Developing Thin-film Photovoltaics from Nontoxic and Earth Abundant Materials

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Abstract and Introduction

The most abundant source of renewable energy is the sun. Thin film Photovoltaic Cells (solar panels or solar cells) directly convert sunlight to electricity using a combination of several semiconductor layers. Choosing the right material to capture light involves measuring the difference between two energy levels called the valence band and the conduction band.

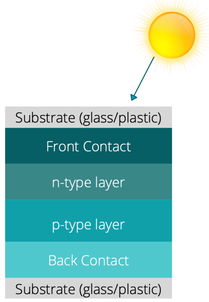

Figure 1: General structure of a Photovoltaic Cell

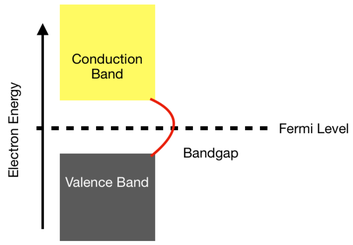

Figure 2: Conduction and Valence Band Energy Diagram

So far, The current leading solar PV technology is wafer based crystalline silicon (c-Si) as it is technologically mature and currently large scale in manufacturing capacity (MITEI). However, c-Si is very expensive since converting silicon dioxide into silicon requires a lot of energy, and pure silicon requires a lot of energy as well. This has thus led to research into thin film PV alternatives. Current commercial thin film PV technologies are primarily made up of Cadmium Telluride (CdTe) and Copper Indium Gallium Diselenide (CIGS). Unfortunately, these commercial thin film technologies are based on rare elements, making it costly as well (MITEI). With solar power being one of the most promising renewable energy technologies, an abundance of research efforts has gone into developing technologies that will reduce cost of PV generated electricity. However, despite technological advancements thus far, solar cells still face many obstacles with cost, efficiency, and safety in production being some of the largest issues. The current best thin-film PV options require toxic or rare elements (e.g. CdTe). Given these limitations, the current challenge is to prepare thin films of light absorbing materials with control over the possible defects.

In this research study, I used the SCAPS modeling software[1] to simulate different photovoltaic devices with the goal to find the highest efficiencies possible with different parameter combinations. These findings are essential information to my continued research when I return back to campus and continue to create physical photovoltaic devices in the Davis Lab as I will then be able to construct devices with the highest efficiencies possible based on modeling results.

Materials and Methods

After coming to a conclusion to focus on GeS and CuO for my p-type layer in PV cells, the SCAPS modeling software was used to model different devices using GeS and CuO as the p-type layer and ZnO as the n-type layer. I focused on varying layer thickness, electron and hole mobility, and acceptor and donor density to see how these parameters affected the efficiencies of the photovoltaic device created. I also looked at which front and back metal contacts would be the most the most appropriate contacts for each type of device.

References

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Results

GeS/ZnO Photovoltaic Cell

From modeling this cell with base parameters and no defects, I found a open current (Voc) of 0.7401, a Fill Factor (FF) of 56.1, and an overall efficiency of 6.91%. **This efficiency is the electrical power out divided by the solar power in shining on the device.**

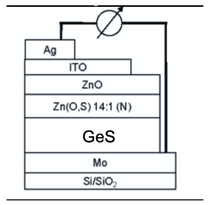


Figure 3: GeS/ZnO PV Cell Structure

From varying layer thickness of the different layers, it was found that increasing the thickness of p type layer GeS, the efficiency increases, while increasing the n type layer ZnO leads to a decrease in efficiency, but all to a very small extent. It was thus found that increasing layer thickness will not affect efficiencies by much.

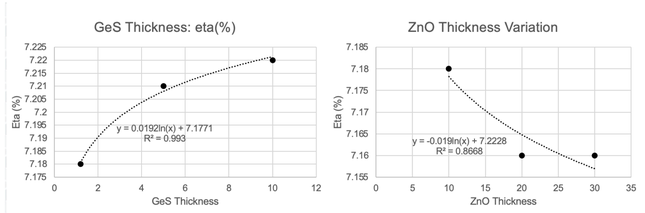


Figure 4: GeS Thickness and ZnO Thickness Variation Graph

Varying Acceptor and donor density, it was found that there were general increases in efficiency with acceptor and donor density, but the increases grew smaller as it increased further. The highest efficiency is when ZnO has a Donor Density of 1.1E+19 and GeS has an acceptor density of 2E+17.

