UCD School of Chemical & Bioprocess Engineering

Pat McAdam Scholarship Report 2017

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INTRODUCTION

Cadmium telluride solar cells are currently the most popular type of PV (photovoltaic) solar cell. CdTe solar cells employ thin film semiconductor technology, whereby they absorb light and convert it to electricity. CdTe solar cells acquire their name from one of just a number of layers which compose a cell. The various layers which form a solar cell can be seen in Figure 1. The layer of interest for the research described in this report is the n-type window, which is composed of CdS. The commercial success to CdTe cells stems from their low production cost relative to their competitors. These solar cells have the smallest CO_2 footprint of all solar technologies.

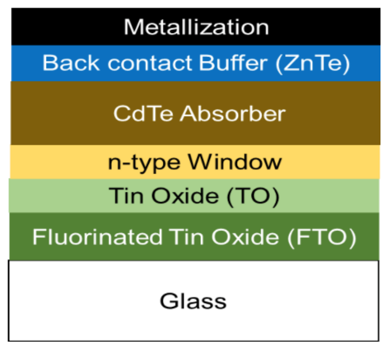

Figure 1: Layers in a CdTe solar cell

However, CdTe cells also have a number of disadvantages associated with them. The toxicity of cadmium has caused public divide when it comes to the use of CdTe in renewable energy technologies. However, in terms of efficiency, the main issue regarding CdTe cells is the transparency of the CdS window layer. A faint yellow complexion hinders the absorption of light into the cell and hence limits the efficiency of electricity production. The purpose of the research conducted is to replace this layer with materials that afford increased transparency and higher efficiency.

WHY MZO?

MZO, of chemical composition MZO = MgxZn1-xO, is the suggested replacement for the CdS n-type layer. The associated band gap of such a layer is the incentive for its use in solar cells. Figure 2 illustrates the layers of a CdTe solar cell, as well the advantages of MZO versus CdS. MZO offers a large adjustable band gap via Mg substitution into the ZnO lattice and can tune the conduction band offset.

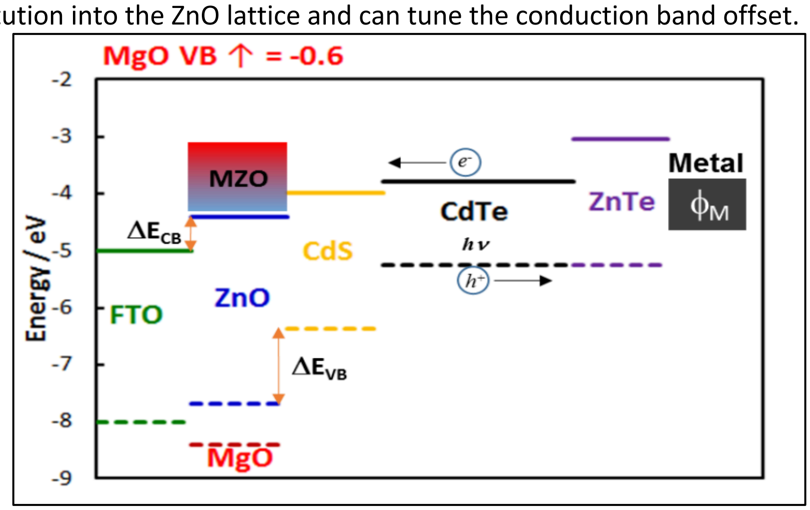

Figure 2: Diagram illustrating band gap of window layers in CdTe solar cell

EXPERIMENTAL WORK

Daily experimentation focused on the investigation into the sputter deposition of both ZnO and MgO. The aim was to validate the rate and investigate the properties of ZnO and MgO. Following said investigation, MZO could then be synthesised by co-sputtering.The substrates used for the sputter depositions were glass and Si slides.

Figure 3: Sputter deposition chamber

ZnO Film Deposition:

For the sputter deposition of ZnO, a ZnO target (disc) was inserted into the sputter chamber and the depositions were carried out using Argon gas at ambient conditions. Primary investigation involved determining the rate as a function of power. Professor Wolden wanted to achieve a rate of approximately 5 nm/min, as he believed that this rate would best facilitate co-sputtering in future experiments. Depositions were carried out at room temperature and varying levels of power.

