UNIVERSITY OF NOTRE DAME
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CENTER FOR NANO SCIENCE AND TECHNOLOGY

ND*nano* Undergraduate Research Fellowship (NURF) 2015 Project Summary

1. Student name: Edward Hunckler

2. Faculty mentor name: Susan Fullerton

3. Project title: Removing surface residue from graphene *via* CO_2 annealing

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

During this summer, I learned several new techniques. The first is Atomic Force Microscopy (AFM). I learned how to produce high-resolution scans with this machine. I also used the Glove Box because the AFM was housed inside. Finally, I learned how to work inside of a cleanroom where I operated the Nanotube Furnace to anneal my samples in a CO_2 environment.

5. Briefly share a practical application/end use of your research:

This research will be used to clean the surface of graphene for use in nanoionic memory – a new type of flash memory that utilizes two-dimensional crystals and lithium ions. The first generation of the memory consist of a graphene transistor with an ordered monolayer of cobalt crown ether phthalocyanine (CoCrPc) molecules deposited on the graphene surface. In order to achieve an ordered monolayer of CoCrPc, the underlying graphene must be atomically clean. During the fabrication of these devices, a significant amount of residue remains on the graphene surface - primarily polymethyl methacrylate (PMMA), a polymer commonly used in electron-beam (e-beam) resist and as a transfer layer for graphene prepared by chemical vapor deposition (CVD). Gong *et al.*[1] demonstrated that a CO_2 anneal can remove PMMA residue from graphene.

This summer, I scaled-up this process to larger sample sizes (1 x 1 cm) and quantified the amount of residue using atomic force microscopy. To determine the optimal annealing temperature and time, CVD graphene with PMMA residue was imaged before and after the CO_2 anneal. A CO_2 anneal at 500˚C for 30 minutes was optimal for cleaning the graphene. Exfoliated graphene flakes exposed to PMMA were tested to verify the effectiveness of the anneal. The CO_2 anneal reduced the surface roughness by an order of magnitude. In addition, the procedure was used to remove e-beam resist from graphene flakes, and the results showed a similar reduction of the residue.

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[1] Gong, C, et al. Journal Of Physical Chemistry C, 117(44), 23000-23008.

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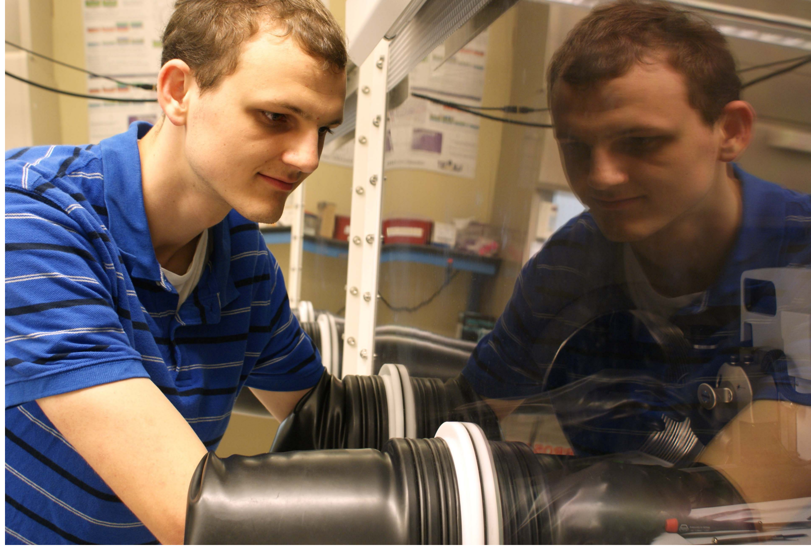

Fig. 1: Edward Hunckler working with the AFM in the glove box

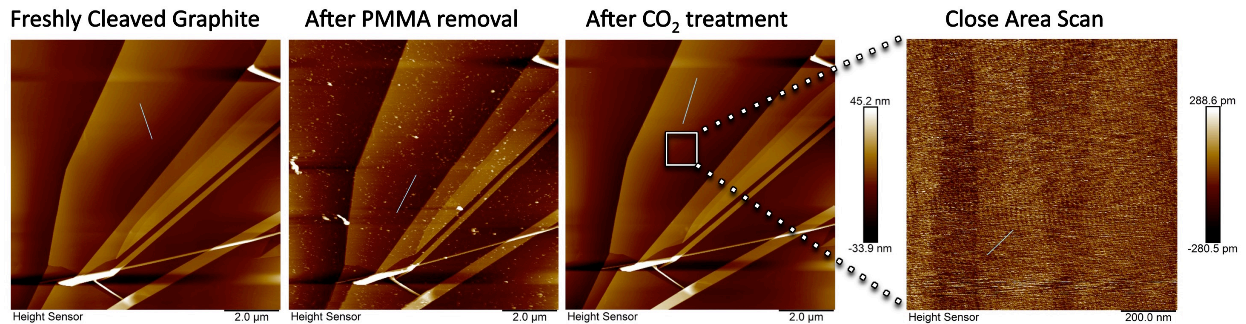

Fig. 2: Graphene clean by CO_2 annealing

Publications (papers/posters/presentations):

E. Hunckler, E. Kinder, S. Fullerton "Removing surface residue from graphene *via* CO_2 annealing" NURF Research Presentation (Oral) 7/22/2015

E. Hunckler, E. Kinder, S. Fullerton "Removing surface residue from graphene *via* CO_2 annealing" Notre Dame Undergraduate Research Symposium (Poster) 7/31/2015