Chalcogenide Letters Vol. 7, No. 3, March 2010, p. 159 - 163

OPTICAL AND STRUCTURAL CHARACTERIZATION OF CdTe THIN FILMS BY CHEMICAL BATH DEPOSITION TECHNIQUE

S. DEIVANAYAKI*, P. JAYAMURUGAN, R. MARIAPPAN,
V. PONNUSWAMY
Department of Physics,Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore-641 020, Tamilnadu, India

The CdTe thin films were prepared by chemical bath deposition technique using commercial glass substrates with bath temperature 85°C and annealing temperatures 350°C, 400°C and 450°C. The X-ray diffraction (XRD) analysis shows that the prepared samples are polycrystalline in nature. A significant increase in the XRD peak intensities for the CdTe films after annealing can be observed.. Optical absorption shows the presence of direct transition with band gap energy 1.5eV and after annealing it decreases to 1.4eV. Scanning electron microscopy (SEM) reveals that spherically shaped grains are more uniformly distributed over the surface of the substrate for the CdTe films.

(Received February 15, 2010; accepted February 22, 2010)

Keywords: Cadmium telluride film, Chemical bath deposition, UV-VIS-NIR spectroscopy, XRD, SEM

1. Introduction

CdTe is a useful material for solar cell preparation. It is cheaper than silicon, especially in thin film solar cell technology. “When it is sandwiched with cadmium sulfide a p-n junction photovoltaic solar cell will be formed [1]”. “CdTe solar cells have produced conversion efficiency as high as 16.5% in CBD method [2]”. CdTe with a band gap of 1.45eV is a technically important class of material. It has band to band type transition and has high optical absorption without any phonon assisted mechanism. “The lack of success in the preparation of CdTe films by chemical reaction is the difficulty in preparing the aqueous solution of telluro carbonyls and the oxidative instability of telluride ions [3-4]”. “CdTe is one of the promising semi conducting materials suitable for producing large area solar cells at low cost [5]. “Out of the various growth techniques like molecular-beam epitaxy(MBE) [6-8], metal organic chemical vapour deposition (MOCVD) [9,10]”, “UHV sublimation [11], metal organic vapour phase epitaxy (MOVPE) [12], hotwall epitaxy [13,14], sputtering, thermal evaporation electro deposition, spray pyrolysis and atomic layer epitaxy and chemical bath deposition (CBD), the chemical bath deposition (CBD) is the simplest and most economical method for the preparation of semiconductor thin films[15]” . In this paper an attempt has been made to prepare CdTe thin films by chemical bath deposition and to characterize the same to assess the recombination quality of the CdTe epilayers by thermal treatment.

2. Experimental

CdTe layers were deposited on commercial glass substrates of 1 mm thickness by the CBD technique. 0.1M of Cadmium acetate solution was prepared and 0.2M of ammonia (NH_3) was added drop wise until clear solution is obtained. Then 0.02M of TeO_2 is dispersed in 50 ml aqueous solution of H_2SO_4. Both solutions were magnetically stirred for 2 hrs under nitrogen atmosphere. Then two glass substrates were immersed into the solution for bath temperature 85°C.

* Corresponding author:deivasrinath@gmail.com

After annealing treatment at 350^{o}C, 400^{o}C and 450^{o}C, the Optical, Structural and SEM studies were made and analyzed. The reaction is,

$$Cd(CH_3COO)_2.8H_2O_2+TeO_2 \text{ ----------} \rightarrow CdTe$$

The effect of annealing temperature on structural, optical, and surface morphology properties has also been studied. X-ray diffraction (XRD) studies were made with Philips X pert PRO diffractometer using CuKα radiation (λ=0.15406 nm). AJEOL JSM -5610 scanning electron microscope was used to record the micrograph of the samples. The optical absorption studies were carried out for the films deposited with UV-VIS NIR spectrophotometer (HITACHI 330) in the wavelength range 300 – 850 nm respectively.

