# NNCI REU at Georgia Tech (SUIN)
# Summer 2022 Projects

## 1) *Piezoresistive Sensors for Measuring Blood Platelet Contraction Forces*

**Prof. Oliver Brand, School of Electrical and Computer Engineering**

By examining contraction forces that blood platelets exert on a substrate, researchers hope to predict abnormal bleeding and clotting behavior. However, current technologies to measure such platelet forces in the tens of nano-Newton range are using microscopy-based optical techniques, which require too much time to be useful in a clinical environment. Thus, with NSF support, an interdisciplinary team of electrical and biomedical engineers at Georgia Tech is currently developing non-optical transducers for measuring platelet contraction forces with the goal to ultimately create a rapid, high-throughput platform capable of assaying large numbers of individual platelets. One approach is to use piezoresistive sensors integrated into a rigid (silicon) substrate, which is covered by a mechanically soft film to which the platelets attach. The goal of the REU project is to explore whether pillar-type microstructures embedded into the soft polymeric film can be used to effectively transduce the forces generated on the surface to the underlying piezoresistive sensors. The REU student will use conventional optical lithography using a maskless lithography tool as well as a 3D printer with sub-micrometer resolution, both available inside the GT-IEN cleanroom facilities, to print appropriate pillar-type microstructures, embed them into a soft, polymeric film, and characterize the mechanical behavior of the resulting hybrid films in the lab. The project will introduce the student to micro- and nanofabrication techniques used to build a microelectromechanical system (MEMS) with application in the biomedical field. Visit the Brand website.

## 2) *Thermoelectric Nanofiber Textiles for Body Heat Regulation and Energy Harvesting*

**Asst. Prof. Blair Brettmann, School of Chemical and Biomolecular Engineering and School of Materials Science and Engineering**

Increased demand for wearable devices has led to new technologies being developed that are flexible, stretchable and durable, with advanced functions such as electrical conductivity, thermal conductivity, pressure sensing, and energy storage and harvesting. Wearable devices made from fibers are particularly attractive, since they are similar to clothing in that they are soft, flexible, durable, breathable, and washable. Thermoelectrics are materials (n- and p-type conductors) that convert a temperature differential (or heat flux) directly into electric energy and vice versa. Organic thermoelectrics (OTEs) are polymer-based materials that behave the same as traditional thermoelectrics, but consist of organic conducting material, making them more flexible. The main goal of the REU project is to increase the conductivity of electrospun nanofibers using solvent interactions in the spinning dope, leading to a stronger thermoelectric effect. This has the potential to overcome the low conductivity of the carrier polymer, but requires a fundamental study of how the solvent interacts with the conducting particles and the carrier polymer. The REU student will learn cutting edge fiber processing technologies, including formulation of the spinning dope and selection of processing parameters. The REU will gain experience in conductivity measurements on porous materials, a particularly challenging experimental characterization for an important material class. The student will learn fiber imaging via scanning electron microscopy and image analysis for measuring fiber diameters and will perform optical profilometry to measure fiber mat thickness. The student will be embedded in a research group that works on a number of projects to tie formulation to processing and solid-state structure of polymer-based materials and this project will introduce the student to both wearable electronics nano-manufacturing and interdisciplinary polymer science concepts. Visit the Brettman lab website.

### 3) *Hyper-Scalable Nanomanufacturing of Electronic Devices*

**Assoc. Prof. Michael Filler, School of Chemical and Biomolecular Engineering**

The fabrication of increasingly faster and denser integrated circuits (ICs), as described by Moore's 'Law', is one of the greatest stories of technological innovation in human history. Yet, the 60-year-old manufacturing paradigm that underpins the IC industry is not without limitations. In particular, its underlying tenets prevent the distributed manufacturing of high-performance ICs and, relatedly, their mass customization. Such a capability, akin to that made possible by the 3-D printing revolution, would enable entirely new use cases at the intersection of IC uniqueness (in terms of device type, spatial arrangement, and electrical interconnection) and low-cost, on-demand manufacturing. To enable the orders-of-magnitude reduction in cycle times and costs required for the distributed manufacturing and mass customization of high-performance ICs, we are developing a series of chemical processes to 'deintegrate' nanoelectronic device and circuit fabrication. To this end, new synthetic methods are needed to bottom-up fabricate fully modular devices that include all the structures needed to enable their function and electrical contacting near room temperature with non-toxic consumables. The REU will develop semiconductor nanowire growth, surface patterning, and/or selective deposition methods needed to form fully functional transistors or diodes. Nanoscale characterization of crystal structure, dopant profile, surface patterning, and thin film placement and composition will be accomplished by the REU with electron microscopy. Devices will be electrically characterized using current-voltage, transfer length, internal photoemission, and low-frequency noise measurements to gain insight into series resistance, contact resistance, and deep-level defects. The project will introduce the REU to the fundamentals of crystal growth, polymer chemistry, atomic layer deposition, and nanoelectronic device operation. The student will collaborate with a team working on various aspects on this multidisciplinary research program. Visit the Filler Lab website.

