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SYNTHESIS AND STRUCTURAL CHARACTERIZATION OF CdTe/CdS/ITO THIN FILMS GROWN BY CLOSE SPACE SUBLIMATION WITH THERMAL TREATMENT OF $CdCl_2$

A. R. Rivera-Gómez[1], H. E. Esparza-Ponce[1], E. Orrantia-Borunda[1] and A. Duarte-Moller[1,2]

[1]Centro de Investigación en Materiales Avanzados
Departamento de Materiales Nanoestructurados
Miguel de Cervantes 120
Comlejo Industria Chihuahua Chih 31109
Mexico

[2]Universidad Tecnológica de Querétaro
Avenida Pie de la Cuesta 2501, Unidad Nacional
76148 Santiago de Querétaro, Querétaro de Arteaga
Mexico

Abstract

In this work, we present the influence of heat treatments with $CdCl_2$ prepared with ethanol on the characteristics of CdS/CdTe thin films. CdTe thin films were grown by using the closed space sublimation technique combined with substrate rotation (CSSSR) on CdS/ITO substrates. CdS film was previously deposited by chemical bath deposition (CBD) without stirring. The X-ray diffraction was used to identify the crystal structure and found that the films exhibit a cubic crystal structure with a spatial orientation (111), a grain growth with a uniform compacting. Also, a heat treatment in a muffle furnace at 450°C for a period of 30min was done.

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1. Introduction

In recent years, there has increased the study of binary semiconductors formed by elements of groups II-IV, in particular, so-called calcogenides CdX (X = Te, Se), because they exhibit semiconductor properties such as energy gap (1.45eV and 1.74eV) [1] and high optical absorption coefficient that make them suitable for use in the solar cells technology. CdTe is a “p” type semiconductor and in a heterojunction “pn” solar cell has a high absorption coefficient that allows 99% of the photons with energy larger than the bandgap energy. The thickness of this film will vary from 60nm to 80nm [2].

In particular, the characteristics of the solar cells NCDs/pCdTe, with layers of CdS and CdTe, vary to be deposited by various techniques [3]: evaporation of material by close space sublimation (CSS) [4], deposition bath chemical, electro-deposition in aqueous solution, photochemical deposition, and molten salts at high temperature to [5].

For growth of thin film of CdTe, a common technique used is the sublimation (CSS), which is that the material in powder form is sublimated in vacuum and condensed upon a substrate at temperatures between 500 and 700°C. This technique provides high rates of deposition of the material and can be applied to continuous production lines flows vacuum systems using low cost [6].

This paper shows the synthesis and the morphological, or roughness, structural characterization, consisting of the appearance of a lateral potential difference in a sample exposed to a magnetic field when it passes longitudinally by a current [7].

2. Experimental Details

The properties of thin films deposited by CSS-modified substrate CSSSR rotation are controlled by parameters such as temperature, deposition rate and the substrate rotation.

Three-ITO glass substrates with a layer of CdS grown by chemical bath deposition technique, identified as F1, were used for the deposition of CdTe for the CSSR technique: the experimental arrangement is shown in Figure 1. It consists of a graphite container heated by a 300W OSMAR halogen lamp. A stainless steel cylinder supports the lamp, the CdTe material is placed in the form of pressed powder in the graphite container.

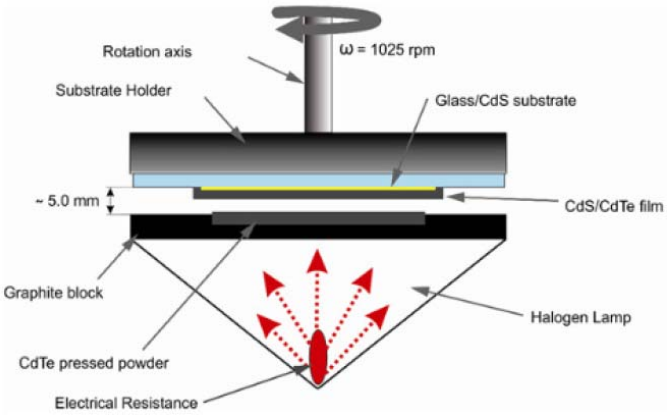

Figure 1. Experimental setup used in the technique of close space sublimation combined with substrate rotation.

