Ordered Nanocrystalline Thin Films for High Efficiency CdS/CdTe Solar Cells

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Solar energy is one of the most abundant and nonpolluting renewable energy source our planet has. In recent years, solar cell devices of polycrystalline CdS/CdTe thin films have received intensive attention [1] [2] [3]. Before 1992 CdS/CdTe solar cells conversion efficiencies increased considerably as data shows in figure 1.[6] However, the conversion efficiency has been stagnated for the last 10 years between 16 and 16.5%. [1]

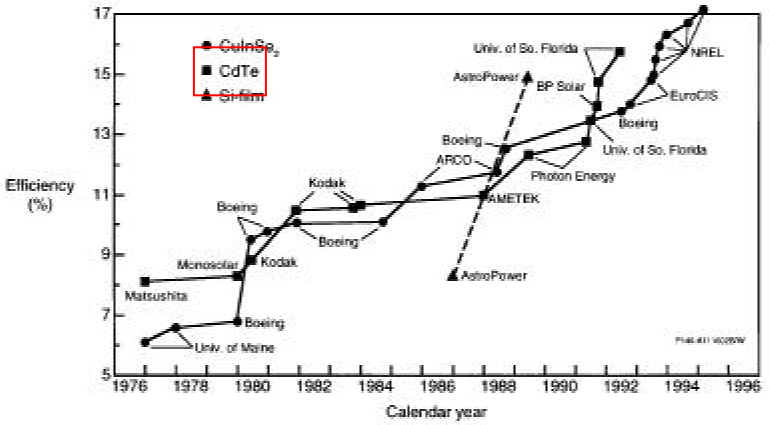
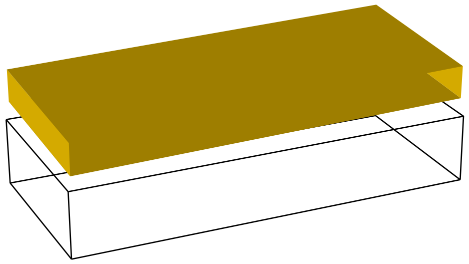


Figure 1. *Conversion Efficiency for CdTe solar cells*

Cadmium telluride has been recognized as a promising photovoltaic material for thin solar cells because of its near optimum bandgap of approximately 1.45 eV and its high absorption coefficient. [2] CdS has been found to be a well suited material as a heterojunction fellow with CdTe thin film solar cells. [2] Previous research has been done by Kyotaro, et al [3], that showed that thickness of CdS and CdTe affects solar cell efficiency. Researchers have also tried to increase the solar cell efficiency by changing the conventional SnO_2/CdS/CdTe structure into a modified CTO/CdS/CdTe device structure. [1] However, the solar cells conversion efficiency has not exceeded 16.5%.

The random nature of polycrystalline growth and non-uniform grain size of crystals are also a cause of problems. For example, device shunting [4], high surface recombination velocities and non uniform CdTe doping have all been attributed to grain boundaries and non-uniform grain sizes. [5] These types of problems lower the solar cell efficiency. We believe that by growing uniform and equally spaced CdTe single crystals on the CdS substrate we will solve the problems related to random natural polycrystalline growth. The typical structure of CdS/CdTe solar cell structure is shown in figure2.



In order to reduce the issues related to random natural polycrystalline films an ordered and uniform single crystals array of CdTe have to be grown on top of CdS. To grow an ordered array of CdTe crystals photolithography will be used to pattern a silicon wafer in squares with areas of 1-3 square micro-meters. This pattern will be able to provide a selective area growth for the CdTe crystals.

Silicon Dioxide (SiO_2) will be deposited on a TCO/CdS substrate. The substrate is on a corning 7059 borosilicate glass. The ITO layer has already been deposited on the glass when purchased. CdS will be deposited on the TCO substrate by Chemical bath deposition. The SiO_2 will act as an insulator were photolithography will be used to pattern the areas were we want CdTe crystals to grow. SiO_2 can be deposited by various methods such as plasma enhanced chemical vapor deposition (PECVD) or electron beam evaporation. A mask will have to be designed to pattern the SiO_2 previously deposited. Figure 3 shows partial selected areas to grow CdTe crystals on top of the CdS substrate.

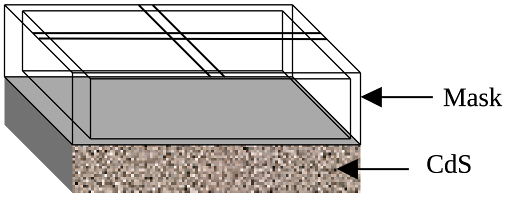


Figure 3. *Patterned mask on CdS film*

When a layer of 2 to 3 micro-meters of SiO_2 is achieved photolithography is used to transfer a desired array of square shapes created in *Mentor Graphics* software to create a pattern in the SiO_2. A layer of Positive (AC1518) photoresist material will be applied using a spinner. After applied, the photoresist material has to be baked in a thermal oven at the specified photoresist baking temperatures. Positive photoresist will be exposed to UV light after carefully aligned in a mask aligner to prepare it for etching. Hydrofluoric acid (HF) will be used to etch and expose CdS selected areas. The procedure is illustrated in figure 4.

