INFLUENCE OF CLOSE SPACE SUBLIMATION PROCESSING UPON THE GRANULAR GROWTH OF THIN-FILM CDTE SOLAR CELLS

L. Ghimpu[1], V. V. Ursaki[2], T. Potlog[1], L. Sirbu[3] and I. M. Tiginyanu[2,3]

[1]*Department of Physics, Moldova State University, MD-2009 Chisinau, Moldova*
[2]*Laboratory of Low Dimensional Semiconductor Structures, Institute of Applied Physics, Academy of Sciences of Moldova, MD-2028 Chisinau, Moldova*
[3]*National Centres for Materials Study and Testing, Technical University of Moldova, MD-2004 Chisinau, Moldova*

There are three semiconductors that show potential to replace single crystal silicon as primary materials for photovoltaic energy converters: amorphous silicon, polycrystalline CdTe and $Cu(In,Ga)Se_2$. The use of CdTe as a light absorbing material in solar cells is attractive, because it possesses an optimal band gap of 1.5 eV for conversion efficiency [1]. The direct band gap allows considerable light absorption for film thickness of only few microns resulting in low material usage. Polycrystalline CdTe solar cells manufactured by a wide variety of deposition techniques, including electrodeposition, vapour transport deposition, laser deposition, radiofrequency sputtering, spray pyrolysis, slurry spraying, screen printing, close space sublimation (CSS) techniques result in conversion efficiencies greater than that obtained with single crystal material [2,3]. Although CdTe can be doped both p-and n-type CdTe homojunction cells have not shown very high efficiency. Due to the high absorption coefficient and small diffusion length, the junction must be formed close to the surface, which reduces the carrier lifetime through surface recombination. Considerable higher efficiencies are obtained by using n-CdS/p-CdTe heterojunctions. The CdS layer serves as a window layer and helps to reduce the interface recombination. All processing technologies used for CdTe/CdS solar cells fabrication include postdeposition heat-treatment with the $CdCl_2$ application. Many investigators have shown that using this $CdCl_2$ treatment promotes CdS and CdTe film recrystallization and leads to a significant increase in grain size associated with the increases of the photovoltaic efficiency of the junction by approximately an order of magnitude [4,5]. Therefore, the choice of appropriate film morphology is critical for reaching high photovoltaic efficiency.

In this paper we study the impact of CSS processing parameters upon the morphology of CdTe/CdS solar cells.

Thin film CdS/CdTe hetero-junction solar cells were fabricated on glass substrates covered by a SnO_2 layer with a sheet resistivity of about 10 Ω/□. SnO_2 layer served as a transparent front contact to CdS layer. Both CdS and CdTe layers were deposited by CSS method. Different hetero-junctions were fabricated with various source temperatures from the interval of 520-550 °C at a fixed substrate temperature of 290 °C, and with various substrate temperatures from the interval of 300-340 °C at a fixed source temperature of 570 °C. After the CdTe layer was deposited, the structures were held in a $CdCl_2$:H_2O saturated solution and subsequently annealed in air at the temperature T = 400 °C during 30 min. More details on hetero-junction fabrication are presented elsewhere [6].

The morphology of the CdTe/CdS solar cells was studied using a high quality optical microscope and a NANO-Station atomic force microscope.

Figures 1 and 2 compare the morphology of CdTe films in CdTe/CdS solar cells grown with different source and substrate temperatures, respectively. The substrate temperature was 290 °C during the growth of films illustrated in Fig. 1. The source temperature in the CSS process was kept at 570 °C for the films which morphology is shown in Fig. 2. The size of micrographs is 250x200 μm^2. One can see that all the CdTe films consist of crystallites with different sizes. Fig. 1 and Fig. 3 demonstrate a gradual growth of the granule sizes with the increase of the source temperature. Apart from that, the rate of the CdTe layer deposition increases with the increase of the source temperature. Thus, the increase of the source temperature is beneficial from the point of view of both the granule sizes and the deposition rate. However, the increase of the source temperature could result in a higher contamination of the CdTe film with impurities from the source. For instance, we observed a high degree of contamination with Cu at source temperatures above 560 °C. Therefore, the source temperature of 550 – 560 °C is optimum from the point of view of granule sizes and deposition rate at a reasonable degree of contamination with impurities.

