Nanoelectronics Undergraduate Research Fellowship (NURF)
2010 Project Summary

Student name: *Timothy Schumer*
Faculty mentor name: *Dr. Prashant Kamat*
Project title: *Storing and Shuttling Electrons in Graphene: Controlling the Size and Loading of Catalyst Metal Nanoparticles with Light.*

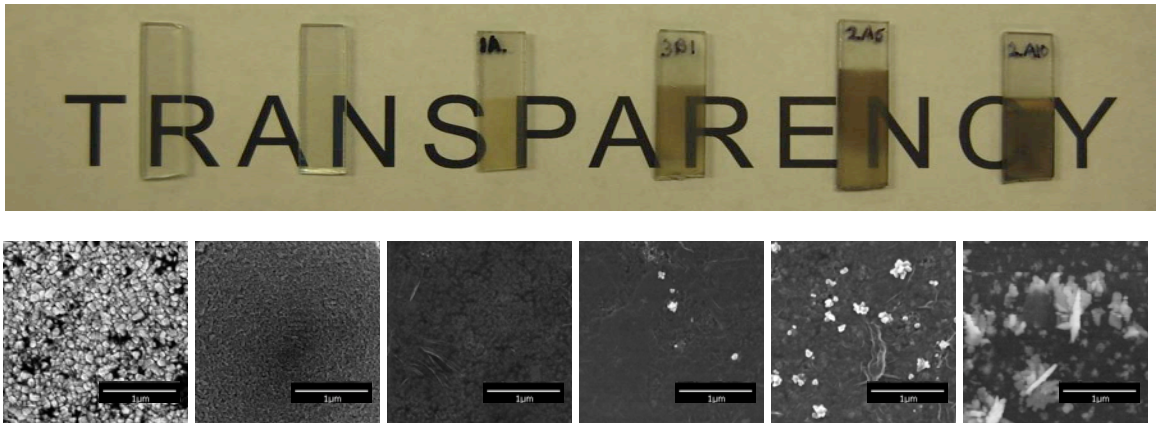
It has been shown that Reduced Graphene Oxide (RGO) is able to shuttle and store electrons (Lightcap, I. V., Kosel, T. H., and Kamat, P. V. Nano Lett. **2010**, 10, 577– 583). In this project they employed a solution of RGO, TiO_2, and $AgNO_3$ in ethanol and irradiated it with UV light. Bandgap excitation of TiO2 creates electron-hole charge separation. The ethanol scavenges the holes while the electrons are stored in surface defects of the TiO_2. The electrons are transferred to a RGO sheet, which shuttles them across its planar surface. Ag+ ions reduce onto the RGO sheet at a location different from the TiO_2 proving the RGO able to shuttle electrons. The goal of my project was to mimic the first experiment but to do so in solid state.

The first task was to create a uniform coating of TiO_2 then to deposit a uniform monolayer of RGO on top of the TiO_2 layer. Finally after trying a variety of methods Doctor Blading proved to be useful in creating a uniform TiO_2 film. I would lay two pieces of scotch tape perpendicularly across a Fluorine Doped Tin Oxide (FTO) slide creating a trough (few microns deep) in the middle. I would cover the trough with a TiO_2 paste and pushed across the excess paste with a flat edge. The TiO_2 coated FTO plates were annealed at 400°C burning off the organics. I was left with a uniform TiO_2 film about 5-8μm thick.

Depositing the RGO film on top of the TiO_2 film proved to be much more difficult. The film needed to cover all of the TiO_2 but still be as thin as possible. After weeks of trying numerous methods I found a solution. I used Electrophoretic Deposition. I immersed my TiO_2 slide in a .5mg/mL Graphene Oxide (GO)/Ethanol solution with a clean FTO slide as the counter electrode. I applied a 30V dc between the two slides. The negatively charged RGO sheets were drawn to the positive TiO_2 electrode depositing a covering layer varying from one to a few layers deep.

After I had prepared a few slides to ensure reproducibility I immersed the films in ethanol and irradiated with UV light onto the deaerated sample. Purging the sample with N_2 prevented the photogenerated electrons from being scavenged by the O_2. Deaerated 20μL of $AgNO_3$ was then added to the ethanol solution and we irradiated each sample for different amounts of time. Ag+ ions scavenged the electrons and become reduced on the RGO film. With increasing irradiation time we expect more of Ag cluster deposition. Using absorption spectra and SEM imaging the silver deposition onto the RGO films was recorded.

These experiments confirm that the RGO layer deposited on TiO_2 film can transport electrons across and reduce Ag+ ions at the interface. With continued UV irradiation the Ag clusters grow in size, thus enabling the control of particle size. Further experiments are needed to establish the thickness dependence of RGO layer for electron transport and develop new catalyst materials.



Photographs and SEM images of FTO slides coated with TiO_2 (5µm thick) and reduced graphene oxide (1-4 layers) and deposited Ag clusters using UV irradiation at different times. (a) FTO, (b) FTO/TiO_2, (c) FTO/TiO_2/RGO, (d) FTO/TiO_2/RGO/Ag (1 min irradiation), (e) FTO/TiO_2/RGO/Ag (5 min irradiation), and (f) FTO/TiO_2/RGO/Ag (10 min irradiation). Note the growth of Ag clusters durng UV irradiation in panels d-f

I took part in the Summer Research Symposium held in Jordan Hall on August 6th with my poster: Storing and Shuttling Electrons in Graphene: Controlling the Size and Loading of Catalyst Metal Nanoparticles with Light.

I presented a powerpoint of my project for Dr. Kamat's and Dr. Kuno's research groups on Thursday August 5th.