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

1. Student name: Isaac Wappes

2. Faculty mentor name: Prof. Prashant Kamat

3. Project title: Maximizing the Potential of Energy Transfer in Squaraine Dye / CdSe Quantum Dot Hybrid Solar Cells

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

During my research, I gained a great deal of both experience working in a lab and understanding the basic principals of photovoltaics. I learned an excellent method of synthesizing CdSe quantum dots as well as how to assemble efficient liquid junction quantum-dot-sensitized solar cells (QDSC). Another important aspect of my research was testing the cells. To do this I became familiar with several methods of spectroscopy and solar cell characterization including absorption spectroscopy, solar simulation using a PEC lamp and potentiostat, and IPCE.

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

The goal is to find a sustainable and clean source of energy for the long run. Solar energy has by far the most potential of any alternative energy source, but costs need to be lowered before the technology can have widespread use. We are trying to utilize the energy transfer capabilities of quantum dots to increase the efficiency of solar cells that are relatively low cost compared to their silicon counterparts.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities / results:

The goal of our project was to produce efficient QDSCs with CdSe quantum dots, using a squaraine dye called SQSH as the linker molecule. This design of solar cell was first completed by Choi[1], a former Postdoc in the Kamat Group. We set out to expand on his project by using different sizes of quantum dots to see how that affected the solar efficiencies. Furthermore, our goal was to add a zinc sulfide shell around half of the large QDs and compare the efficiencies of the solar cells which used the core-shell dots to those that just use the core dots. The thinking was the core-shell QDs should improve the solar efficiency because the shell increases the quantum yield of the dot by passivating surface trap states. The ultimate goal of this project was to make and test reproducible QDSCs using three sizes of QDs and one set of core-shell dots, and compare the efficiencies. This was not all completed this summer, but much of the groundwork was made, and I will continue with this project in the fall.

These cells are made by sandwiching together an electrode and a counter electrode with an electrolyte in the middle to complete the circuit. For the electrode, clean FTO glass was treated with $TiCl_4$, then thin layers of active and scattering TiO_2 were deposited on the FTO using the doctor blade technique. The electrodes were baked at various temperatures and finally treated with $TiCl_4$. Activating the TiO_2 required soaking for 12 hours in SQSH, then 48 hours in the QD solution. The active layer of the cell ideally looked something like this:

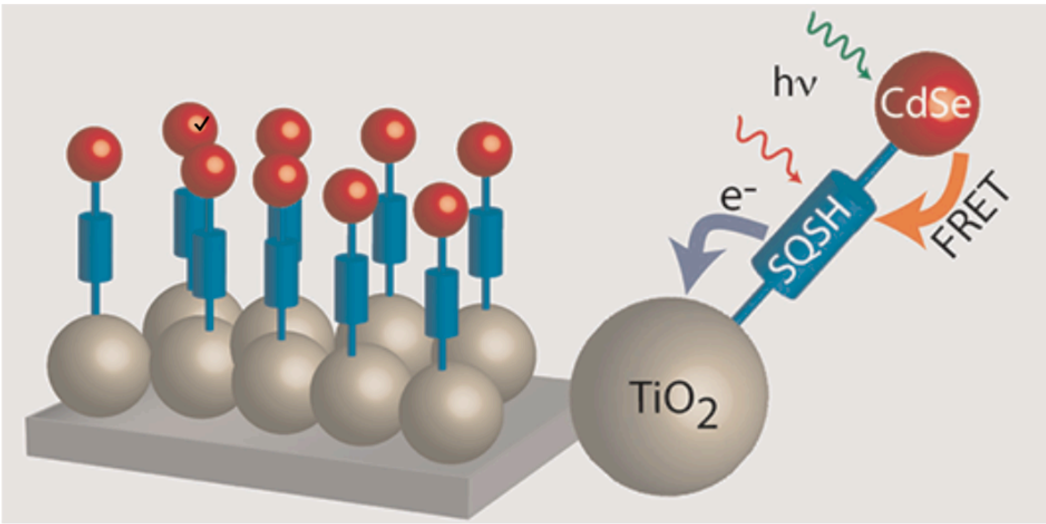

Figure 1: This illustration shows how that active layer of one of the cells should look. Notice the energy transfer from CdSe to SQSH and the injecting of electrons from SQSH to TiO_2. In addition to the CdSe absorbing solar energy, SQSH absorbs solar energy making it a better linker molecule than others such as 3-mercaptapropionic acid[1].

