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

1. Student name: Albert Pucci

2. Faculty mentor name: Prof. Mark Wistey

3. Project title: Efficient Upconversion in Solar Cells

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

I worked extensively with Sentaurus TCAD in order to model the rate of recombination losses in the project's proposed solar cells (CSUNs). I had never worked with TCAD before and I therefore learned a new language and modeling application. I also learned how to navigate files and directories using UNIX. I had never use UNIX before and I therefore acquired this skill as well. I also have acquired the skill of reading technical papers in order to find relevant information for the project.

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

The main focus of my research was creating a model for the recombination rate in the Core-Shell Upconversion Nanostructures (CSUNs) that the Wistey group is studying to make solar cells more efficient. Recombination is one of the biggest sources of energy loss in the solar cell when trying to convert light to power. The losses that my model calculates will be included in a computer model that calculates absorption rates in CSUNs. Combining the two will create a more accurate and realistic model for the efficiencies of different CSUN designs. The combined model will then be used to design the most efficient CSUN based solar cells.

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

The world currently generates most of its power from fossil fuels. However, fossil fuels will run out, and burning them has negative environmental effects. Therefore there is a need for alternative energy sources. Solar power is one of the alternative energy sources that can help replace fossil fuels. In order for solar power to replace fossil fuels, solar cells must become more efficient. The project I worked on uses a core-shell upconversion nanostructure (CSUN) solar cell design in order to get higher efficiencies. CSUNs consist of a core of one type of semiconductor with a second semiconductor wrapped around it, all embedded within a host solar cell. The core has a smaller bandgap than the host, which allows it to upconvert two low-energy photons to excite one electron from the valence band up to the conducting band of the host. This allows the solar cell to absorb low-energy photons that are being wasted by current solar cells. The upconversion process process is shown in Figure 1. The first photon excites the electron from the valence band of the core to the conduction band of the core. Then the second photon excites the electron from the conduction band of the core to the conduction band of the host. The barrier prevents the electrons in the host's conducting band from falling back into the core and recombining.

In my project I looked at the recombination rate as a function of the thickness and potential energy height of the barrier. I used TCAD to simulate how much tunneling through the barrier would occur at different barrier heights and thickness and what the recombination rate was associated with specific barrier heights and thickness. For my simulation I used GaAs for the host material, AlGaAs for the barrier material, and InGaAs for the core material. The height of the barrier was adjusted by the concentration of Al in the AlGaAs. The higher mole fraction of Al the higher the barrier is. I result from TCAD gives the recombination rate versus barrier heights and thickness at a voltage of about 0.1 mV. I had to extract this data using a Perl script. I then used MATLAB to plot the results, which are shown in Figure 2. The results show indicate that a barrier thickness of at least 5 nm would be best and that the mole fraction of Al in the AlGaAs barrier should be as high as possible. These results will be used to help design the best geometry and materials for the CSUN design.

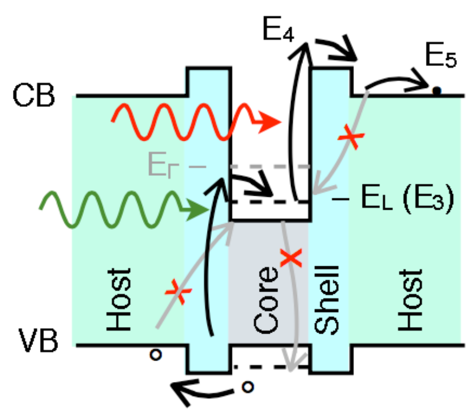

Figure 1. Energy bandgap of CSUN upconversion model

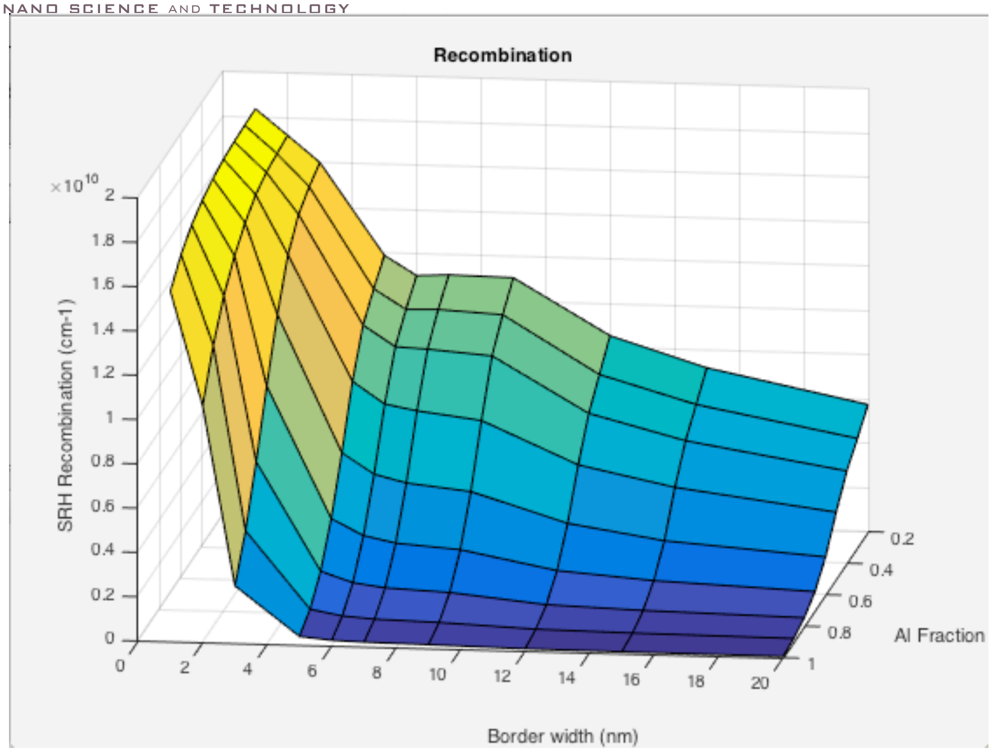

Figure 2. Recombination versus border width and Al fraction