ND*nano* Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Amy Garde
2) Faculty mentor name: Luis C. Fernandez-Torres
3) Project title: Synthesis of novel semiconductor nanostructures

4) Briefly describe any new skills you acquired during your summer research:
Before starting this research project I was not familiar with chemistry in any form. However over the course of the 10 weeks, the knowledge and skill involved in chemistry and specifically the skills required for this project have now been acquired. Now I can confidently prepare a solution and understand the reactions that may occur as a result. I have also acquired a familiarity with several analytical machines, such as X-ray photoelectric scanning and scanning electron microscope, and I understand the data that they acquire.

5) Please briefly share a practical application/end use of your research:
One practical application of this research is to use the method to develop semiconductor nanostructures, which will be used in solar cells. The project is to develop a simple method that will not only be cheaper but it will also aid in the further development and distribution of solar technology.

Project summary:

At present the methods used, to develop semiconductor nanostructures, are complex, time consuming, very expensive and not always environmentally friendly. The challenge for this project is to test a simpler method, which is quick and easy to prepare using water or ethanol as solvents. It is to take place at a lower temperature and for a shorter period of time. These desires enable the method to be straightforward and not as expensive. Although it is not explicitly environmentally friendly, it is a lot better then its complex counter part.
The goal of this project is to show that this simple method develops semiconductor structures that conform to the results found in more complex methods, with the application of photovoltaic cells in mind.

This project is the synthesis of zinc, cadmium and lead nanostrucutres. Using mostly environmentally friendly solvents and solutes, aqueous and ethanolic solutions are produced. The method involves taking a metal source (Zn, Cd or Pb) and reacting it with a sulphur (Thioacetamide, Thiourea or Adamantanethiol) or selenium (Selenourea) source. Most of the reactions required additional help in the form of a reducing agent (Hexamethylenetetramine). The reactions take place at low temperatures, below 100C and under atmospheric conditions.
The resulting nanostructures were CdS, CdSe, ZnS, ZnSe, PbS and PbSe. These possible nanostructures were analysed by various means. This analysis includes X-ray Photoelectron Spectrometer (XPS) and Scanning Electron Microscope (SEM). Here the composition and image, respectively, of the sample is devised. The XPS can confirm the presents of the desired

component, such as the metal and sulphur component, and will produce a graph with binding energy of each element. While the SEM gives an image of the sample and this helps with identifying the size and shape of the sample. Most of the nanostructures were nanoparticles, ranging from 150 nm to 500 nm in size. For most nanoparticles the shape was spherical with the possible exception of the PbS, which appeared to have formed a conglomerate of cylindrical features.

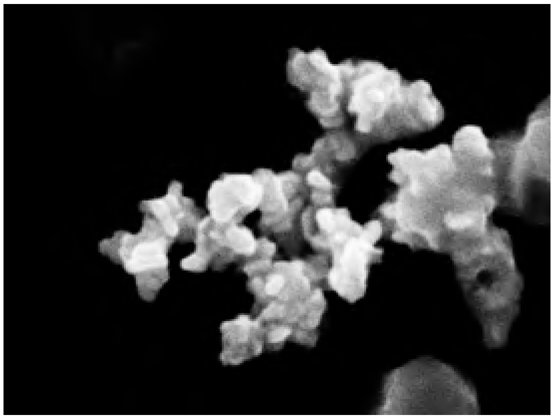

Figure 1: Lead Sulphide image from SEM

Another interesting result was in the Adamantanethiol based sulphur samples. Here the nanostructure that appeared was fibrous, ranging in thickness from 100 nm to 350 nm. Through further analysis it became clear that these nanofibres might work well when bonded with other nanoparticles.
A usual result that occurred was when a sample was heated to a high temperature, above 100C. Here the XPS analysis identified a set of peaks as chlorine. However there was no chlorine used in any of the processes and hence this mystery element was investigated further. Through a temperature-varying test, where a sample was heated in increments followed by an analysis using the XPS after each heating, it became clear that the mystery element only appeared when the temperature was above 100C and grow in strength as the temperature grow.

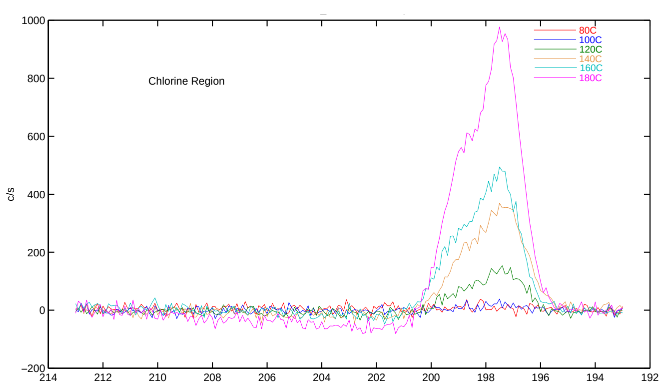

Figure 2: XPS spectrum of the Mystery Chlorine region

The main outcome of this research is that there is a lot of promise for future application into photovoltaic cells by developing these nanoparticles and nanofibres in such a simple and more affordable way. Therefore a proof of concept of organic photovoltaic cell assembly was demonstrated. Here a process called self assembled monolayer (SAM) was employed. This process involved using flame annealed gold, which has been incubated in Mercaptoundecanoic acid (MUDA), and dipping it into a sample which has not reacted yet. Then with the gold in the solution, the reaction takes place by placing the sample in the oven. The mounted gold was then analysed using XPS and the results revealed that the nanoparticles became attached to the gold. The samples that were tested using this method were cadmium and zinc sulphide nanoparticles.