ND*nano* Undergraduate Research Fellowship (NURF)
2014 Project Summary

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2) Faculty mentor name: Dr. Kevin Stamplecoskie, Dr. Prashant Kamat

3) Project title: The Effect of Different Sized Gold Clusters in Solar Cells

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

During the past ten weeks I have acquired numerous technical skills as well as knowledge of the chemistry behind glutathione-capped gold clusters and solar cells. I became familiar with the synthesis of gold clusters and liquid-junction solar cells, which includes the Doctor Blade method of synthesizing solar cells. I also became familiar with several machines in the lab required for preparing and testing of solar cells, such as a UV-visible spectrophotometer and a centrifuge. Along with these technical skills, I also gained interpersonal skills such as presentation experience.

5) Solar cells can be used to satisfy the world's growing energy needs. The fact that solar power is renewable and carbon neutral makes it an even better source of energy. It can supply energy without harming the environment the way fossil fuels do. For these reasons, it is necessary to continue our research on solar power; this starts with research on solar cells. The main focus of solar cell research is to make them more energy efficient at a reasonable cost. In this field today, scientists are trying to determine which materials produce the best solar cells.

<u>Project Summary</u>

The goal of my project was to prepare liquid junction solar cells made with glutathione-capped gold clusters. I used four different sized gold clusters and observed the trend of each within solar cells. Out of the four clusters I dealt with this summer, $Au_{10\text{-}12}GSH_{10\text{-}12}$, $Au_{15}GSH_{13}$, $Au_{18}GSH_{14}$, and $Au_{25}GSH_{18}$, I wanted to determine which one would make the most efficient cell. From previous research, I knew that the electron transfer properties of gold clusters are size dependent. It was also determined that $Au_{18}GSH_{14}$ has the highest potential as a photosensitizer. From this, it was hypothesized that $Au_{18}GSH_{14}$ would also make the best solar cell. My research was used to verify this hypothesis.

Liquid junction solar cells work by electron transfer within the cell. When light hits the cell, it excites electrons in the photosensitizer, which in this case are the gold clusters. These excited electrons are injected into the conduction band of the TiO_2 electrode. The now oxidized gold clusters accept electrons from the redox mediator to return to the ground state. In my cells, I used a cobalt (Co(II)/Co(III)) electrolyte as my redox agent. Co(II) donates an electron to the gold clusters and is oxidized to Co(III). Co(III) is reduced back to Co(II) by accepting an electron from the platinum counter electrode.

The first part of my project focused on synthesizing the gold clusters and determining whether they were the correct size. I used a previously developed method to produce the gold clusters. It involved creating a solution of gold tetrachloroaurate (III) hydrate and $_L$-glutathione in deionized water. I separated the solution into four equal parts and raised the pH's to 7, 9, 10, and 11 using sodium hydroxide. The four solutions were then purged with carbon monoxide for approximately 2 minutes, which reduced the solutions to their corresponding Au_{10-12}, Au_{15}, Au_{18}, and Au_{25} clusters overnight. I repeated this process many times throughout the summer. The solutions did not always turn out and sometimes were a mixture of different sized clusters. I used a Varian UV-Visible Spectrophotometer to verify each solution was correct. Figure 1 shows correct absorbance spectra of each gold cluster solution.

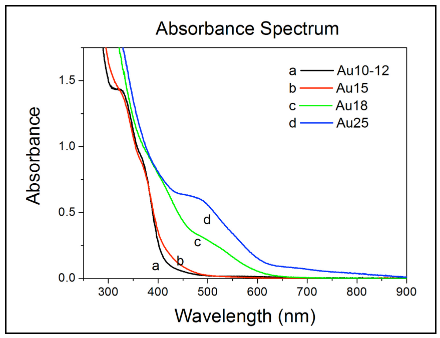

Figure 1. Absorbance spectra of CO reduced Gold Nanoparticles

The most challenging part of this project was the production of the cells. For my cells, I used the doctor blade method to make liquid junction solar cells for each gold cluster solution. This involves preparing electrodes by spreading TiO_2 active and scattering layers onto $TiCl_4$ treated FTO glass. Spreading the TiO_2 and absorbing the gold clusters onto it were the most challenging parts of the process. It takes practice to get consistent cells and a simple mistake can ruin an entire batch of cells. During a few of my batches, the TiO_2 I used was cracked and ruined the results of all the cells. To load the gold clusters onto the active layer of TiO_2, I had to immerse the electrodes in the gold solutions and change the pH of the solution to about 3. In my earlier batches of cells, excess Na^+ and GSH and low concentration resulted in low loading. Towards the end of the summer, we tried a new technique, which involved washing each gold cluster solution through a filter using a centrifuge. This removed excess Na^+ and GSH, as well as decreased the volume, which increased the concentration of the gold clusters in the solution dramatically. This allowed better loading onto the TiO_2, which is clearly visible in Figure 2. The active layer of the cell that was immersed in the washed solution is much darker than the cell immersed in the original solution.