Figure 4 shows that a linear relationship was observed between power and deposition rate. The optimum power for the targeted rate was determined to be 150 W.

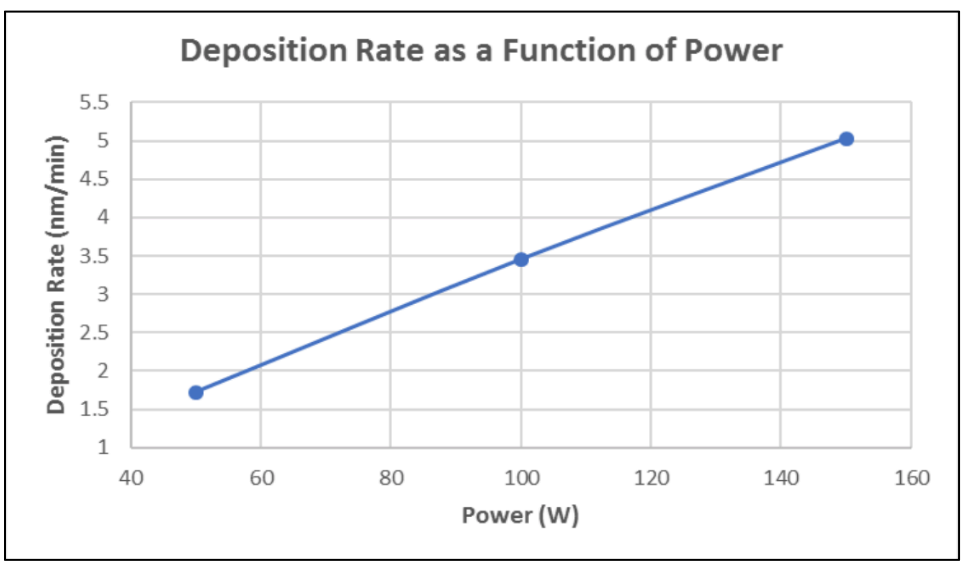

Figure 4: ZnO deposition rate as a function of power at room temperature

Following the determination of the optimum power, sputter depositions were carried out at 150 W, with the variation of temperature.