3. Results and discussion

3.1 Structural characterization

The XRD pattern of the CdTe thin films prepared on glass substrates with bath composition 0.2 M cadmium acetate and 0.02 M tellurium dioxide at bath temperature 85^{o}C annealed at temperatures of 350^{o}C, 400^{o}C and 450^{o}C are shown in figs.1a-c."The XRD pattern reveals that the deposited films are polycrystalline in nature as reported earlier [16]". The (111) peak corresponds to phase of polycrystalline structure of CdTe. The strong and sharp diffraction peaks indicate the formation of well crystallized sample. It can be seen that the major peak (111) is strongly dominating the other peaks. In figs.1a-c, the samples annealed at 350^{o}C, 400^{o}C and 450^{o}C also develop the weaker peaks (220), (311), and (331) for CdTe. The different peaks in the diffractogram were indexed and the corresponding values of inter planar spacing 'd' were calculated and compared with standard values of JCPDF (file no. 75-2086). The height of (111) peak in X-ray diffraction patterns for CdTe thin films deposited at higher annealing temperature (450^{o}C) exhibit sharper peaks and small FWHM data.

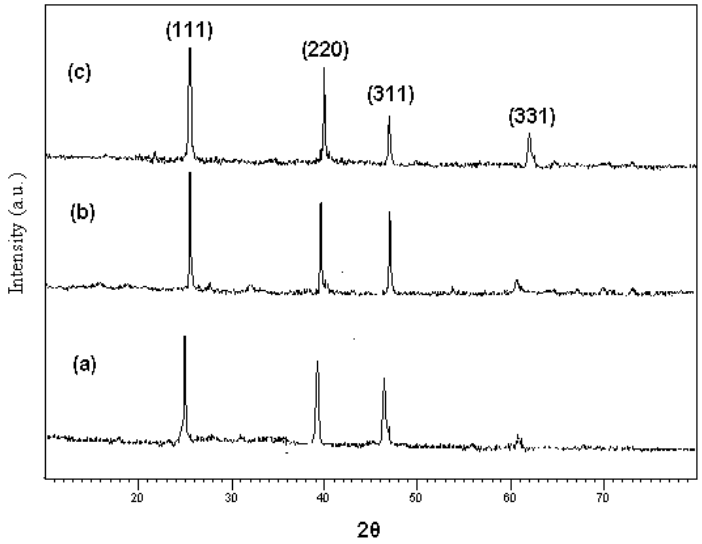

Fig. 1. X-ray diffactograms of thin films at annealing temperatures of a) 350^{o} C b) 400^{o}C and C) 450 ^{o} C.

Using FWHM data and Debye-Scherrer formula, the crystalline size, lattice constant, strain and dislocation density were calculated for the CdTe thin films synthesized at various annealing temperatures 350^{o}C, 400^{o}C and 450^{o}C. The variation of crystallite size and strain with

bath temperature 85^{o}C and annealing temperatures from 350^{o}C to 450^{o}C is shown in Fig. 2. It is observed from Fig. 2, the crystallite size increases with annealing temperature and at 450^{o}C the crystallite size reaches the maximum value and at the same time strain decreases. Fig.3 represents the variation of dislocation density and it is found to decrease while increasing annealing temperature from 350^{o}C to 450^{o}C.

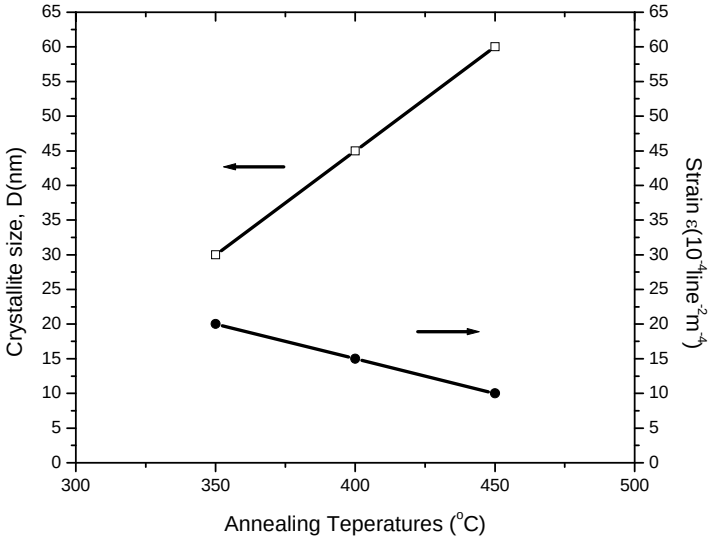

Fig. 2. Variation of crystallite size and strain with annealing temperatures of CdTe thin films.

