International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 8 Issue 9 ǁ 2020 ǁ PP. 51-54

Synthesis and Structural Characterization of Binary Compound Cadmium Telluride Thin Films

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Abstract: *Cadmium Telluride thin films were prepared on a glass substrate at room temperature using thermal evaporation method under the vacuum of* 10^{-5}*torr. The structural properties of films were evaluated by XRD and Scanning Electron Microscopy. The quantitative analysis was done by Energy Dispersive Analysis for X – Ray to determine atomic % of the material used. The X-ray diffraction (XRD) patterns of these CdTe samples were recorded by X-ray diffractometer. The X-ray diffraction analysis confirms that films are polycrystalline in nature. The lattice parameters in the prepared thin films have been determined as a= 4.57Å and c=7.48Å. The crystallite size (D) were calculated and found to be 10.9 – 13.6 nm. The internal strain and dislocation density of these films were found to decrease with increase in thickness. The surface morphology of CdTe thin films were characterized by Scanning Electron Microscope (SEM). The SEM image of CdTe thin films shows that the films are uniform, polycrystalline, well cover on glass slide. The particle sizes were found to be 19.6 – 20.6 nm. From AFM analysis we observe that the grains are formed by a nanograin structure. The root mean square value of the surface roughness of the films from different area of the film was calculated and found to be 19.16 nm.*

Keywords: *Thermal evaporation method, nanoparticles, XRD, SEM, AFM.*

Date of Submission: 09-10-2020 Date of acceptance: 24-10-2020

I. INTRODUCTION

Cadmium Telluride is an important member of II-VI semiconductor group of binary compounds. It has a direct intrinsic band gap of 1.74 eV which makes it an interesting material for various applications such as solar cells, high efficiency thin-film transistors, electron-beam pumped lasers, LED, electroluminescent devices, etc [1-5]. In addition, CdTe has good absorption coefficient to visible light. This property is useful for conversion efficiency and has led to the investigations for obtaining efficient solar cells. There are a number of reports on the different structural, optical and electrical properties of CdTe polycrystalline thin films prepared by various techniques such as vacuum evaporation [6-7], quasi-closed volume technique [8], electrode position [9-12], chemical bath deposition (CBD) [13-14], spray pyrolysis [15], sputtering [16] etc. It is seen that different parameters of a film are structural dependent which is also depends on the method of preparation, its thickness and other factors. In this work we have studied the effect of thickness on the structural properties of CdTe thin films of different thicknesses prepared by Thermal evaporation technique. Structural parameters such as lattice parameters, crystallite sizes measured from XRD spectra and particle size by SEM and are found to depend on the film thickness. The details have been reported in this paper.

II. EXPERIMENTAL

2.1 Preparation of Compound Ingot

The compound ingot of CdTe was obtained by mixing quantities of high-purity (99.999%) cadmium foil and Tellurium metal in the atomic proportion 1:1. The mixture was sealed in an evacuated quartz tube at a pressure of 10^{-5}torr and heated at 940^0C for12 hours, and then quenched in ice cooled water.

2.2 Synthesis and Characterization of Sample

Polycrystalline CdTe films have been deposited by thermal evaporation technique under vacuum of about 10^{-5}torr. The substrate to source distance was kept 12cm. The samples of different thicknesses were deposited under similar conditions. The thickness of the films was controlled by quartz crystal thickness monitor model No. DTM-101 provided by Hind-Hi Vac. Further confirmation of thickness was estimated by Tolansky's method [17] using multiple beam Fizeau fringes. The deposition rate was maintained 5-10 Ǻ/sec throughout sample preparation. Before evaporation, the glass substrates were cleaned thoroughly using concentrated chromic acid, detergent, isopropyl alcohol and distilled water.