### 4) *Nanoscale Design and Characterization of 3D-Printed Bio-Mineral Composites*

**Prof. Kimberly E. Kurtis, School of Civil and Environmental Engineering**

This research explores the ability of 3D-printing to align nanocellulose fiber reinforcements within construction materials. Cellulose nanomaterials have a high aspect ratio, allowing individual fibers to align under induced shear load and extensional flow during extrusion. The alignment of fibers can dramatically increase material strength and thermal conductivity. The goal of this project is to maximize nanocellulose fiber alignment for high strength, low cost, sustainable structural building materials. Nanocellulose fibers will be added to samples of concrete, geopolymer, clay and raw earth, UV-cured polymer, heat-cured polymer, and other chemical reaction polymer mixes, which will be extruded using various techniques known to impose shear and extensional flow on the material. Samples will then be analyzed for fiber alignment and its effect on compressive, tensile, and bending strength, as well as insulative value and weather resistance. The orientation angle of the fibers along a single axis will be measured using SEM imaging. The hypothesis is that the smaller the orientation angle the higher the strength and conductivity will be in the direction of that axis. This will be proven by testing the mechanical properties of samples, both with and without nanocellulose reinforcement, and comparing the results to the measured orientation angle of fibers. The REU student will measure strength using universal testing machine systems, bend strength machine systems, and other bench-scale methods, such as focused ion beam milling (FIB) and nanoindentation. Further material characterization will be done by the student including curing evaluation and tomographic analysis, with testing done using, e.g., NMR/MRI and XRD. Materials with acceptable strength properties will later be tested for weather resistance. Visit the Kurtis website.

### 5) *Engineering Biophysical Microtechnologies for Hematologic Applications in Health and Disease*

**Prof. Wilbur Lam, Wallace H. Coulter Department of Biomedical Engineering**

Via NIH funding (R35HL145000), our laboratory takes a multidisciplinary approach spanning biology, physics, engineering, and medicine to develop new tools to answer hematologic questions that are technologically infeasible with current systems. While our basic interests involve developing microtechnologies to investigate the biophysics of hematologic processes at the micro-to-nanoscales, these microdevices can then be adapted to function as novel pre-clinical disease models, for clinical diagnostics, and as drug discovery platforms. Overall, we adopt a "basement-to-bench-to- bedside" approach in which the invention, translation, and clinical assessment of diagnostic and therapeutic microtechnologies takes place under one scientific "roof" with the ultimate goal of improving the lives of patients with blood disorders. The REU student will gain experience in photolithography, 2-photon polymerization and 3D printing, soft lithography, microfluidics, cell biology, and clinical hematology and medicine. Visit the Lam Lab website.

### 6) *Functional Neuro-Development*

**Prof. Hang Lu, Chemical and Biomolecular Engineering**

It is largely unknown how early life stress exposure triggers neural circuit dysfunction and leads to neuropsychological disorders. Using *C. elegans* model organism and droplet microfluidic technology, we will probe neuronal dynamics during development upon adverse stimulation. The REU student will be mentored by a research scientist, will be in charge of fabricating devices, culturing animals, and performing neuronal functional imaging on *C. elegans* animals. Visit the Lu Lab website.

### 7) *On-chip Spheroid Culturing under Pulsatile Pressure*

**Asst. Prof. Chengzhi Shi, George W. Woodruff School of Mechanical Engineering**

Through faculty startup support, we have designed and developed a microfluidic device for spheroid culturing and the protocols of spheroid growth and measurement. The main goal of this REU project is to characterize the effect of pulsatile pressure on the delivery of nutrient into the spheroids and the formation of a death core, which is a challenging problem for spheroid and organoid growth as a result of limited nutrient in the core region of these 3D organisms. We hypothesize that the use of pulsatile pressure will enhance the nutrient delivery into the core area of the spheroids and will reduce the size of the death core in them. The REU will test the hypothesis by measuring the penetration depth of fluorescent nanoparticles into the spheroids as well as cell live and death staining for the measurement of the death core size. A larger nanoparticle penetration depth and smaller death core size will demonstrate the validity of our hypothesis. The amplitude, frequency, repetition, and duration of the pulsatile pressure will be tested to obtain an optimized set of parameters for on-chip spheroid culturing under pulsatile pressure. This project will introduce the REU to spheroid and organoid culturing as well as fabrication and testing of microfluidic chips, optical fluorescence measurements, and cell staining measurements. Visit the Shi Lab website.

