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Synthesis and Characterization of Nanostructured $(CdS)_{0.8}Te_{0.2}$ Thin Films for Solar Cell Application

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Abstract

Tellurium doped Cadmium Sulfide thin films were deposited by vacuum evaporation onto rotating amorphous glass substrates at pressure of 10^{-5} torr. The crystal structure, surface morphology, elemental analysis and optical properties of the deposited films were studied with help of X-Ray Diffractometer (XRD), Scanning Electron Microscopy (SEM) and UV-VIS Spectrophotometer. X-Ray diffraction analysis reveals that the deposited films have orthorhombic structure and polycrystalline in nature. The crystalline size (d) and dislocation density (δ) were determined and found to be 28.1nm and 1.266 x 10^{15} lines / cm^2 respectively. SEM revels that the films are homogeneous having dense morphology. The optical band gap was determined by absorption spectra and found to be 2 to 2.17 eV.

Keywords: Vacuum Evaporation, XRD, SEM, UV-VIS..

Introduction

The polycrystalline CdS and CdTe thin films are one of the most important materials for photovoltaic energy conversion because of the high efficiency, low cost, stability and reliability [1]. The inter diffusion between the absorber layer and window layer occurring during the production of CdTe/CdS solar cells [2-5]. The proper amount of inter diffusion is necessary for a superior efficiency solar cell, but extreme inter diffusion is believed to affect device efficiency through the resulting change in the optical band gap, may be directed towards the deterioration of the device performance [6]. The deterioration of the device performance due to inter diffusion processes can be reduced by depositing a CdS_xTe_{1-x} absorber layer [7, 8]. The incorporation of the absorber layer CdS_xTe_{1-x} in between the absorber layer and window layer causes in reduce lattice mismatch and corresponding reduction of the interface states.

Thin films of CdS_xTe_{1-x} can be deposited by various techniques, Closed Space Sublimation (CSS) [9-11], MOCVD [12], Pulse Plating [13] and Chemical Bath Deposition (CBD) [14]. The physical properties of the films can be affected by deposition techniques and deposition parameters. The thin films prepared by vacuum evaporation technique are uniform with excellent crystallinity, dense and highly oriented [15, 16]. The quality and properties of films mainly depend on pressure, deposition rate, substrate temperature and thickness of the film.

In this paper, we studied the effect of thickness on the structural, morphological and optical properties of $(CdS)_{0.8}Te_{0.2}$ thin films, grown by vacuum evaporation technique deposited onto rotating amorphous glass substrates.

Experimental

Preparation of $(CdS)_{0.8}Te_{0.2}$ Compound

The ternary alloy of $(CdS)_{0.8}Te_{0.2}$ have been prepared by melt quench method. The direct mixture of extremely pure CdS and Te with purity of 99.999% was kept in evacuated quartz tube at pressure 10^{-5} torr, in accordance with their atomic ratio. The tube was sealed and heated at about 1150^0C for 10 hours duration. Then the tube was quenched in ice cooled water.

Synthesis of Thin Films

Alloy of $(CdS)_{0.8}Te_{0.2}$ have been deposited by vacuum evaporation technique under the pressure of 10^{-5} torr onto rotating amorphous glass substrate. The substrate to source distance was kept at 15 cm. The films were synthesized with various thicknesses under similar conditions. The thickness of the films was monitored on Digital Thickness Monitor (DTM-101) provided by Hind-Hi Vac. During the synthesis, deposition rate was maintained at 5-8 Ǻ/sec. Before evaporation, the glass substrates were cleaned thoroughly using detergent, distil water, chromic acid and acetone.

The structural properties of thin films were investigated by XRD, within 20º-80º scanning range, having CuKα radiation. Surface morphological studies have been done by Scanning Electron Microscope (Hitachi, Japan). The elemental analysis was carried out by EDAX (Energy Dispersive X-ray Analysis) technique attached with the SEM. Optical characteristics were determined by UV-VIS Spectrophotometer (Shimadzu – 2450) between the wavelength ranges of 400 – 900 nm.

Results and Discussions

XRD

Figure1 demonstrate the XRD spectrum of $(CdS)_{0.8}Te_{0.2}$ thin film, prepared at room temperature.

