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Comparative Study of CdTe Thin Films: Effect of Molarities and Annealing Temperature

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Abstract : Thin films of CdTe have been deposited on glass substrates using the solution method from a solution containing Cadmium acetate and Tellurium salts. The CdTe films were prepared at different molarities and different annealing temperatures. The structural characterization of the films was carried out using X-ray diffraction technique (XRD) and the structure was found to be cubic in nature. Also, the grain size (D), dislocation density (ρ) and micro strain (ε), were calculated from the XRD data. The surface morphology of the films was done by Scanning Electron Microscopy (SEM) technique. The optical band gap was calculated using a UV spectrometer.
Keywords: Thin films, CdTe, XRD, SEM and UV.

Introduction

Chalcogenide Cadmium Telluride (CdTe) is recognized as a versatile semiconductor material. It is a binary II-VI material that can be found both n and p-type conductivity. The band gap of the material is nearly 1.5 eV, its direct optical transition in a large absorption coefficient, suitable for thin film solar cells[1,2]. Number of preparation methods available for preparation of CdTe thin films such as vacuum deposition, electro-deposition, molecular beam epitaxial, metal-organic chemical vapour depositions, close space sublimation, screen printing, sol-gel and solution method[3-10].

In this present study, we focus on the basic and fundamental properties like structural and optical properties of CdTe thin films prepared by simple and coat effective dip coating method for the solar cell applications.

Experimental procedure

Cadmium acetate [$(CH_3COO)_2Cd.2H_2O$] dissolved in Ethanol, and Tellurium salts dissolved in sulphuric acid in the molar ratio of (0.5:0.5 and 1:0.5), it was mixed up each other and stirred for 2 hours. The resultant solution was used as a base solution of CdTe. The films were grown on microscopic glass substrates (2 cm x 2 cm, 1.35 mm in thickness). The glass substrates were cleaned with solution, washed with distilled water and then alcohol in an ultrasonic cleaner. Cleaned glass was dipped into the as prepared solution with the help of a dip coating machine and vacuum annealed at 300^{o}C. Then 2 more samples were prepared by the same method

in the molar ratio of 1:0.5. The films were vacuum annealed at 350 ^{o}C and 400 ^{o}C for 30 minutes and allowed to cool at room temperature.

The prepared films were characterized using XRD studies for structural analysis, Surface morphological analysis using SEM study and optical properties was analysed using UV spectroscopy.

XRD analysis was carried out by X'Pert PRO diffractometer, employing CuKα radiation (λ=1.5418 Å). The SEM images were taken using Hitachi S–3000N scanning electron microscope with an accelerating voltage of the electron beam of 30 kV. The optical absorption and transmittance measurements, recorded within the wavelength range from 200 to 1100 nm, were used to calculate the absorption coefficient (α), and the optical band gap (E_g).

Result and discussion

XRD study

The films were analyses using X Ray Diffectrometer. The 2θ value analysed from the angle of 0^{o} -90^{o}. The fig.1-a, b shows that the XRD pattern of CdTe thin films coated on glass substrate using a dip coating method with different molraities and annealing temperature.

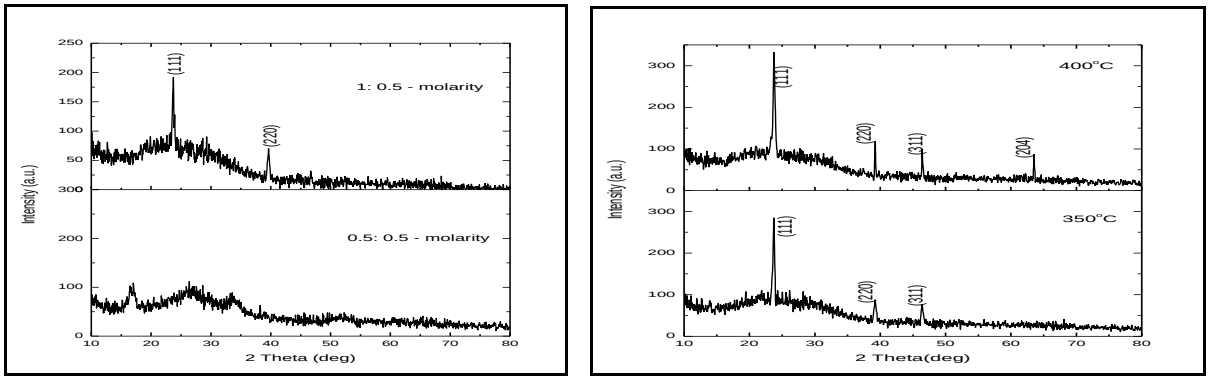

Fig.1-a and Fig.1-b shows the CdTe films with different molarities and annealing temperature

The molarities of 0.5:0.5 ratio film has separate Cd and Te peaks and CdTe peaks at 2theta value of 39.4 with (204) orientation. Further increasing of Cd concentration CdTe peaks appears. The main diffraction peaks are at 2theta of 23.6 and 39.4 occurred, the corresponding h k l values are (111) and (220) planes of cubic structure of CdTe. These values are good agreement with JCPDS file no. 80-0090[11-14]. 1: 0.5 ratio with 350 ^{o}C and 400 ^{o}C shown in Fig 1-b. The peaks of 2θ values in the graph 23.8, 39.4, 46.3 and 67.34 occurred, the corresponding h k l values are (111) (220) (311) and (204) orientation. The grain size for the most dominant peak is calculated using the Debye Scherrer formula[15]. During the film growth and post annealing treatment, there is a possibility to develop some defects like strain, stress and dislocation density. It is may be affect the mechanical, optical and electrical properties of the films. The calculated grain size, micro strain and dislocation density of the samples are shown in table 1.