X – Ray diffractogram (Bruker, Germany) were obtained of these samples to find out structural information and to identify the film structure qualitatively. The scanning angle (2θ) range was from 20^0 - 80^0

(CuKα line). Surface morphological studies of the thermally deposited CdTe thin films were done using the Scanning Electron Microscope (Model S-5500, Hitachi) operating with an accelerating voltage 50 kV and Atomic Force Microscopy (AFM). The quantitative compositional analysis of the CdTe films were carried out by EDAX (Energy dispersive X-ray Analyzer) technique attached with the SEM.

III. RESULTS AND DISCUSSIONS

3.1 XRD Characterization

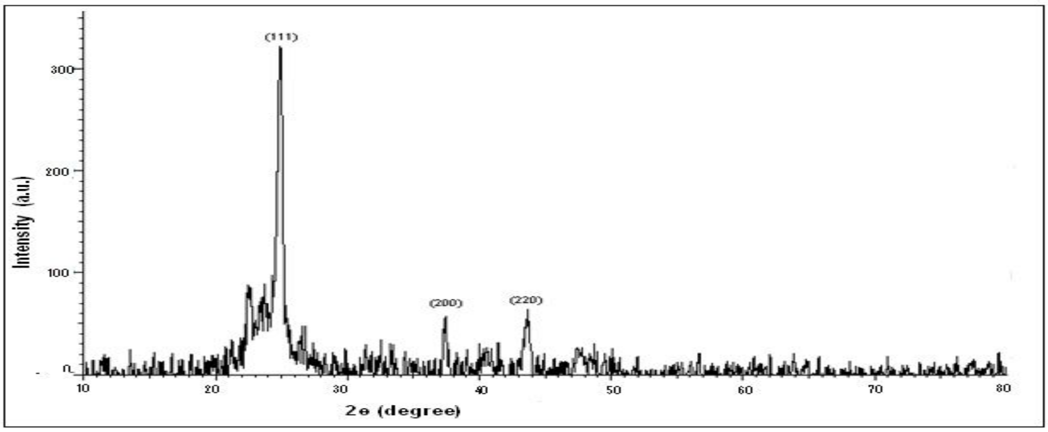

Fig.1: XRD of CdTe of thickness 1500Å

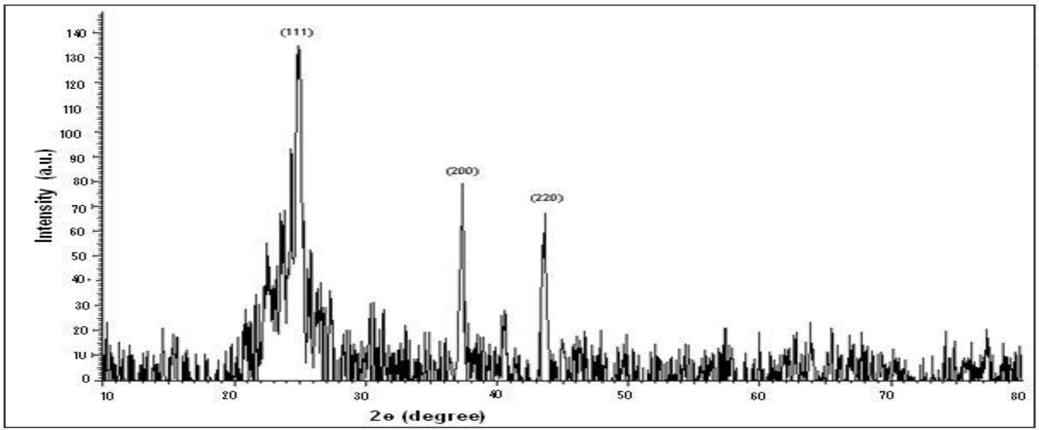

Fig.2: XRD of CdTe of thickness 3000Å

Fig.1 and Fig.2 illustrates the XRD pattern of CdTe thin film prepared at substrate temperature of 303K. The 2θ peaks observed at 24.914^0, 37.316^0 and 43.582^0, exhibit the formation of the cubic phase of CdTe which is correspond to the (111), (200) and (220)) planes of reflections. The inter-planar distances as indicated in the XRD result were found to be 3.5711 Å, 2.4078 Å, and 2.0750 Å. The presence of large number of peaks indicates that the films are polycrystalline in nature. From the results shown above, the strongest peak for the grown films occurred at 2θ=24.914° with d = 3.5711 Å which is correspond to (111) plane. The lattice parameters in the prepared thin films have been determined as a= 4.57Å and c=7.48Å. The average particle size of Cadmium Telluride thin films was determined using Debye–Sherrer's equation and found to be 10.9 – 13.6 nm.