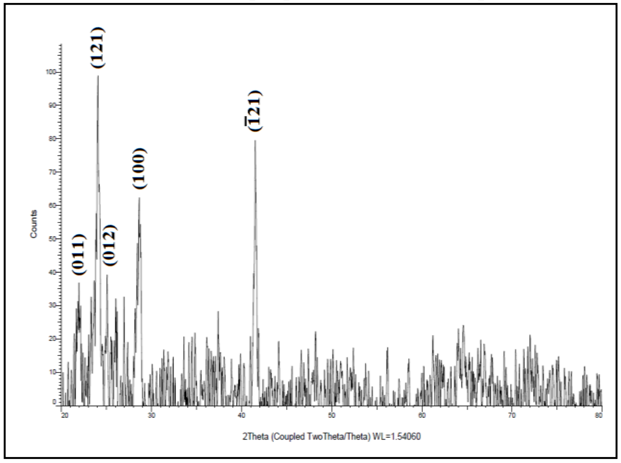


Figure1. XRD Spectrum of $(CdS)_{0.8}Te_{0.2}$ Thin Film

The 2θ peaks observed at 22.08º, 23.9º, 25.4º, 28.77º and 41.6º which corresponds to the (011), (121), (012), (100) and (121) planes of reflections. These results are well in agreement with JCPDS data card no: 43-0985 and 65-2216. The presence of large number of peaks indicates that the films are polycrystalline in nature. From the dominant peak the crystalline structure was found to be orthorhombic phase. The grain size (D) of $(CdS)_{0.8}Te_{0.2}$ thin film was found to be 28.1 nm by using Debye–Sherrer's equation:

$$D = \frac{0.9\,\lambda}{\beta \cos\theta} \qquad \text{….. (1)}$$

Where, θ is the Bragg angle, λ is the X-ray wavelength and β is full width at half maxima. The lattice parameters a, b, c and volume was found to 3.471, 4.873, 3.399 and 57.49 respectively.

The dislocation density (δ) has been estimated 1.266 x 10^{15} lines / cm^2 using the following equation:

$$\delta = 1 / D^2 \qquad \text{….. (2)}$$

The low value of dislocation density indicates good quality of thin film.

SEM

Surface morphological study of sample was carried out by using Scanning Electron Microscope (SEM). Figure2 shows the magnified microphotographs of $(CdS)_{0.8}Te_{0.2}$ thin films.

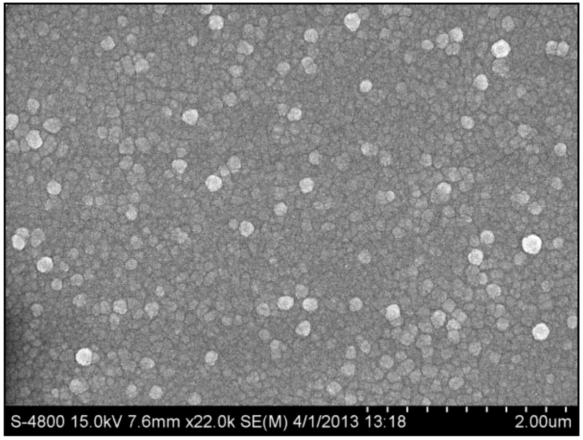


Figure2. SEM Image of $(CdS)_{0.8}Te_{0.2}$ Thin Film.

Figure2 reveals that the film is smooth and homogeneous. It covers the entire surface area of the substrate. It has dense morphology and compact structure**.** The image clearly demonstrates particles are granular in size and free from any microscopic defects. The particles are coalesces to form a bigger particle. The particle size from SEM image found to be 98 - 179 nm.

Quantitative Analysis

The elemental analysis performed with the help of EDAX. Figure3 shows the EDAX spectra of $(CdS)_{0.8}Te_{0.2}$ Thin Film.

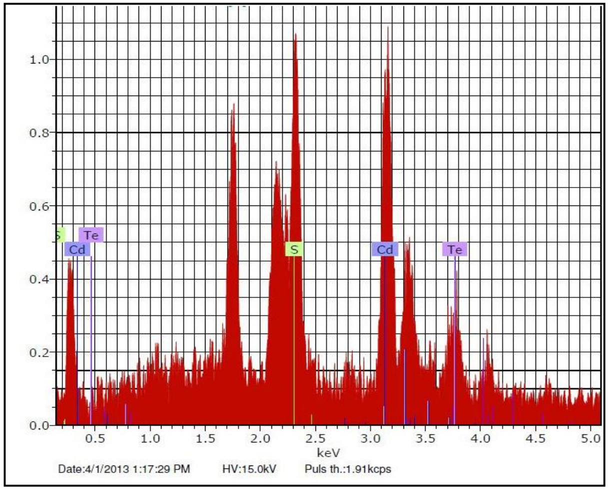
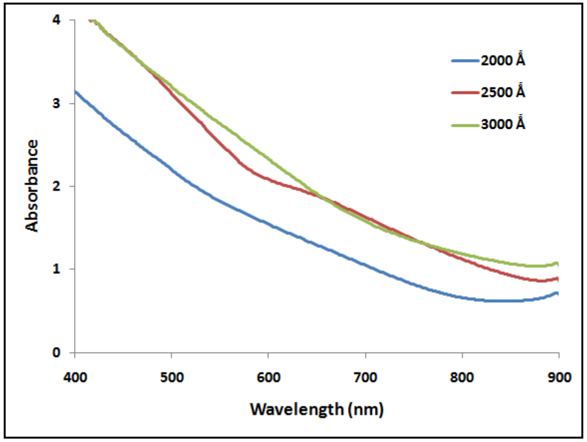