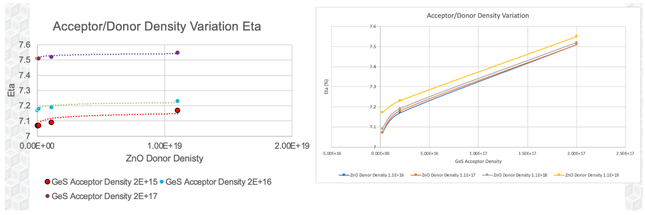


Figure 5: GeS Acceptor and ZnO Donor Density Variation Graph

From varying hole mobility, it was found that there were general increases in efficiency with GeS Hole mobility but efficiency did not vary much with ZnO Hole mobility. The highest efficiency found was when GeS had a hole mobility of 1.5E+1.

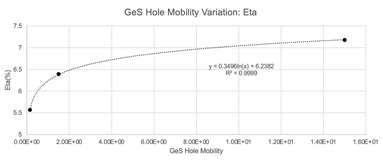


Figure 6: GeS Hole Mobility Variation Graph

GeS/ZnO Photovoltaic Cell without the Sulfur Doped Layer

This modeled cell only had GeS and ZnO for the p and n type layers. The data for the parameters used for ZnO was taken from experimental results that the Davis lab previously recorded, while the GeS data (such as acceptor and donor density and hole mobility) was based on data from other studies. From base parameters, overall efficiency of 10.09%. Varying various metals for front and back contacts, the best metal contact options found for Nickel to be the back contact and Molybdenum to be the front contact metal.

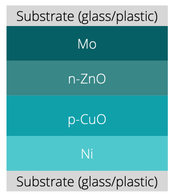


Figure 7: GeS/ZnO PV Cell Structure with front and back metal contacts

Results (continued)

CuO/ZnO Photovoltaic Cell

The CuO/ZnO cell modeled in this study was based on the parameters from the study, Chudy et al, that also modeled PV Cells using SCAPS. From base parameters, the open current (Voc) found was 0.7918, Fill Factor was 85.96%, and overall efficiency was 17.38%.

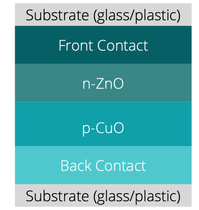


Figure 8: CuO/ZnO PV Cell Structure

Varying electron mobility, it was found that the cell efficiency did not vary much with electron mobility of both CuO and ZnO.

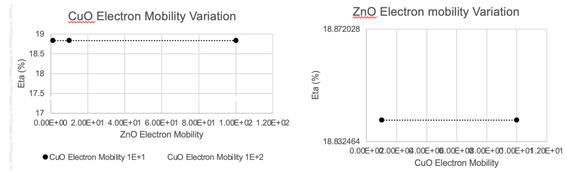
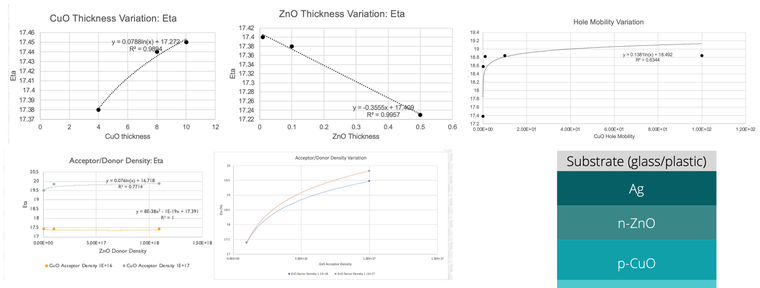


Figure 9: CuO and ZnO Electron Mobility Variation Graph

Similar trends to the GeS/ZnO cell were found when varying layer thickness, acceptor and donor density, and hole mobility.



The most appropriate metals found for the front and back metal contacts of this cell structure was Nickel (Ni) for the back contact and silver (Ag) for the front contact.

Figure 10: CuO and ZnO Cell Structure with front and back metal contacts

Conclusions and Future Work

The applications following this research has potential to impact the everyday lives of people as once low manufacturing cost solar energy has been harnessed, solar energy can be used by more people. With solar cells being clean and renewable energy, the widespread use will thus greatly benefit the environment and limit climate change. Photovoltaics make good use of the energy of the sun and convert it into electricity that can be used to make households greener and more environmentally friendly. For future work, I will be continuing this research when I return back to the campus Davis Research Lab by creating the cells that I have modeled on SCAPS in the lab.

Acknowledgements

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