The dislocation density (δ), defined as the length of dislocation lines per unit volume, has been estimated using the equation $\delta= 1/D^2$

Where δ being the measure of amount of defects in a crystal. The number of crystallites per unit area (N) and the strain (ε) of the films were determined with the use of the following formulae: $N= t/D^3$ & $\varepsilon= \beta\cos\theta/4$

Where, t is the thickness of the film. The calculated structural parameters are δ = 8.416 x 10^{15} lines / cm^2, N = 1.158 x 10^{17}, ε = 3.52 x 10^{-3}. The small values of δ obtained in the present study confirm the good crystallinity of the thin films fabricated by the thermal evaporation technique.

3.2 Surface Morphological Studies

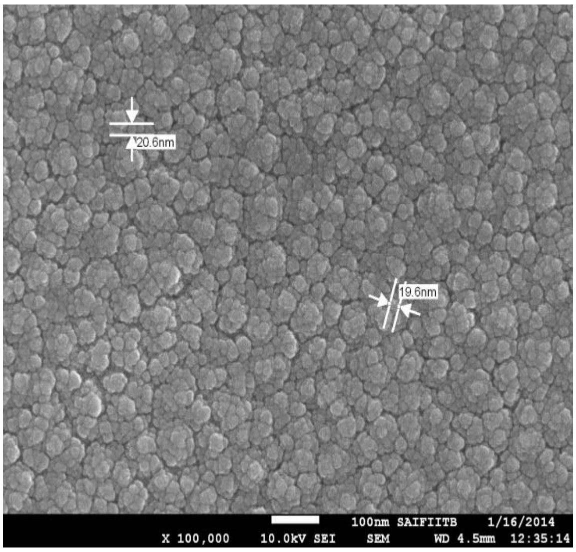

Fig. 3: SEM photograph of CdTe thin film of thickness 3000Å

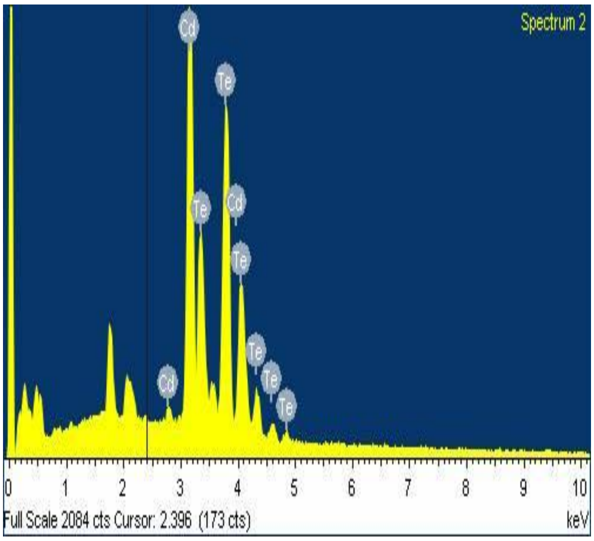

Fig. 4: EDAX spectrum of CdTe thin film

Fig.3 shows SEM images of CdTe thin film of thickness 3000Ǻ with magnifications of 10K. The SEM image of CdTe thin film shows that the film is uniform, polycrystalline, well cover on glass slide. Nano size grains were uniformly distributed over smooth homogeneous background. The particle sizes were found to be 19.6 – 20.6 nm for as deposited. It is observed that the average value of grain size measured from SEM is higher than that of average crystallite size measured by XRD technique.