The substrate keeps separated a distance of 5mm beyond the stainless steel cylinder and has a rotation 1025rpm. The experimental assembly was placed in a vacuum chamber $(1 \times 10^{-6} \text{Torr})$. The film growth is facilitated by the use of a glass "shutter" placed between the substrate and the stainless steel cylinder. The substrate is heated by radiation from the halogen lamp. Cycle deposition of the CdTe film is as follows: the graphite is heated to 650°C during 10min, and by radiation from the substrate reaches a temperature of 280°C depending on the distance between the edge of the substrate and the source, then the "shutter" opens and the CdTe film is obtained. After 10min of deposition, the temperature gradually decreases to ambient temperature [8].

After this process, a thermal treatment, TT, with a solution of 7mg of $CdCl_2$ on 50ml of ethanol is applied, moistening each of the films in the

solution, then introduced a preheated muffle furnace at 450°C leaving the films for a period of 30min, cooling and pass characterization as mentioned above, and then compared before and after treatment.

3. Results and Discussion

3.1. AFM characterization

To characterize the evolution of the morphology of CdTe thin films, atomic force microscopy (AFM) was used specifically for semiconductor films. Samples F1 (Figure 2) were processed using the WSxM [8] software which allows to display the topographic images (Figure 2(a)) and provides tools to study height profiles, histograms roughness analysis, [11], etc. A height profile is a cross-sectional image on a topography where profiles between the valleys and the maximum heights of the grains (Figure 2(b)). Figure (Figure 2(c)) presents the 3D image of last figures. Figure 2(d) displays the frequencies histogram of the characteristic height of the [12] which can be observed as a uniform compaction of the material, with grains of unequal size, but the same way with no holes. These films without TT of 10×10 and $5 \times 5\mu m$, respectively (Figure 3).

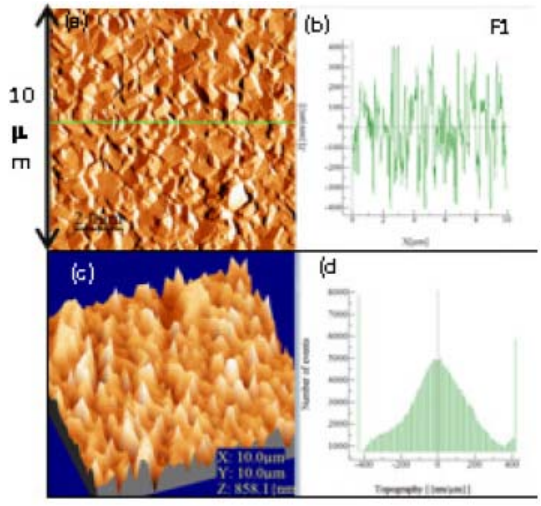

Figure 2. AFM image at 10µm scale of sample before TT.

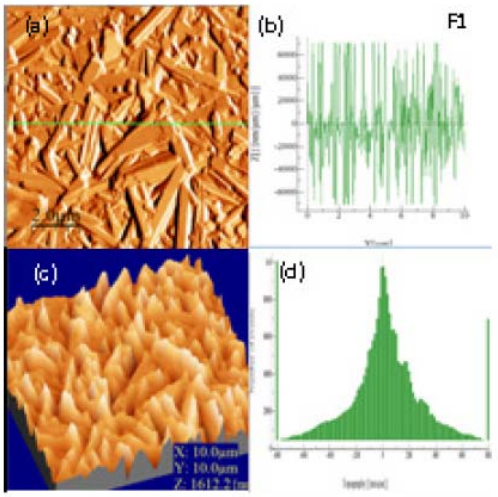

Figure 3. AFM image at 10µm scale of sample after TT.