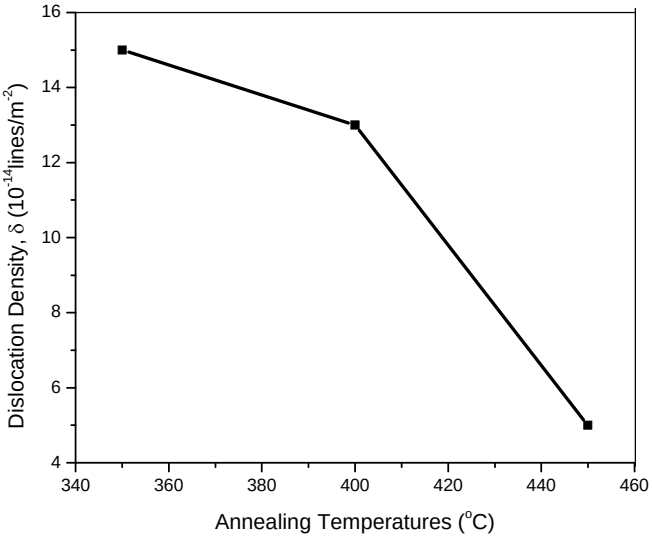

Fig. 3. Variation of the dislocation density with annealing temperatures of for CdTe thin films.

3.2 Surface morphology

The SEM photographs of the annealed CdTe thin films are shown in Fig. 4. No pinholes or creaks are seen for these samples. Theannealing of the film at 450^{o}C for 30 min improves the grain structure. The film after annealing shows smooth and uniform crack free surface with spherical-shaped grains spread all over. The average grain size was found to be 250 nm.

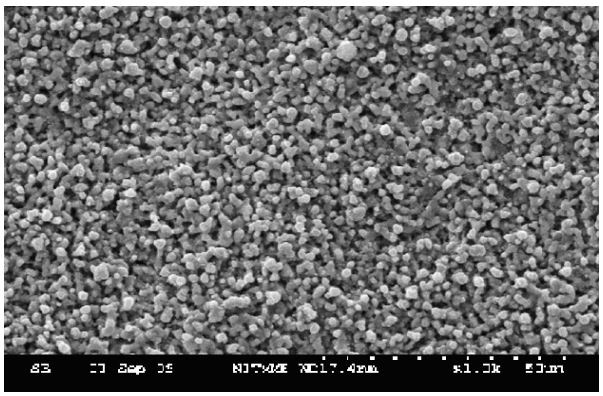

Fig. 4 SEM micrograph of chemical bath deposition of CdTe thin film after annealing at the temperature of 450 ^{o} C.

3.3 Optical properties

The variation of optical density with wavelength was analyzed to find out the nature of transition involved and the optical band gap, using the relation "[17]"

$$\alpha = \frac{A(h\upsilon - E_g)}{h\upsilon} \tag{1}$$

where, A is a constant and E_g is the band-gap energy.

The optical energy gap E_g could be obtained from the intercept of $(\alpha h\upsilon)^2$ vs $h\upsilon$ for direct allowed transitions. The $(\alpha h\upsilon)^2$ vs $h\upsilon$ plots for typical sample deposited at optimized preparative parameters (deposition time 30 min, bath temperature 85^{o}C) and annealed at 350^{o}C, 400^{o}C and 450^{o}C are shown in Figs. 5a-b. CdTe thin films as-deposited and annealed in air are presented in Figs.5a-b. In the case of chemical bath deposition of CdTe thin films, the optical band gap was shifted from 1.5eV to 1.4eV. This leads to a shift of lower annealing temperature 350^{o}C to a higher annealing temperature to 450^{o}C.

