NDnano Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Tim Siegler
2) Faculty mentor names: Prashant Kamat and James Radich
3) Project title: Optimization of Lithium Ion Batteries Using Nanostructured Graphene Composites as Cathode Materials
4.) Briefly describe any new skills you acquired during your summer research
New equipment skills: potentiostat, impedance spectroscope, SEM, glove box
Synthesis methods: Cu_2S NP, Cu_2S/RGO, Cu_2Se NP, NW , Cu_2Se/RGO, CuSe NW,NT

5) Please briefly share a practical application/end use of your research:
Creating a cheaper counter electrode for rechargeable lithium ion batteries

Project summary:

Lithium ion batteries are of great interest as an energy storage mechanism for electric vehicles and intermittent energy sources. The high capacity and good reversibility of lithium ion batteries shows great potential for replacing most current battery technologies. However, this high capacity is mostly limited by the cathode (or positive electrode) of the cell. New materials that show good stability and moderate capacity could easily overtake the current $LiCoO_2$ commercial cell developed by Sony. Copper Selenides (Cu_2Se and CuSe), although largely unstudied as cathode material in this system, exhibit stable charge and discharge plateaus during high discharge rates and provide acceptable theoretical capacities. This summer, I attempted to utilize nanostructure synthesis methods to optimize the reversibility of batteries consisting of a lithium metal anode and copper selenide cathode.

In order to do this, several batteries were assembled in a custom-made separable battery tester with a Lithium anode and a cellulose separator, utilizing charge carrying metals to assist the transfer of electricity into the external circuit, as seen in Figure 1.

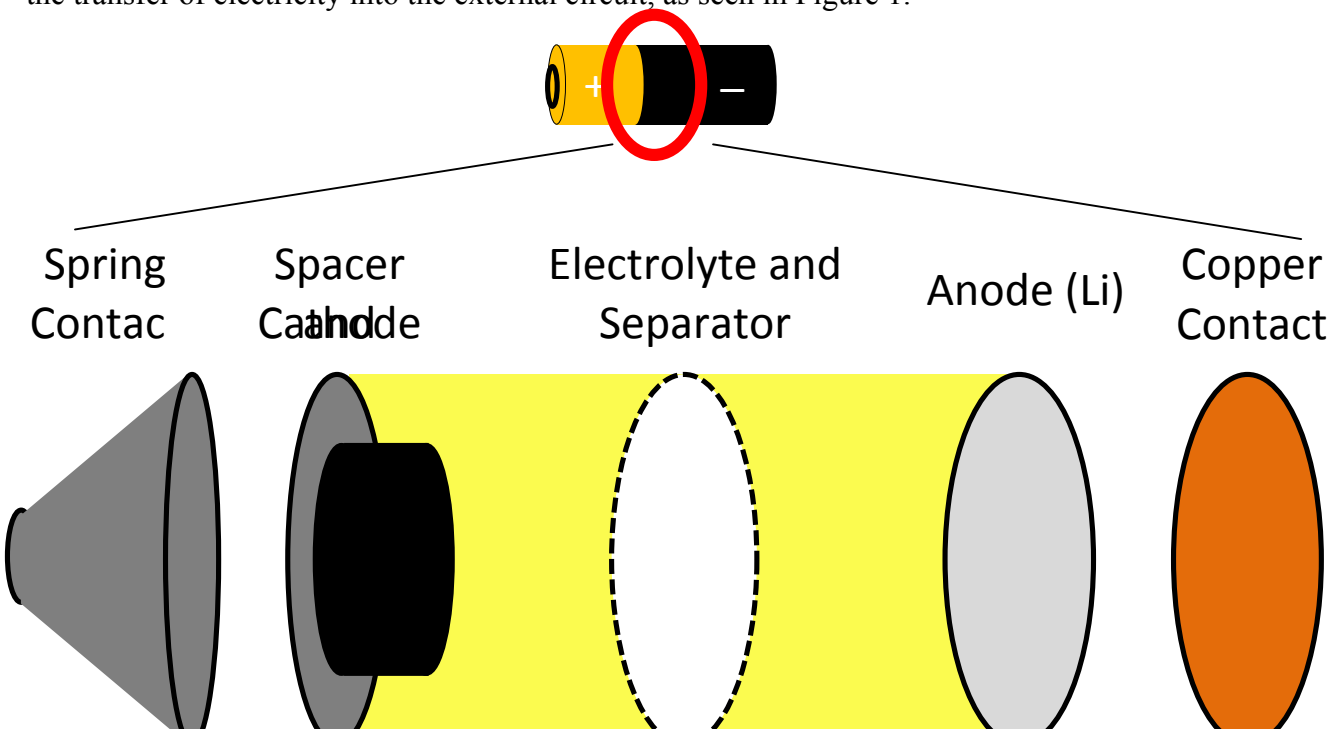

Figure 1: Schematic of Li Ion Storage Battery Employed in the Present Work

The various cathode materials were synthesized though different chemical pathways using chemical bath deposition methods. These materials then were mixed with carbon black and a binding material, converted to a paste, smeared thinly onto a sheet of roughened aluminum foil, and dried under vacuum. The first tested cathode consisted of bare Cu_2Se nanoparticles. This system showed good reversibility at high charge and discharge rates (specifically 1C), displaying a discharge capacity of around 90 mAh/g with only 1% capacity lost on average between cycles though 10 cycles. The capacity of this material was improved through the creation of a reduced graphene oxide (RGO)-Cu_2Se composite. Graphene, or superconductive single layered sheets of sp^2 hybridized Carbon atoms, was utilized in this system both as a method of increasing charge transfer and conductivity within the cathode material and as a nucleation substrate that inhibited dissolution of the conversion intermediates into the electrolyte upon discharge. The performance of these cells is detailed below in Figure 2.

