ND*nano* Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Samuel Leung
2) Faculty mentor name: Professors Susan Fullerton and Alan Seabaugh
3) Project title: Ion Transport in a Solid Polymer Electrolyte Between 2-D Graphene Surfaces

4) Briefly describe any new skills you acquired during your summer research:

This project gave me the opportunity to work with multiple instruments, including a semiconductor parameter analyzer and a probe station. I learned how to prepare a solid polymer electrolyte (SPE), which entailed purifying the polyethylene oxide polymer, dissolving the salt $LiClO_4$ into the PEO and acetonitrile solution, and hot pressing the SPE into a Teflon mask. I was trained to enter the clean room facility and to utilize some of the instruments offered, such as microscopes and ovens. In addition, my project involved using Comsol Multiphysics, a software package used for modeling and analysis, and OriginPro, a program used to organize, graph, and analyze data.

5) Please briefly share a practical application/end use of your research:

Understanding ion transport in graphene and solid polymer electrolyte devices is the first step to developing faster, safer, and more efficient future electronic devices. This idea of modulating electrons using ions in a polymer and 2D material like graphene has applications in a wide range of electronic devices for electronic memory, supercapacitors, THz modulators, switches, light emitting devices, nanobatteries, etc.

Project summary:

Graphene is a one atom thick sheet of carbon with remarkable properties that may pave the way for faster, smaller, more efficient electronic devices. Combining graphene with an ionically conductive solid polymer electrolyte (SPE) should enable greater modulation of the graphene conductivity via the formation of an electronic double layer at the graphene-SPE interface. In order to develop these next generation graphene/SPE devices, it is important to understand ion-electron transport at the graphene-SPE interface.

Figure 1. Side view diagram of graphene/SPE device

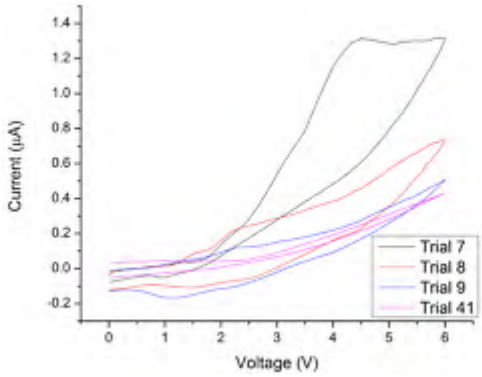

Figure 2. *I-V* measurement of graphene/SPE device from 0 to 6 V (double sweep)

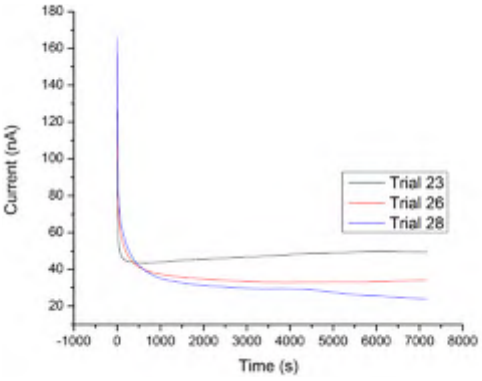

Figure 3. Wagner polarization test over 2 hours at 1 V

This project focused on ion-electron transport between graphene surfaces. We constructed a model system of polyethylene oxide (PEO) and $LiClO_4$, sandwiched between two graphene electrodes (Figure 1). The polyethylene oxide (PEO) and $LiClO_4$ was prepared in a molar ratio of 20:1. Current-voltage (*I-V*) measurements were performed on the device at a low ramp rate (277 µV/s) from 0 to 6 V (Figure 2). These measurements show that only ~0.15% of the Li^+ ions available in the bulk SPE are reduced at the graphene surface, equating to a layer of Li approximately 20 nm thick on the graphene surface in our device. Peaks in the *I-V* measurements likely correspond with the reduction of Li^+ and the oxidation of ClO_4^-. The absence of peaks on the reverse sweep also indicates that the redox of Li^+ and ClO_4^- ions is an irreversible reaction on the time-scale of the *I-V* measurement. Sampling the current of the device versus time, however, shows that reactions continue for many hours after any type of measurement – the device acts like a nanoamp battery. Wagner polarization tests (i.e. transient response of the current in response to a constant voltage) reveal that ions contribute ~80% of the total current, with electrons contributing the remainder (Figure 3). Because PEO and $LiClO_4$ are hygroscopic, humidity could also be a factor in the measured response. Water was shown to increase the current by as much as a factor of 5, which is possible because water acts like a small-molecule plasticizer, increasing polymer and hence ion mobility. This study is aiding in the basic understand of ion-electron transport in graphene-SPE systems, laying the foundation for the development of future devices.

Publications (papers/posters/presentations):

Poster:

A poster was presented at the 2012 Summer Undergraduate Research Symposium, hosted by Notre Dame. The poster was titled “Ion Transport in a Solid Polymer Electrolyte Between 2-D Graphene Surfaces” and was coauthored by Dean Schaetzl, Wan Sik Hwang, Alan Seabaugh, and Susan Fullerton.