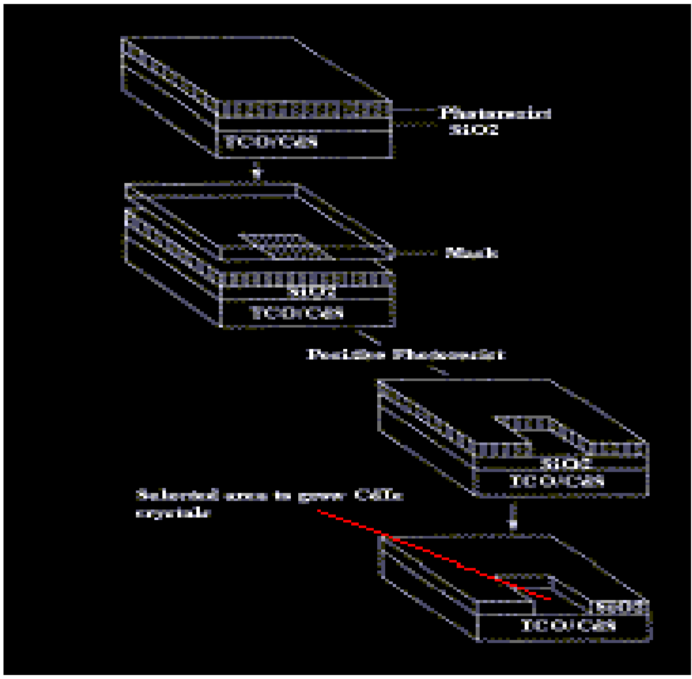


Figure 4. *Process of exposing mask to photoresist*

With the CdS exposed CdTe crystals will be grown on top of the selected areas. This will provide uniform distributed and evenly shaped crystals. Characterization will be made on the completed tasks. To continue the process we will have to complete the solar cell and test it to measure the efficiency.

Results:

The project is divided in different stages to be performed either in the University of Texas at El Paso or Purdue University. The goals to be achieved in Purdue University were to (1) Design the mask, (2) fabricate the mask, (3) deposit SiO_2 and (4) pattern the SiO_2.

This paper will focus on (3) the deposition of SiO_2. The first step was to select an adequate method and equipment to deposit the Silicon Dioxide and then measure the deposited thickness. In addition, The CdS layer was measured using a non-destructive method. Future tasks will include etching the SiO_2, etch rate calculations and exposing the CdS. These tasks will be performed at UTEP.

The SiO_2 was deposited using the Leybold/Homebrew electron beam evaporator located in EE 206 in Purdue University. The electron beam evaporation method was chosen over plasma enhanced chemical vapor deposition (PECVD) to prevent equipment contamination, because Cd and S are listed as traps for silicon in the machine manuals and the machine is used to fabricate Silicon devices. SiO_2 acts as an insulator material and can be substituted by Silicon Nitride (Si_3N_4). The reason why SiO_2 was chosen is because the electron beam evaporator can deposit SiO_2 on our TCO/CdS layer without causing any damage or contamination to the equipment and because the Si_3N_4 can't be deposited using electron beam evaporation.

I measured the thickness of the deposited films with the *Filmetrics* interferometer. I chose the *Filmetrics* and not the *Tencor Alphastep* profilometer to prevent film damage and because the profilometer requires a "step" in the film to measure the thickness. I preferred the *Filmetrics* because it uses the spectral reflectance method to measure the film thickness and it doesn’t require any film preparation nor it damages the measured film.

Six samples were deposited. However, only the first two samples were successful. The electron beam evaporator presented several vacuum problems after I deposited the first two samples and the other four samples were not correctly deposited; furthermore, the electron beam evaporator was unable to use for 2 weeks.

Measured data:

Sample Number	CdS thickness	SiO_2 thickness	Pressure at chamber when deposited
26	95.31nm	2.023µm	10.6x10-6 torr
30	93.57nm	1.461µm	10.6x10-6 torr

Selected Sources:

[1] X.Wu, R.G. Dhere, D.S. Albin, T.A. Gessert, C. DeHart, J.C. Heane, A. Duda, T.J. Coutss, S.Asher et al. “High-efficiency CTO/ZTO/CdS/CdTe Polycrystalline Thin-Film Solar Cells” *National renewable Energy Laboratory (NREL)*,1617 Cole Blvd., Golden Colorado 80401.

[2] Miwa Tsuji, Tetsuya Aramoto, et al. “Characterization of CdS thin film in high efficient CdS/CdTe solar cells”, *Journal of Crystal Growth* 214/215 (2000) 1142-1147.

[3] Kyotaro Nakamura, Masahiro Gotoh, Toshihiko Fujihara, Toshihiko Toyama and Hiroaki Okamoto. “Influence of CdS window layer on 2-μm thick CdS/CdTe thin film solar cells*” Graduate School of Engineering Science, Department of Physical Science*, Osaka University, Toyonaka, Osaka 560-8531, Japan

[4] D.Zubia, “Critical parameters in CdS/CdTe solar cells formed by thermal evaporation” *thesis University of Texas at El Paso*, (1993).

[5] D.H. Levi, L.M. Woods, D.S. Albin, T.A. gessert , R.C. reedy et al. “The influence of Grain Boundary Difussion on the Electro-Optical Properties of CdTe/CdS solar cells.” *National renewable Energy Laboratory (NREL)*, 1617 Cole Blvd., Golden Colorado 80401.

[6] Ken Zweibel “Thin Films: Past, Present, Future” *Thin-Film PV Partnership Program National Renewable Energy Laboratory*, Golden, CO 80401