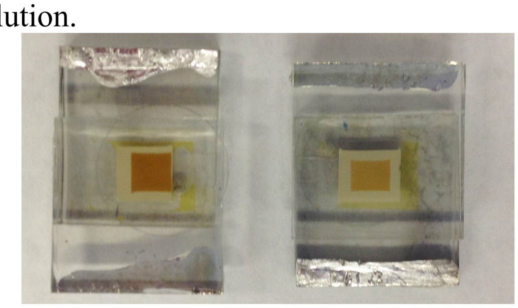
Figure 2. $Au_{18}GSH_{14}$ solar cells by doctor blade and backfilling method; right cell using original concentration and left by highly concentrated, washed solutions.

Once the cells were produced, I measured them using a lamp that imitates sunlight. I measured current vs. time (It), voltage vs. time (Vt), and current vs. voltage (IV) on each cell. I then plotted the results and compared the cells made with different sized gold clusters. Figure 4 shows the results for one of the batches of cells I prepared this summer. The results followed the trend we expected in that Au_{18} made the best solar cell by far. This trend was consistent in all of the batches of cells I produced.

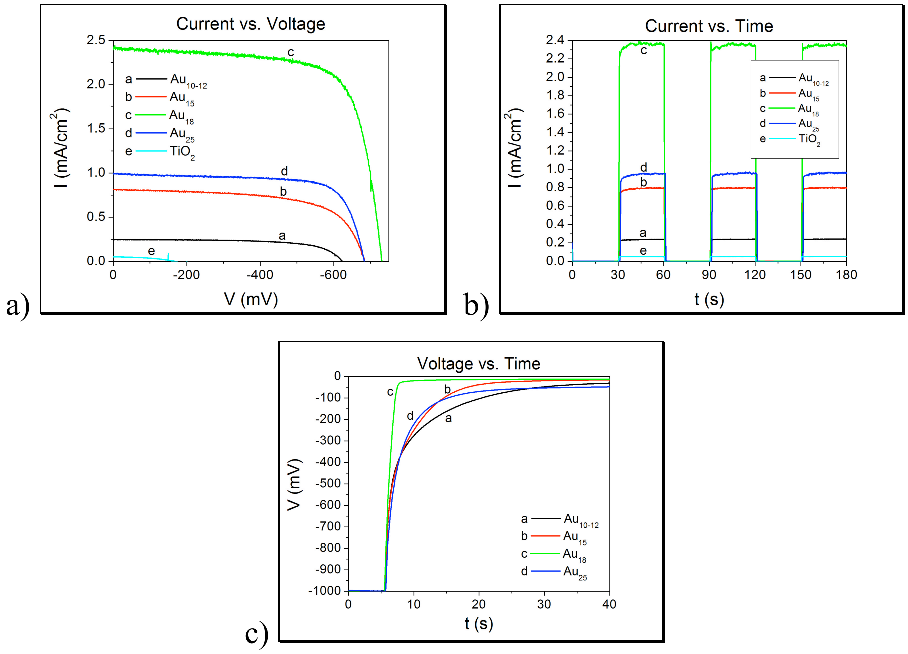

Figure 4. a) IV graph b) It graph and c) Vt graph for a batch of Au_xGSH liquid junction solar cells.

It has already been established that the efficiency for gold cluster solar cells are low. The highest ever recorded was a little over 2%, and that was with a solution made up of a mixture of different sized gold clusters. The highest I ever recorded was 1.4% for a Au_{18} cell. The average efficiency I recorded for the Au_{18} cells I made this summer was around 1%. Aside from the 1.4% efficient batch, the cells were fairly consistent all summer. Due to faulty TiO_2, I did not have enough time to determine whether the newly washed solutions dramatically increased the efficiency of the solar cells.

Overall, I reached the goal we made this summer. I produced numerous gold cluster solar cells and helped develop a more effective way to prepare them. I may have come across some obstacles this summer, but I succeeded in proving the hypothesis that Au_{18} clusters make the most efficient solar cells out of the four gold clusters I tested. I was also able to gain exceptional lab experience and am glad to have the opportunity to return to the lab this fall and continue my work with liquid junction gold cluster solar cells.