We can clearly observe the morphological change after the heat treatment applied illustrating bars instead of the grains obtained before the TT (Figure 4), which allows displaying topographical images (Figure 4(a)), profile valleys and maximum heights of grains (Figure 4(b)), 3D representation (Figure 4(c)) and the characteristic height of the grains (Figure 4(d)). These thin films for 10×10 and $5 \times 5\mu m$ after the TT (Figure 5).

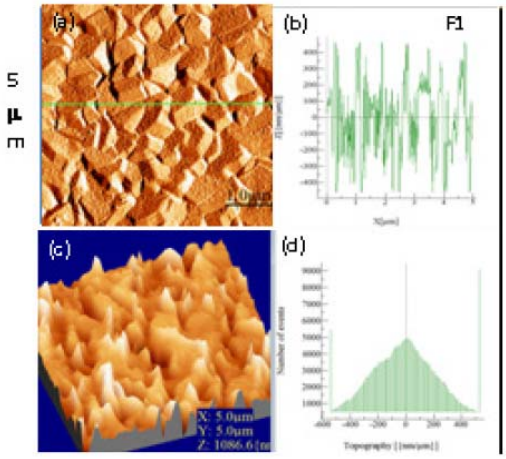

Figure 4. AFM image at 5µm scale of sample before TT.

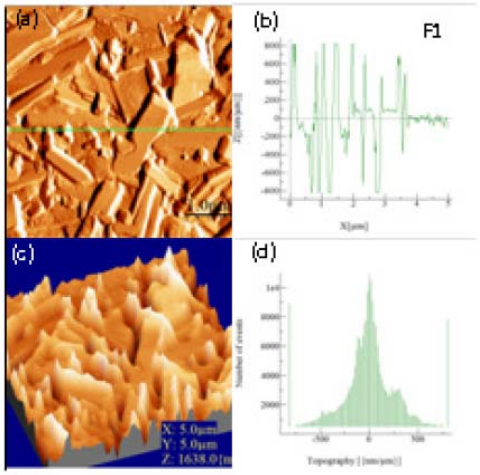

Figure 5. AFM image at 5μm scale of sample after TT.

3.2. XRD characterization

The X-ray diffraction was used to identify the crystal structure and found that the films exhibit a cubic crystal structure with a spatial orientation (111). A grain growth compacted uniform but with unequal size. Figure 6 shows the diffraction pattern representing each of the films as well as in Table 1 the relationship of the properties such as the identification of the crystal structure is shown.

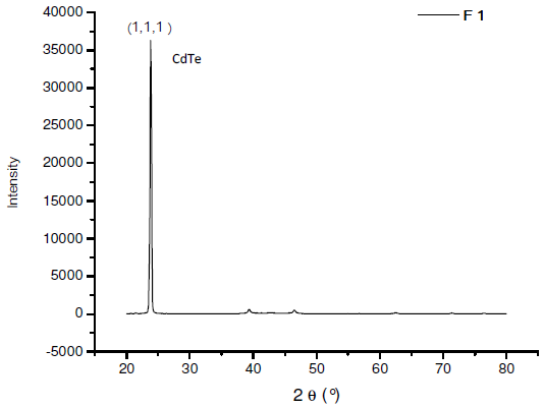

Figure 6. XRD pattern of sample without TT. We appreciate a main crystallographic direction (111).

Table 1. Crystallographic parameters of the sample after TT

Crystal structure						
Crystallographic data						
Space group	F-43m (216)					
Crystal system	Cubic					
Cell parameters	a = 6.4800Å					
Atom coordinates	**Ele.**	***x***	***y***	***z***	**Bi**	**Focc**
	Cd	0	0	0	1	1
	Te	0.25	0.25	0.25	1	1