The analysis of the morphology of films grown with different substrate temperatures (Fig. 2 and Fig. 3) shows that the grain sizes increase with the increase of the substrate temperature up to 310 °C and decrease with the further increase of the substrate temperature. The increase of the grain size with the temperature increase up to 310 °C is explained by the increase of the migration velocity of atoms on the substrate surface leading to a smaller number of active crystallization centers which results in bigger grains. The increase of the substrate temperature above 310 °C leads to the decrease of deposition rate which results in smaller grains.

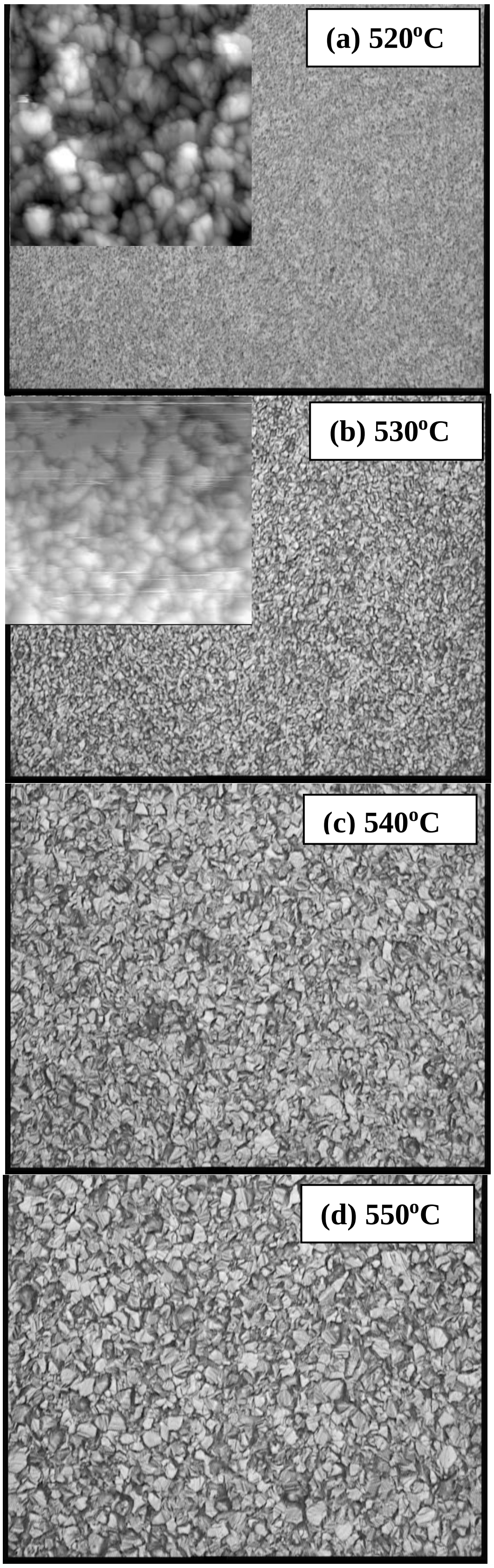

Fig. 1. Micrographs of CdTe films grown with different source temperatures. Inserted are AFM images of 10x10 μm^2 (a) and 50x50 μm^2 (b).