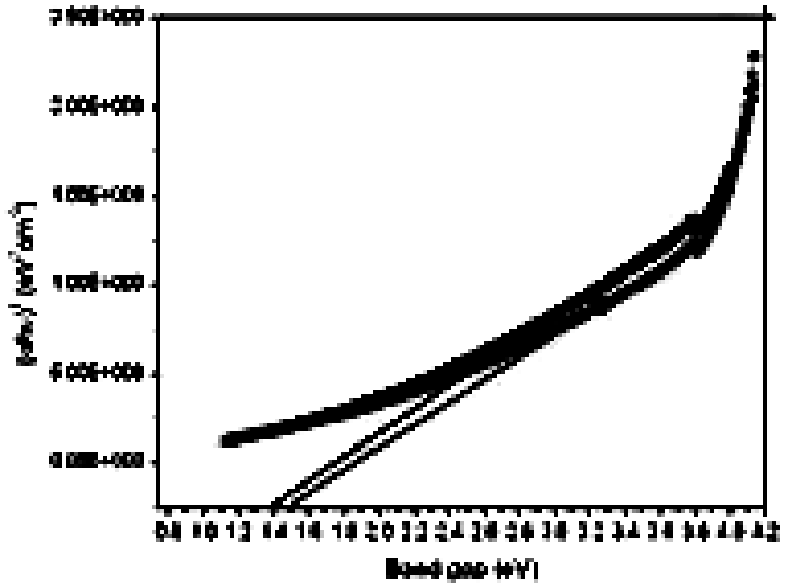

Fig.5a-b Plots of $(\alpha h\upsilon)^2$ vs. $h\upsilon$ for CdTe films after annealing at temperatures of a) 350^{o} C b) 400^{o} C and 450 ^{o} C

3.4 Conclusions

The chemical bath deposition of CdTe thin films and the effect of annealing temperature have been studied. The optical, compositional and morphological analysis of prepared and annealed films have been done. The energy gap of the synthesized material is found to vary between 1.5 eV and 1.4 eV. The films prepared with the optimized deposition parameters show preferential orientation along (111) plane. The annealing treatment of the film in air determines an improvement in the polycrystalline nature of the film. The SEM study shows the smooth and uniform growth of spherical-shaped grains on substrate surface with a crack free appearance and the average grain size was found to be 250 nm.

References

[1] The Mora –Sero, R.Tena – Zacra, J.Gozalez, V.Munoz sanjose, J.Crys growth **262**, 19 (2004).
[2] C. S Feretides, D.Marinskiy, V. Viswanathan, B.Tetall, V. Palekis, P.Selvaraj, D.L Morel, Thin solid films, **361-362**, 520 (2000).
[3] G.M.Li.R.A.Zingaro, M. Segi J.H Reibenspies, T.Nakajima, Organometallics 756 (1997).
[4] G.M Li.R.A.Zingaro, J.Chem.soc.perkin Trans.**1**, 647 (1998)
[5] B.E.mc Candless ,J.R.sites,in; Luque,A.Hegedus,s.S.(Eds),Handbook of Photovoltaic Science and Engineering, john Wiley$sons, (617-662) 2003.
[6] M. S. Han, T. W. Kang, J.H. Leem, M.H. Lee, K.J. Kim, T.W. Kim, J. Appl. Phys. **82,** 6012 (1997).
[7] S. Rujirawat, Y. Xin, N. D. Browning, S. Sivananthan, D. J. Smith, S. -C. Y. Tsen, Y. P. Chen, V. Nathan, Appl. Phys. Lett. **74**, 2346 (1999).
[8] H. Ebe, T. Okamoto, H. Nishino, T. Saito, Y. Nishijima, M .Uchikoshi, M. Nagashima, H. Wada, J. Electron. Mater. **25**, 1358 (1996).
[9] R. Chou, M. Lin, K. Chou, Appl. Phys. Letts. **48**, 523 (1986).
[10] I. Baht, W.S. Wang, Appl. Phys. Letts. **64**, 566 (1994).
[11] J. H. Pei, C.M. Lin, D. S. Chou, Chin. J. Phys. **36**, 44 (1998).
[12] H. Nishino, Y. Nishijima, J. Cryst. Growth **167**, 488 (1996).
[13] R. Korenstein, P. Madison, P. Hallock, J. Vac. Sci. Technol. B **10**, 1370 (1992).
[14] H. Tatsuoka, H. Kuwabara, Y. Nakanishi, H. Fujiyasu, J. Cryst.Growth **129**, 686 (1993).
[15] M.Stoelo- Lerma, Ralph.A.Zingaro, S.J.Castillo, Journal of Oregano metallic Chemistry **623**, 81-86 (2001).
[16] A.V. Kokate, M.R. Asabe, P.P. Hankare, B.K. Chougule, Journal of Physics and Chemistry of solids **68**, 53-58 (2007).
[17] A.V. Kokate, U.B. Suryavanshi, C.H. Bhosale, J. Sol. Energy **80**, 156 (2006).