Diffraction data					
Diffraction lines					
d[Å]	**Int.**	**h**	**k**	**l**	**Mult.**
3.7412	1000	1	1	1	8
3.24	1.2	0	2	0	6
2.291	745.1	2	0	2	12
1.9538	441.8	3	1	1	24
1.8706	0.4	2	2	2	8
1.62	112.4	0	4	0	6
1.4866	162	3	1	3	24
1.449	0.6	4	0	2	24
1.3227	204.2	2	4	2	24
1.2471	108.4	3	3	3	8
1.1455	59.3	4	0	4	12
1.0953	102.4	5	1	3	48
1.08	0.3	0	6	0	6
1.0246	84.8	6	0	2	24

Figure 7 shows the diffraction pattern of the films with TT, in which we found a peak corresponding to SO_2 behaves as an insulator with orthorhombic crystal structure.

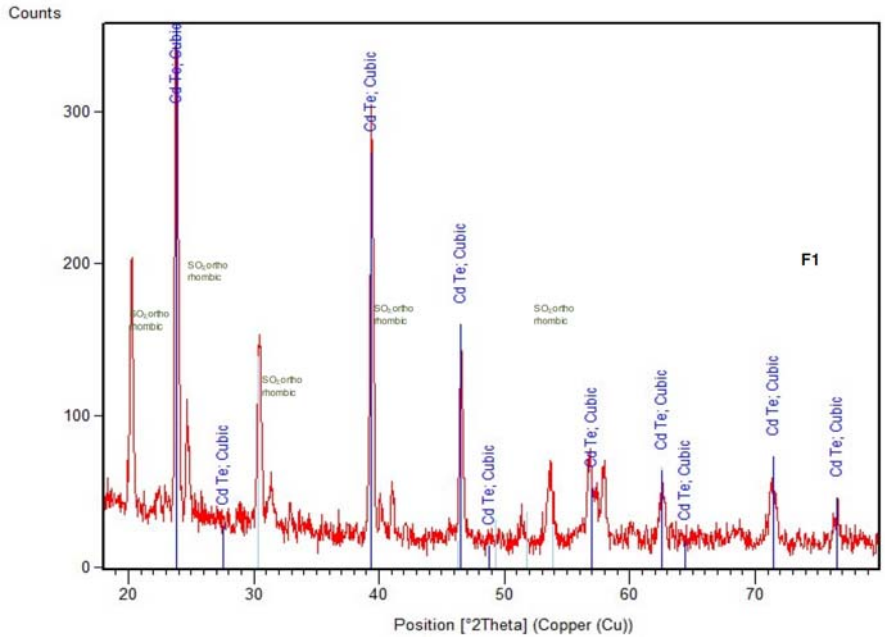

Figure 7. Diffraction pattern of the sample after TT. The cubic phase of CdTe appears as dominant structure in the sample, which was expected.

3.3. Characterization of optical transmission measurement optics UV-Vis

It was made to this article film 1 in both cases, without TT (F1) and TT (TT F1). Spectral transmittance is obtained using a Perkin Elmer UV/Vis spectrophotometer Lambda 10, showing a consistent behavior in the various replicas of deposit, these films are dark, Figure 8 shows the curves UV visible, compared to the F1 and F1TT thin film, including a keyboard is seen at 830nm wavelength, which is in agreement with that reported in the literature is 827nm [13] and a transparent region up to 1100nm. It is noticeable that a flat window in the sample with TT has been useful for solar energy conversion.

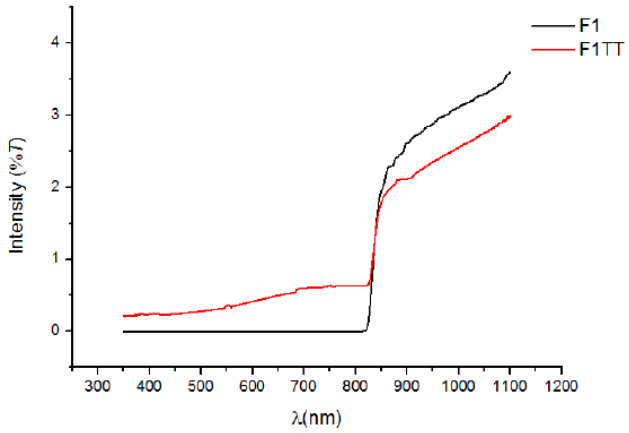

Figure 8. Optics UV transmission spectrum. For CdTe by CSSSR.

