NDnano Undergraduate Research Fellowship (NURF)
2014 Project Summary

1) Student name: Katie O'Neill
2) Faculty mentor name: Professor Susan Fullerton
3) Project title: Depositing and characterizing two-dimensional electrolytes for low-voltage memory

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

This summer allowed me to gain valuable experience in operating an atomic force microscope (AFM) and scanning tunneling microscope (STM) in the unusual location of an argon glovebox. I also developed my skills in drop-casting, annealing and also poster presentation.

5. Briefly share a practical application/end use of your research:
The aim of this project was to explore novel, low-voltage memory concepts that involve the movement of ions within and between two-dimensional (2D) materials, such as the planar molecule 15-crown-5-ether-substituted cobalt(II) phthalocyanine (CoCRPc) deposited on a graphene surface in preparation for a low-voltage logic device.

Project Summary:

To decrease global energy consumption, low power electronic devices are needed. An example of one specific need is low-voltage flash memory for low-voltage logic devices. The aim of this project was to explore novel, low-voltage memory concepts that involve the movement of ions within and between two-dimensional (2D) materials, such as the planar molecule 15-crown-5-ether-substituted cobalt(II) phthalocyanine (CoCRPc) deposited on a graphene surface. Low concentrations of CoCRPc (0.3 mg/L) were deposited by drop-casting in a solvent mixture of benzene and ethanol (9:1), followed by annealing at 180°C in an argon-filled glovebox to produce monolayers of CoCRPc (CCP) on a highly ordered pyrolytic graphite (HOPG) surface. The resulting monolayers were characterized using an atomic force microscope (AFM), located in the same argon-filled glovebox. The thickness of the CCP monolayer was approximately 0.5 nm, in agreement with theory. Large numbers of nanometer-sized CCP aggregates were initially observed on the surface; however, further annealing in air reduced the size and number of particles. Because the CCP molecules are hygroscopic, we suggest that the water molecules in the air increase the mobility of the CCP, allowing the large clusters to spread out into a monolayer. Current-voltage (IV) measurements were performed on the CCP monolayer and bare HOPG using PeakForce tunneling AFM (PFTUNA). Bare HOPG produced an IV curve similar to that of a conductor, whereas with the CCP monolayer, it was more resistive. To increase the surface coverage, the concentration of the drop-casting solution was increased to 13 mg/L followed by annealing in argon and air respectively at 180°C. This treatment resulted in nearly a full monolayer of coverage. Finally, a mixture of CCP and lithium perchlorate ($LiClO_4$) was deposited on HOPG in preparation for a device.

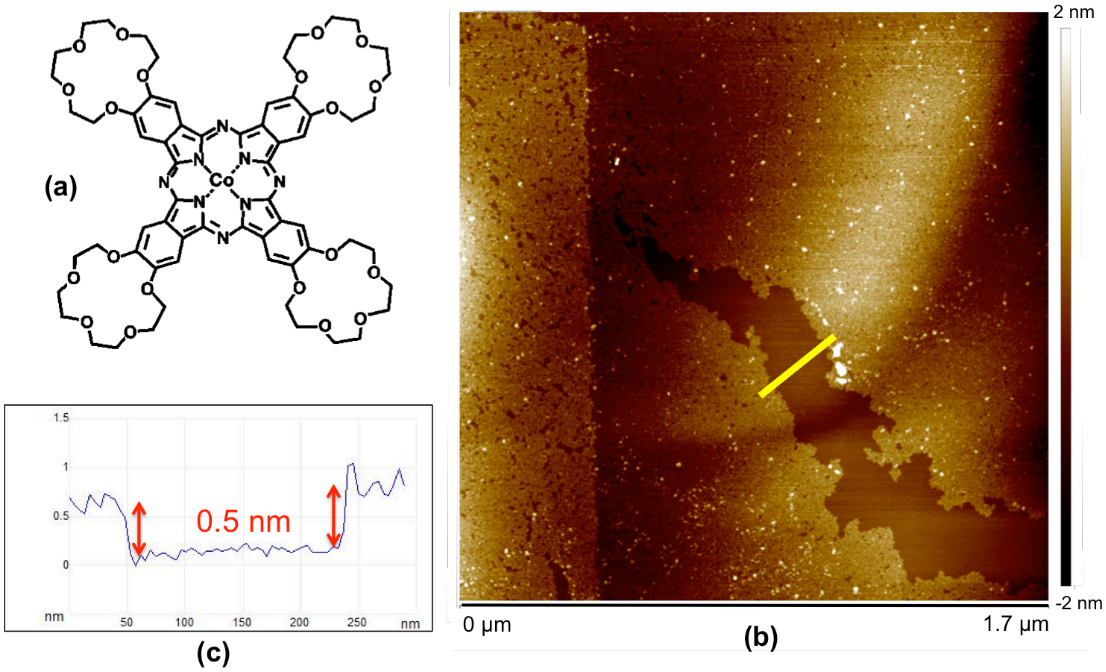

Fig. 1 (a) CoCRPc (CCP) molecule - used to create 2D monolayer. **(b)** AFM image of CCP monolayer on HOPG. **(c)** Line scan of yellow line indicated in (b). Monolayer thickness = 0.5 ± 0.1 nm.

Publications (papers/posters/presentations):

I presented a poster at the 2014 Summer Undergraduate Research Symposium. The poster was titled "Depositing and characterizing two-dimensional electrolytes for low-voltage memory" and was coauthored by Hao Lu, Alan Seabaugh, and Susan Fullerton.

Abstract submitted 6/24/14 to IEDM 2014

Title: "A new approach for 2D crystal memory utilizing nanometer-thick ion conductors"

Authors: Fullerton, Susan K. (Notre Dame), Lu, Hao (Notre Dame), Bourdon, Buchanan (Notre Dame), Kinder, Erich W. (Notre Dame), Li, Huamin (Notre Dame), O'Neill, Katie (Notre Dame), Nahas, Joseph J. (Notre Dame), Sabnis, Sushant A. (Notre Dame), Xu, Huilong (Notre Dame), Wang, Weihua (UT/Dallas), Gong, Cheng (UT/Dallas), Kim, Hanchul (UT/Dallas), Kwak, Iljo (UC/San Diego), Park, Jun Hong (UC/San Diego), Park, Sang Wook (UC/San Diego), Sardashti, Kasra (UC/San Diego), Furuyama, Taniyuki (Tohoku Univ.), Kobayashi, Nagao (Tohoku Univ.), Cho, Kyeongjiae (UT/Dallas), Kummel, Andrew (UC/San Diego), Seabaugh, Alan C. (Notre Dame).