Table.1 shows the Grain size, strain and dislocation density of the samples

Samples	Grain size (nm)	Strain × 10^{6}	Dislocation density ×10^{14}
0.5:0.5 molarity with 300 ^{o}C	-	-	-
1:0.5 molarity with 300^{o}C	41.1163	0.088052	5.91523
1:0.5 molarity with 350 ^{o}C	47.744	0.07582	4.39504
1:0.5 molarity with 400 ^{o}C	49.33	0.07338	4.10939

SEM analysis.

The structural morphology of the CdTe samples was analysed using scanning electron microscopy. The fig.3 shows the CdTe thin films annealed at different annealing temperature with the molarity of 1:0.5 ratio. The glass substrate was covered with CdTe particles with irregular shaped structure and the particles are agglomerated.

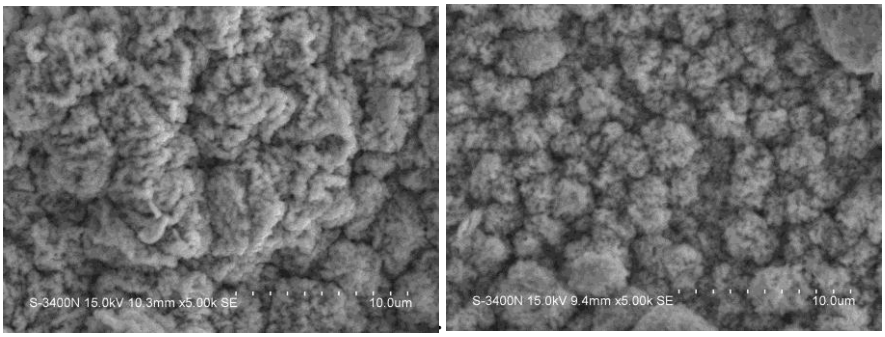

Fig.2 shows the SEM image of CdTe thin films on glass substrate with the annealing temperature of 350 ^{o}C and 400 ^{o}C with the molarity of 1: 0.5

Optical study

Spectral transmittance (T) data were recorded using UV-Vis spectrometer in the wavelength range 200 to 1100 nm. From the spectral date the absorption coefficient, α calculated by using this formula

$$\alpha = \frac{2.303}{d} In(1|T)$$

Absorption coefficient can be calculated the optical energy band gap (E_g):

$$\alpha = \frac{(h\upsilon - E_g)^n}{A\upsilon}$$

Where A is constant, hυ is photon energy; n is the value related to either direct or indirect transition.

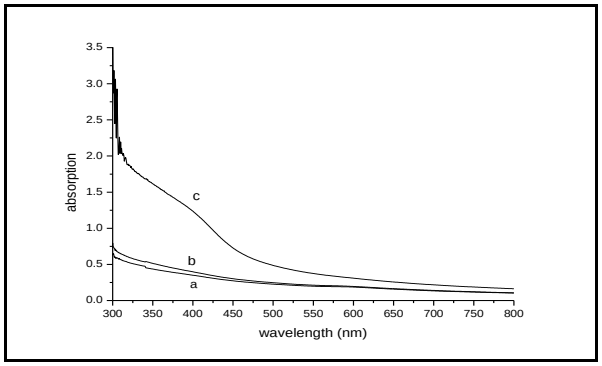

Fig.3 shows the absorption spectra of CdTe thin films (a) 1:05 molarity with 300 ^{o}C, (b) 1:05 molarity with 350 ^{o}C and (c) 1:05 molarity with 400 ^{o}C .

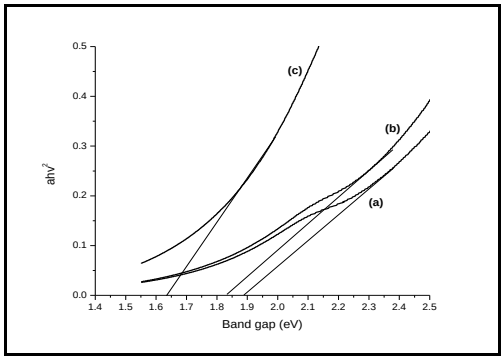

Fig.4 shows the variation of $(\alpha h\upsilon)^2$ against band gap (a) 1:05 molarity with 300 ^{o}C,(b) 1:05 molarity with 350 ^{o}C and (c) 1:05 molarity with 400 ^{o}C .

Annealing temperature increases the absorbtion of the prepared CdTe films also increased, it is shown in fig.3. This band gap energy can be obtained by plotting $(\alpha h\upsilon)^2$ versus band gap shown in fig.4. The values are varied with between approximately 1. 8 to 1.65 eV for the samples deposited with different morality and annealing temperature. It is good agreement with those found in the literature data for the CdTe band gap [11 and 16]. The lower band gap obtained from the samples coated at a higher annealing temperature could be attributed to the change with the grain size.

Conclusion

The thin films of Cadmium Telluride were coated on glass substrate using simple and cost effective dip coating method. 1:0.5 molarity is better then that of 0.5:0.5 molarity. The XRD data exhibited the polycrystalline nature with a cubic structure of Cadmium Telluride and perfectly orientation. The grain size, micro strain and dislocation density was calculated. The surface morphology shows the agglomeration of CdTe particles. From the UV results showed the observance, and optical band gap of the CdTe films. An optical band gap of CdTe films was due to the direct transition which was found to be ~ 1.8 eV to ~ 1.6. It is suitable for optoelectronic application.

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