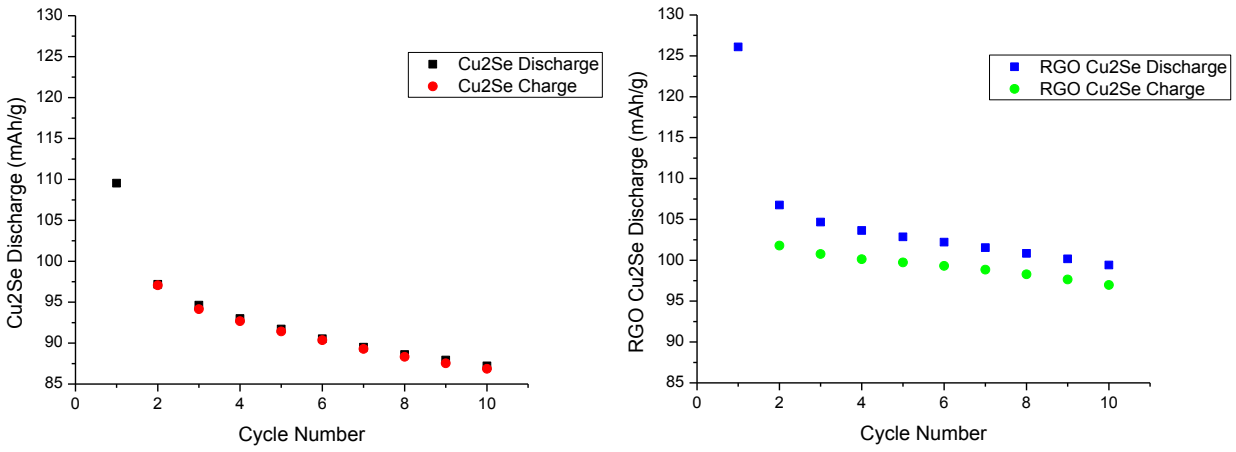

Figure 2: Copper (I) Selenide Cycling Performance

CuSe nanowires were also investigated as a cathode material in this system. Bare wires showed decent reversibility, displaying an initial discharge capacity of 114 mAh/g and only losing 4% from cycle to cycle. Likewise, an RGO-CuSe nanocomposite showed improved capacity (174 mAh/g on the first cycle) at each cycle, as is shown in Figure 3 below.

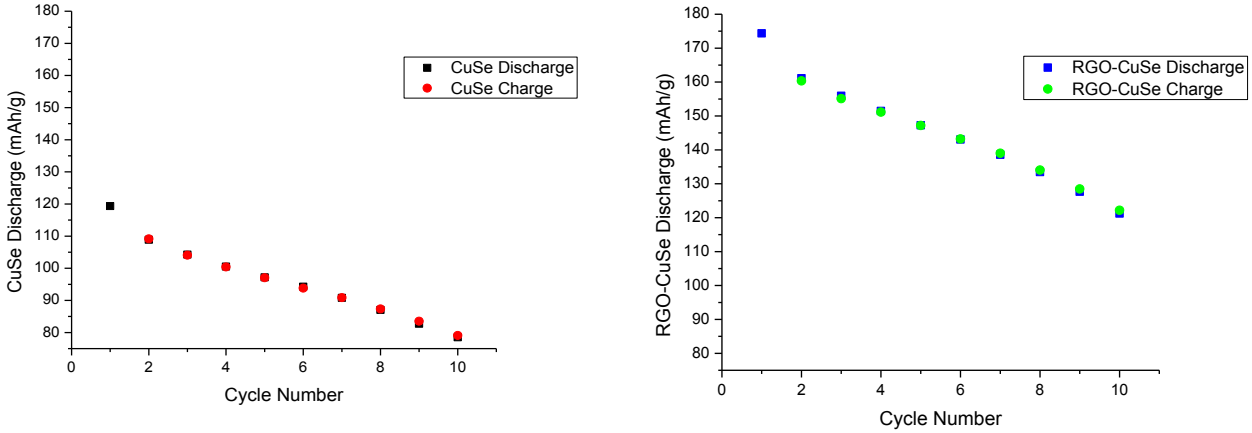

Figure 3: Copper (II) Selenide Cycling Performance

Overall, with RGO enhancements, nanostructured cathodes of Lithium Ion batteries using Cu_2Se were shown to have improved reversible capacity. CuSe, while having higher discharge capacities at each cycle and thereby more potential as a commercial cathode material, still displayed considerable capacity decay from cycle to cycle. Further work is underway to elucidate the capacity fading mechanisms so that better composite electrodes can be designed.

Publications (papers/posters/presentations): TBD (will probably be published later)