplet coarsening mechanisms. However, we do not fully understand how solid nanoparticles behave on fluid-fluid interfaces and their stabilizing effect.
***Objectives and Research Plan:*** In this project, the objective will be for the REU student to conduct computer simulations of multi-phase fluids that contain solid nanoparticles. The simulations will track the fluid-fluid phase separation process as well as the concurrent attachment of nanoparticles onto the fluid-fluid interfaces. Results will be collected that focus on the morphology evolution and the formation of particle-armored droplets that resist droplet-droplet coalescence. The research will utilize a fluid dynamics model that has been implemented in a parallel C++ code. The REU student will gain experience running parallel simulations on the Arkansas High Performance Computing Center, as well as analyzing output data.
***Training Plan:*** Weeks 1-2: Familiarization with the Unix HPC environment; Weeks 3-4: Submitting and visualizing simulations and developing the parametric study; Weeks 5-8: Analyzing simulation results; Weeks 9-10: writing report and presentation.
***Research Facilities:*** Millett Research Lab and the University of Arkansas High-Performance Computing Center (AHPCC).

***<u>Research Topic #7:</u>*** Nanotechnology Based Rapid DNA Sequencing
***Faculty Mentor:*** Steve Tung (PI), Ph.D., Professor of Mechanical Engineering
***Graduate Student Mentor:*** Bo Ma
***Problem Statement:*** Rapid DNA sequencing has becoming increasingly important due to the advancement of personalized healthcare such as gene-based therapy. Nanotechnology has enabled the design and fabrication of nanofluidic devices capable of drastically reducing both the time and cost of human genome sequencing when compared to the conventional Sanger chemistry-based techniques. A number of unique nanofluidic devices have been proposed and experimented with for DNA sequencing, but the field is still in its infant stage, and a tremendous amount of research and development work is required to transform the technology from laboratory models into viable systems for actual biomedical applications.
***Objectives and Research Plan:*** The objective is to fabricate and test nanofluidic devices with integrated nanochannels and nanoelectrodes for DNA sequencing. The research plan consists of three major tasks: utilizing nanotechnology techniques including SEM and FIB to fabricate the nanofluidic device, interfacing the device with control electronics, and testing the device for effectiveness in DNA sequencing.

***Training Plan:*** Weeks 1-4: device design and nanofabrication; Weeks 5-6: interfacing device with control electronics; Weeks 7-9: testing device for DNA sequencing; Week 10: Report writing and final presentation.
***Research Facilities:*** Micro and Nano Systems Laboratory and Arkansas Nano-Bio Materials Characterization Facility.

***Research Topic #8:*** Mechanical Properties of Nanocomposites
***Faculty Mentor:*** Arun Nair, Ph.D., Associate Professor of Mechanical Engineering
***Graduate Student Mentor:*** Raghuram Reddy
***Problem Statement:*** With the availability of several one dimensional (1D) and two-dimensional (2D) materials, and the ability to control the layer thickness and placement of these 1D and 2D materials on metal surfaces, there is a tremendous opportunity to explore these materials for application towards metal nanocomposites embedded with 1D and 2D materials. Recent studies conducted by the principal investigator (PI) and others on metal-graphene nanocomposites have shown that Ni-Cu graphene systems show high strength during nanoindentation, however fracture properties of these metal nanocomposites are largely unexplored. We propose a set of computational studies to find, how to improve the fracture toughness of metal composites embedded with 1D and 2D materials.
***Objectives and Research Plan:*** The objective of this study is to predict the fracture initiation, propagation, and fracture toughness of metal nanocomposites using atomistic models. The proposed study aims to accomplish the following: (a) Develop models of metal nanocomposites embedded with 1D and 2D materials, (b) study the fracture properties of the nanocomposite material system. The model developed and the results will help with design guidelines for metal nanocomposites embedded with 1D and 2D materials.
***Training Plan:*** Weeks 1-2: Training on how to use supercomputer and simulation tools; Weeks 3-4: computational model setup and testing; Weeks 5-8: computational model validation and mechanical testing; Weeks 9-10: writing research report and presentation of results.
***Research Facilities:*** Multiscale Materials Modeling Lab, Arkansas High Performance Computing Center.

***Research Topic #9:*** 3D Printing of Micro/Nano-Patterned Surfaces for Tribological Applications
***Faculty Mentor:*** Min Zou, Ph.D., Professor of Mechanical Engineering
***Graduate Student Mentor:*** Mahyar Afshar Mohajer and Yang Zhao
***Problem Statement:*** It is estimated that a third to a half of the world's energy production is used to combat friction and wear ($500B/year in US alone). Reducing friction and wear in mechanical systems remains a significant challenge and will directly affect many applications, such as manufacturing, aerospace and defense, agriculture, and gas and oil industries. Our research effort focuses on nanoscale surface engineering to improve tribological performance and associated wetting properties of engineered surfaces.
***Objectives and Research Plan:*** Low friction coatings, such as self-assembled monolayers and polymers, have been applied to surfaces to reduce friction, but they are easily worn due to weak mechanical properties and poor adhesion to substrates. The objective of this project is to develop novel 3D-printed mechanical surfaces inspired by nature and novel nanomaterials, which will provide superior low friction and surface durability for a broad range of mechanical systems for applications in both traditional and high-tech industries.
***Training Plan:*** The REU student will develop 3D processes to fabricate the novel surfaces and study the friction and wear properties of the surfaces using tribometer, characterize surface wear and wetting properties through surface profilometry and contact angle goniometry, respectively. Weeks 1-2: training on 3D printing; Weeks 3-4: developing 3D printing processes for patterning micro/nano-patterned surfaces; Weeks 5-6: fabricating samples and performing tribological testing; Weeks 7-8: surface wear characterization; Weeks 9-10: writing research report and presentation of results.
***Research Facilities:*** Nanomechanics and Tribology Laboratory, Arkansas Nano-Bio Materials Characterization Facility, and High Density Electronics Center.