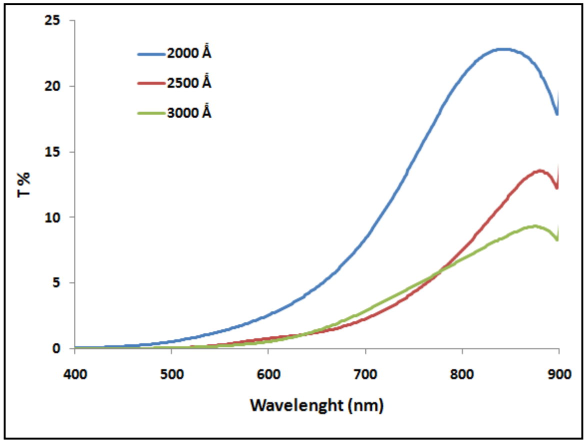
Figure3. EDAX spectrum of $(CdS)_{0.8}Te_{0.2}$ Thin Film.

From the EDAX spectrum, Cadmium (Cd), Sulfur (S) and Telluride (Te) gets detected. The atomic percentage of Cd, S, and Te was found to be 28.56: 53.39: 18.03 respectively. Although there are some peaks are found due to presence of glass substrate and gold coating.

UV-VIS Spectroscopy

The optical parameters were determined by UV-VIS Spectrophotometer. Optical absorption spectra and transmission spectra of samples were recorded in the spectral range from 400 to 900 nm.





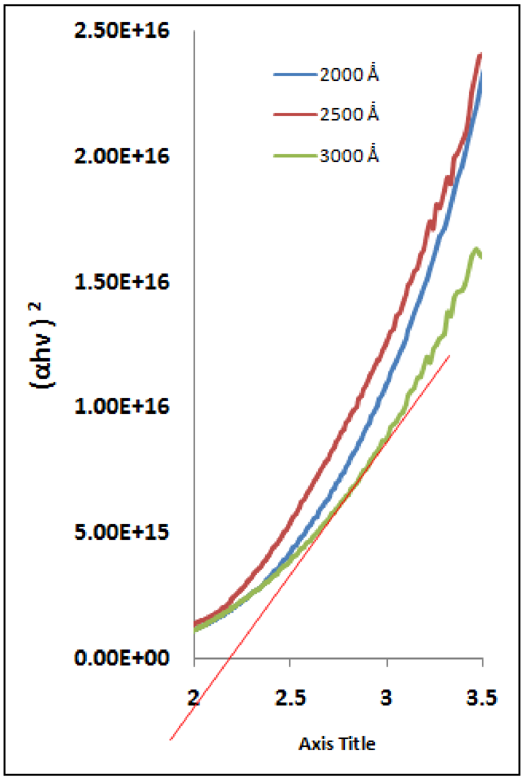


Figure4. a) Absorbance b) Transmittance c) Band Gap

Figure 4a and 4b shows the absorbance and transmittance spectra of $(CdS)_{0.8}Te_{0.2}$ thin films respectively. The films have transmittance bellow the 25% due to the blackish color of samples. Figure 4a and 4b illustrates that as the thickness of the film increases; the absorbance also gets increases and transmittance gets reduces. The optical band gap of these films has been calculated by using the Tauc relation:

$$\alpha h\nu = A\,(h\nu - Eg)^n \qquad \ldots..\ (3)$$

Where, α is the absorption coefficient, hν is the photon energy, A is constant and Eg is the band gap. The optical band gap was determined from the plot of $(\alpha h\upsilon)^2$ Vs. Eg as shown in figure 4c. The linear portion is extrapolated to cut the x-axis, which gives the optical energy band gap. From figure 4c the optical band was found to be 2 to 2.17 eV. The band gap gets modified by the thickness.

Conclusion

Nanocrystalline $(CdS)_{0.8}Te_{0.2}$ thin films with various thickness have been deposited successfully on to rotating glass substrate and studied under the various characterizations technique. XRD confirms that the film is polycrystalline in nature and having orthorhombic crystal structure. The crystalline size (D) and dislocation density (δ) were determined. From

SEM study it is observed that deposited samples are homogenous and partials are found to be in granular phase. The elemental analysis is carried out by EDAX method which confirms the presence of Cd, S and Te. From the optical analysis of the deposited films the optical band gap was estimated within the range of 2 – 2.17eV. The optical investigation illustrates that the $(CdS)_{0.6}Te_{0.4}$ films can be used in optoelectronic / solar cell devices.

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