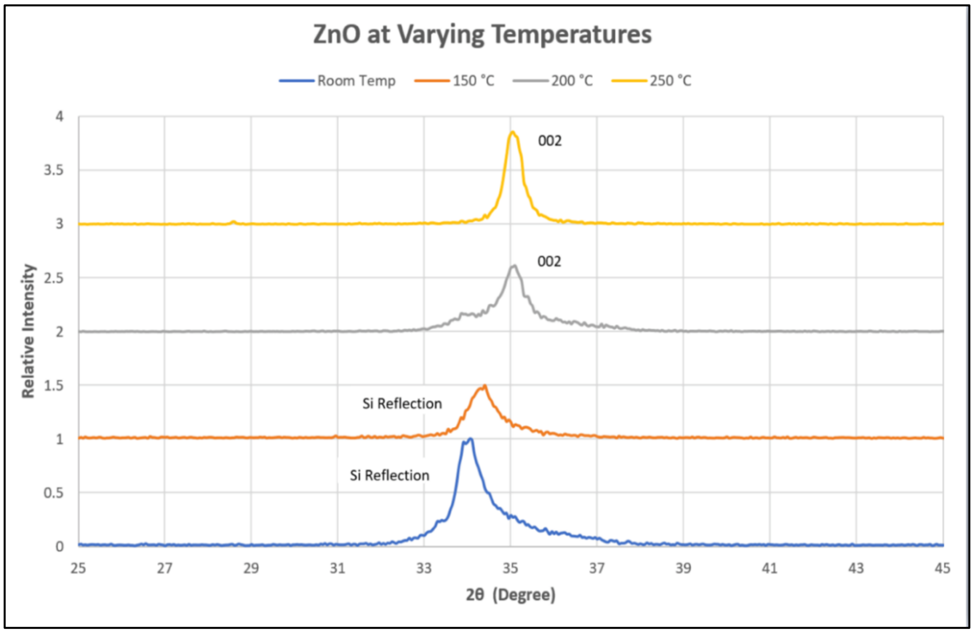

Figure 5: XRD analysis of ZnO at 150 W at various temperatures

XRD analysis of the samples yielded interesting results. At lower temperatures, peaks appear on Figure 5. However, close investigation of these peaks reveal that they are caused by the reflection of a much more intense Si peak at approximately 68 to 69 degrees (not shown in Figure 5). Hence, a peak is observed at the half-way point of approximately 34 or 34.5 degrees on the x-axis. The peaks observed at temperatures of 200 °C and 250 °C confirm that an increase in temperature, increases the crystallinity of the material. Therefore, one can see a transition from amorphous to crystalline as the temperature increases to around 200 °C. The intensity of the peak at 250 °C relative to 200 °C again demonstrates the effect of temperature on crystallinity. It was also found that the material was highly textured in the 002 orientation.

Alongside the sputter chamber and XRD machine, other equipment used included an ellipsometer and UV vis equipment. The ellipsometer was used to determine the thickness of the film produced on the glass and Si samples after sputtering. This facilitated in the determination of the deposition rate. UV vis enabled the determination of the band gap, when various calculations and plots were produced. The band gap of ZnO was found to be approximately 3.3 eV.

MgO Film Deposition:

The sputter deposition of ZnO proved to be relatively straightforward. This was due to the use of a ZnO target. MgO on the other hand was far more difficult. For the production of MgO samples, reactive sputtering was employed. An Mg target was inserted into the sputter chamber and a mixture of argon and oxygen gases was pumped into the chamber at ambient conditions. The challenge was to produce glass slides with a clear oxide layer, as opposed to a metal layer when carried out at undesirable conditions. All depositions were carried out at room temperature and the ratio of oxygen to argon gas was varied, as well as the current. Oxide layers were observed in depositions of approximately 3-4% oxygen.

However, further experimentation revealed inconsistencies. Namely, carrying out two depositions at the exact same conditions, could produce an oxide layer one time, but a metal the next. The current was identified as a source of interest. Further investigation revealed that a surge of power was sometimes observed when varying the current for a deposition. Although the power was often reduced to the same level used in previous experiments, only depositions in which a power surge occurred yielded transparent oxide layers.

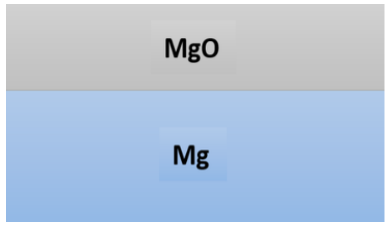

Figure 6: Formation of oxide layer on Mg target

It is thought that the cause for said phenomenon is the possible buildup of an oxide layer on the Mg target (as illustrated in Figure 6). Multiple reactive sputter depositions carried out in succession caused an increase in the thickness of this unwanted layer and so depositions involving only argon gas were carried out to try and reduce the presence of the oxide layer on the target.