Counter electrodes (CEs) were produced by deposited a small drop of H_2PtCl_6 in ethanol on clean FTO glass and baking the CEs at 400 °C for 15 minutes. The cells were assembled via vacuum backfilling, with a hot melting film sealing the two components together, and a cobalt electrolyte was pumped into the cell, which was then sealed with a soldering iron. The final product looked like this:

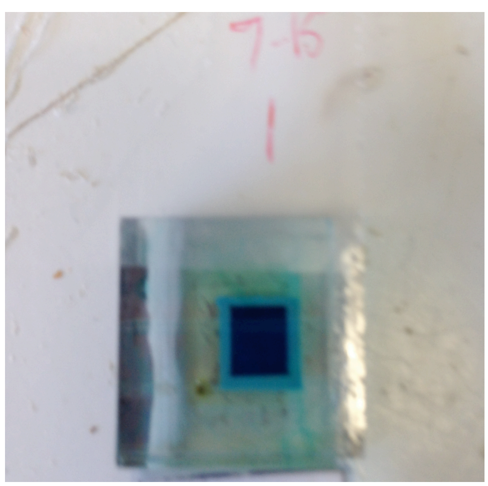

Figure 2: One of the many cells I made this summer. This particular cell happened to be the champion cell at 3.6 % efficiency.

Cells were immediately tested using a PEC lamp and a potentiostat. This kind of testing results in three kind of results: a measure of short circuit current versus time (IvT), a measure of open circuit voltage versus time (VvT), and current versus voltage (IvV). The graph of the champion (pictured above) SQSH cell's current density (J), which is current divided by active layer area versus voltage, is shown here:

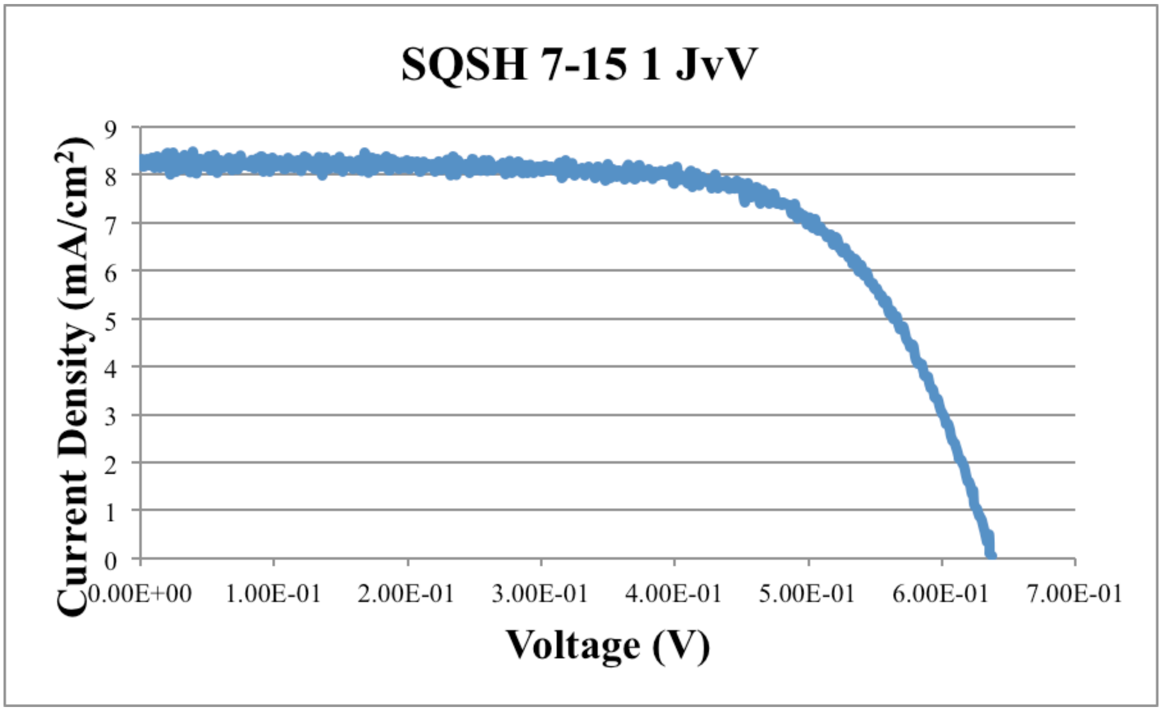

Figure 3: JvV curve for the champion solar cell (pictured above).

Most of the time spent this summer was spent working on getting a consistent SQSH cell. This is just a normal dye-sensitized solar cell that uses SQSH as the sensitizing dye. Once that was completed, the QDs were synthesized and the full QDSCs were made. However, there have been problems with the SQSH partially dissolving during the 48 hour QD soak and coming off the electrode non-uniformly. We have tried to rectify this by doing all the work in a glove box to minimize any exposure to water. There is not enough evidence yet to determine whether or not this has solved the problem, but further research this fall will help decide this. I am very grateful for this opportunity to have worked with an excellent group of people this summer. This experience has been enormously helpful in determining what want to research in the future. Furthermore I have learned many important techniques and skills that I will be able utilize for the rest of my career.

References:

1. Choi, H.; Santra, P. K.; Kamat, P. V.Synchronized Energy and Electron Transfer Processes in Covalently Linked CdSe-Squaraine Dye-TiO_2 ACS Nano **2012**, 6, 5718– 5726.