### 8) *Nanofabrication of Polymer-Based 2-D Photonic Crystal Structures*

**Prof. Natalie Stingelin, School of Materials Science & Engineering and School of Chemical & Biomolecular Engineering**

The goal of this project is to provide nano-structured photonic crystals based on simple 1D- and 2D-photonic structures. Such architectures can be designed to have high transmittance in specific wavelength regimes, while reflecting most of the light in other regions. They may also be used to 'trap' light, or guide it. These crystals thus find applications as optical cut-off filters in the visible, as heat mirrors that reflect heat (NIR irradiation) but are transparent to the human eye, anti-reflection coatings, wave guides, or optical cavities. In this project, the goal is to explore how such structures can be patterned in two dimensions. We will use new equipment in the Stingelin lab, a Flash Photonic Curing system, which allows exposure of specific parts of the hybrid materials to short light pulses. This has shown to lead to refractive index changes, promising to open up pathways towards straight-forward 2D-photonic crystal fabrication. In the project, the REU student will learn how to work with the Flash Photonic Curing set up and engineer methods towards refractive index patterning of inorganic/organic hybrid materials. In addition, the student will be taught how to produce the hybrid material via a very simple one-pot synthesis, and how to characterize the material structurally and optically. The student will be exposed to various coating techniques used to create distributed Bragg reflectors, including spin-coating, wire-bar coating and dip-coating. More complex characterization methodologies will be used to assess the produced photonic crystals, including tools such as electron microscopy probes and XPS/UPS methodologies. Visit the Stingelin lab website.

### 9) *Nanobottles for Controlled Release and Related Applications*

**Prof. Younan Xia, Wallace H. Coulter Department of Biomedical Engineering**

In recent years, efforts have been made to bring the concept of bottles to the nanotechnology arena by downsizing their dimensions to the nanoscale regime. Nanobottles refer to colloidal particles with a hollow interior and a single opening in the wall. Nanobottles are ideal for the encapsulation of different types of functional materials, promising new applications in controlled release, drug delivery, environmental remediation, and cosmetics. Despite recent progress, it remains a major challenge to fabricate and mass-produce nanobottles with uniform, well-controlled compositions, sizes, and openings. We are developing a route based on controlled swelling to transform commercial polystyrene (PS) latex beads into nanobottles. When the surface of a PS bead is coated with a shell made of silica ($SiO_2$) or other materials and then exposed to tetrahydrofuran (THF), a gradually-increased pressure will be built inside the shell. The pressure will eventually reach a level high enough to poke a hole in the shell, pushing out the swollen PS through the opening to generate a Janus particle. When the PS is finally dissolved by THF, a nanobottle made of $SiO_2$ will be left behind. This solution-based route holds promises for the scalable production of nanobottles in large quantities, together with a broad range of compositions, sizes, shapes, and openings. The REU student will learn knowledge and skills related to colloidal chemistry, materials science, and biomedical research, including synthesis and characterization of nanostructured materials, colloidal particles, and surface coatings, as well as tools/tests for controlled release and drug delivery. The student will learn tools including scanning electron microcopy, transmission electron microscopy, UV-vis spectroscopy, and FT-IR spectroscopy. Visit the Xia Lab website.

### **10)** ***Nanoscale Thermal Transport Measurements in Electrically Conductive Polymers***

**Assoc. Prof. Shannon Yee, George W. Woodruff School of Mechanical Engineering**

Polymers are thought to be electrical and thermal insulators. However, the field of (semi-)conducting polymers has advanced to the point where polymers (i.e., plastics) can conduct electricity rather well (i.e., electrical conductivity exceeding 1,000 S $cm^{-1}$). Additionally, the field of thermally conductive polymers has focused on increasing the crystallinity of some polymers (e.g., high-molecular weight polyethylene) to increase the phonic contribution to thermal conductivity resulting in diamond-like thermal conductivity (~50-100 W $m^{-1}$ $K^{-1}$). It may now be possible to observe polymers whose thermal conductivity is dominated by the electronic contribution where charge carriers are responsible for carrying a large fraction of heat. Unfortunately, many (semi-)conducting polymers are plagued with heterogeneous microstructures. To better understand the thermal transport at the nano- and micro-scale, new measurement techniques leveraging nano- and micro-fabrication process are necessary. In this broader research effort, an REU student will work as part of a team and develop skills in lithographic processing, thermal metrology, and collaborative-team science. Additionally, the REU student will experience interdisciplinary research working alongside mechanical engineers and material scientists. Visit the Yee Lab webiste.