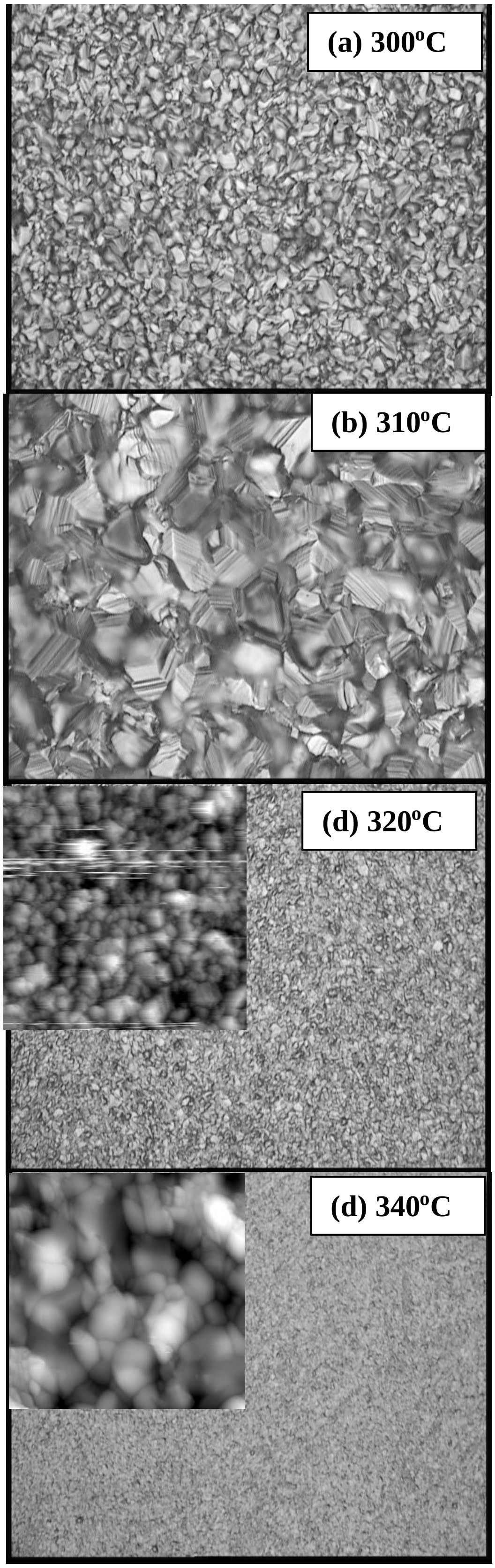

Fig. 2. Micrographs of CdTe films grown with different substrate temperatures. Inserted are AFM images of 50x50 μm^2 (c) and 10x10 μm^2. (d).

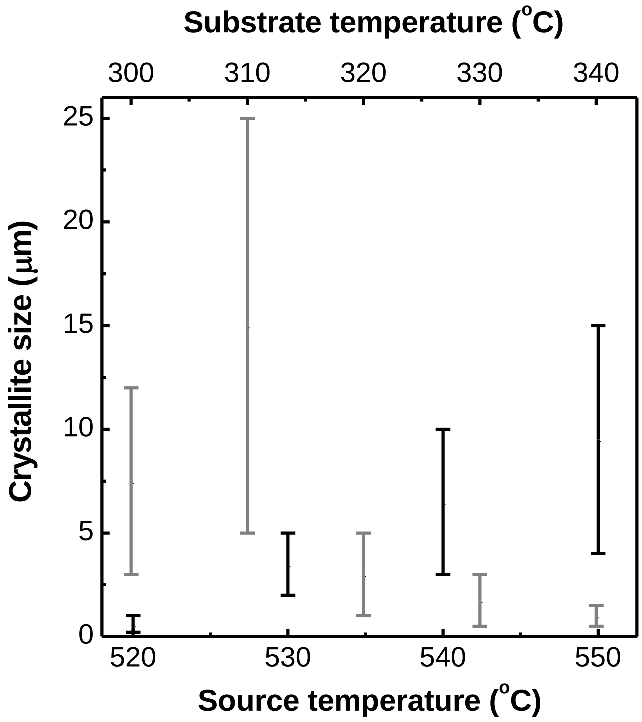

Fig. 3. Dependence of grain sizes upon the source (black bars) and substrate (gray bars) temperature in the CSS process.

Moreover, our investigations of the contamination of CdTe films with impurities from the source material shown that the contamination decreases with the increase of the substrate temperature. Therefore, one should find a compromise between the degree of contamination and the grain sizes. The substrate temperature of 310 – 320 °C seems to satisfy this compromise.

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