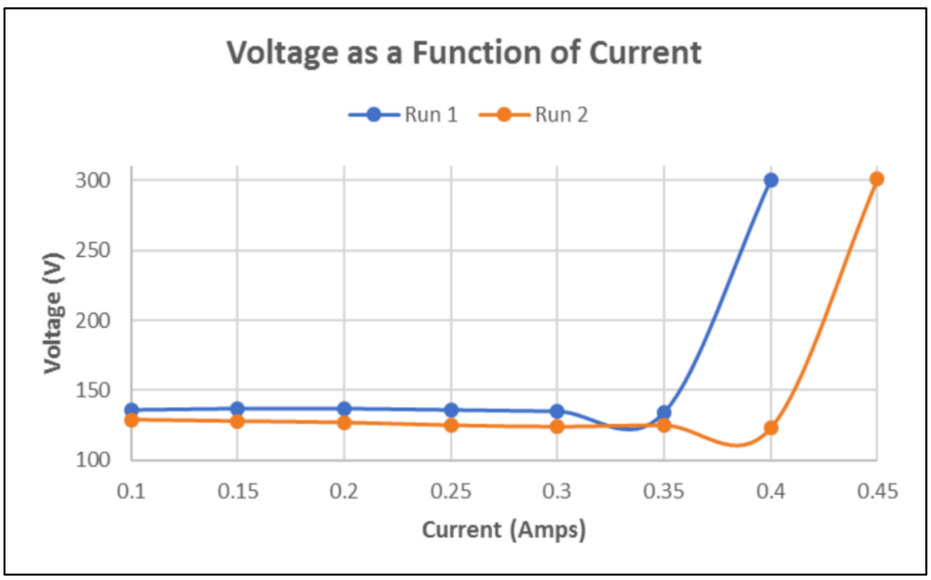

Figure 7: Voltage as a function of current for two depositions carried out at room temperature

Following multiple depositions, it was found that a power surge was often observed at approximately 0.4 Amps. This is illustrated by two separate depositions shown in Figure 7.

MOVING FORWARD

Due to issues involving the reproducibility of MgO depositions and several machine breakdowns, there was not sufficient time for me to carry out co-sputtering of ZnO and MgO. However, Professor Wolden said that he intends to keep working on the project. Achieving reproducible MgO sputtering is of primary importance. Co-sputtering may then be carried out and the MZO thin films integrated into solar cells.

OUTSIDE OF THE LAB

Thanks to the REMRSEC REU program I was fortunate enough to make some fantastic friends over the course of the 10 weeks. Outside of labs we spent all of our time together and living together in the college dorms meant that we became very close over the summer. Weeknights were spent watching movies together or playing soccer or frisbee at the sports field. Everyone was really into being in the outdoors and so every weekend was spent going to interesting places, mostly to go hiking. I made several trips to the Rocky Mountains and spent some time roaming around Denver and Boulder. I was also lucky enough to get to attend a concert at the famous Red Rocks amphitheatre and a baseball game between the Rockies and the White Sox at Coors Field. However, the highlight of the trip was the July 4th weekend. Ten of us decided to take a road trip and go camping for 4 days. We drove to Utah and Arizona and then back to Colorado. Along the way we stopped in Bryce Canyon and camped in Zion National Park while in Utah. We then drove to the Grand Canyon to see the sunrise. As we travelled through Arizona we also stopped at Antelope Canyon to take a tour. We then headed on to Mesa Verde where we camped overnight and finally stopped off at the Great Sand Dunes before heading back to Golden. It was a once in a lifetime experience and the sights were amazing.

Every Tuesday and Thursday we attended talks from different researchers and they told us about their work in the college. The talks were really interesting and the research being done at the School of Mines is without a doubt going to have an impact in the future.

A huge emphasis was put on networking. Professor Chuck Stone organised networking events to not only to help us get to know everyone in the REU programs, but also to meet some people doing internships in nearby science and engineering companies and students doing research at NREL. He also organised a tour of the nearby Edgar Mines.

Emily White, at the Grand Canyon, Summer 2017

CONCLUSION

The summer I spent in Colorado was undoubtedly the best summer of my life and an experience I will never forget. It was amazing to work on such a cutting-edge research project. The program was excellently organised and the attention given to each and every student was incredible. I was trusted to work by myself most of time and enjoyed being given such responsibility considering I had no previous research experience. A real effort was made to make the summer helpful for students who wish to do postgraduate study. I am very thankful to Prof. Wolden and Prof. Stone for taking such a genuine interest and providing me with fantastic support over the 10 weeks. I had never been away from home for a long period of time, nor had I travelled to another country on my own. This made the summer not only beneficial in terms of research and work experience, but also on a personal level it was hugely constructive. Finally, I would like to say how sincerely thankful I am to UCD and in particular, to Mr. Martin McAdam for supporting me with the Pat McAdam scholarship and enabling me to avail of this incredible opportunity.

Emily White (8th from left) at the REMRSEC REU at the Colorado School of Mines, July 2017.

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