Moreover, in Figure 9, curve forbidden bandwidth in films before TT is shown, here we observed the energy bandgap of 1.4948 which is perfect according to that reported in the literature [15, 16]. Figure 10 shows the curve of the film bandgap after TT. As we can see there is a variation giving a higher heat of 3.5eV which represents an increase with respect to that reported in literature, having a representation of the change in geometry of the bead peak.

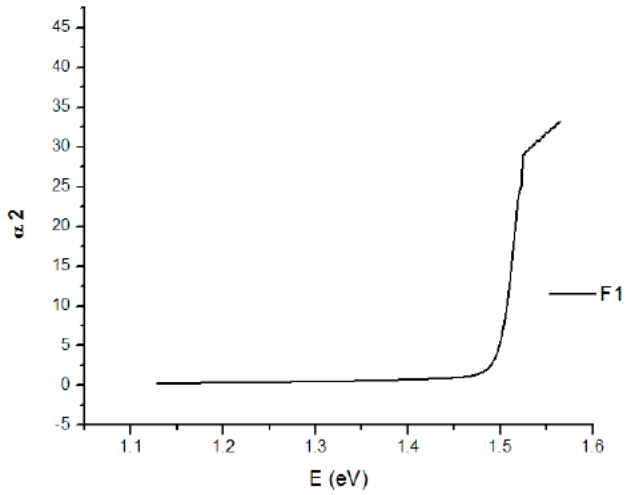

Figure 9. Energy bandgap of the sample without TT.

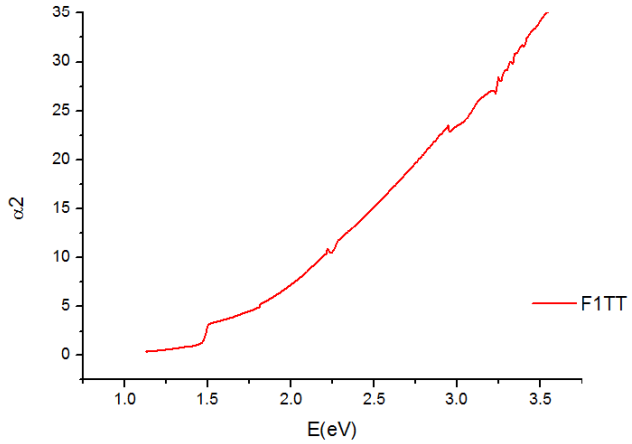

Figure 10. Energy bandgap of the sample after TT. We appreciate a bandgap placed at 1.5eV.

4. Conclusion

CdTe films were grown by the technique of CSSR on three substrates of previously deposited by CBD CdS without agitation. The source temperature was that 650°C, and the substrate temperature up to 280°C. This technique was combined with the rotation of the substrate which was fixed CdS at 1025rpm. To analyze the behavior of the samples, they were analyzed by AFM, XRD, and technical surface profilometer. In profilometer was observed that the samples have a uniform compaction at different defined manner (600nm average) size compared to films without TT, due to application of a change TT obtained grain morphology with large length bars of about 2.15μm and less roughness of the films. The X-ray diffraction shows a preferential orientation in space (111) for the three samples and standard behavior between films of crystalline structure cubes before TT. After heat treatment, we can observe the growth of peaks of SO_2 which produce insulation not allowing the current flux. Finally, the orientation in space (111) for the three samples is preserved.

It was observed that performance of the films before and after the application has a behavior TT% T is similar and consistent with what is

reported in the literature. Moreover, the bandwidth curve shows an energy gap of 1.4948eV, which corresponds to that reported in the literature, but not a uniform calculation graphical behavior therefore, that because the thermal TT underwent a morphological change of uniform rods or pins growth of crystals.

Acknowledgments

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