The EDAX spectral analysis for the CdTe films prepared by thermal evaporation technique is shown in Fig.4. Fully quantitative analysis results were obtained from the spectrum by processing the data through a correction program. The average ratio for atomic percentage of **Cd and Te** was **48.50: 51.50** showing the sample is in good stoichiometric ratio. The obtained results give support for the quality of the prepared CdTe films by thermal evaporation technique.

Fig. 5 (a) and (b) shows 2D and 3D images of CdTe in nanometric range. In this image we observe that the grains are formed by a nanograin structure. The existence of this nanograin structure is very important, as the transport properties of thin films are usually limited by recombination of minority carriers at grain boundaries. Indeed, Keyes, Emery, and Ahrenkiel, [18] after measuring minority-carrier lifetime for different grain size CdTe films deposited by spray pyrolysis and close-spaced vapor transport, concluded that there was enhanced recombination at grain boundaries. This observation by itself shows the importance of AFM in the study of the microstructure of these high resistivity semiconductor materials used for solar cell application. The root mean square value of the surface roughness of the films from different area of the film was calculated. It was observed that the surface roughness of the film is 19.16 nm.

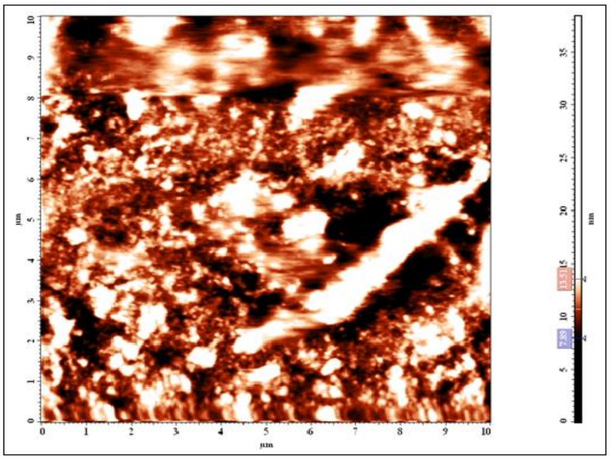

Fig.5 (a): AFM photograph of CdTe (2D image)

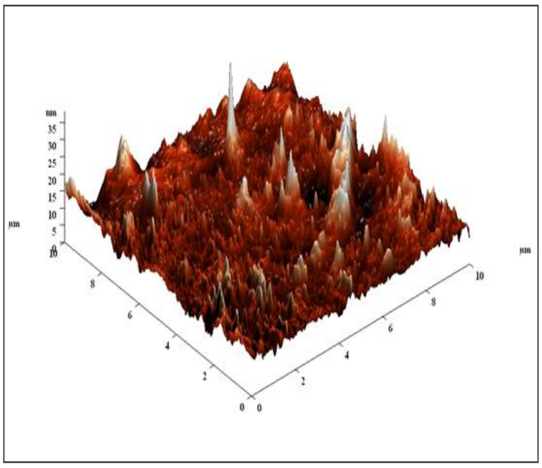

Fig.5 (b): AFM photograph of CdTe (3D image)

IV. CONCLUSIONS

Cadmium Telluride thin films of different thickness have been deposited successfully on glass substrate. XRD confirms that the structure of the film is polycrystalline in nature. It is observed that the particle size varying from 10.9 -13.6 nm. The SEM image of CdTe thin film shows that nanosize grains were uniformly distributed over smooth homogeneous background. The grain sizes are found to be 19.6 - 20.6 nm for as deposited. From AFM study it is observed that surface image is homogeneous and grains are formed by a nanograin structure.

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