

RAMAN SCATTERING STUDIES ON POLYCRYSTALLINE $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ THIN FILMS

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Polycrystalline $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films were prepared by vacuum evaporation onto well-cleaned glass substrates maintained at 300, 373 and 473 K. X-ray diffraction studies revealed that the films have zinc blende structure with preferential (111) orientation. Raman peak of the as-deposited film appeared at 140.30 cm^{-1} and 159.65 cm^{-1} were for the transverse optic (TO) and longitudinal optic (LO) phonons respectively. The XRD patterns of the higher substrate temperature deposited films exhibited an increase in the intensity of the (111) peak and decrease in the FWHM. The Raman peak position did not change appreciably, whereas the peak intensity increases and the FWHM decreases for the higher substrate temperature and the results are attributed to the improvement of crystallinity of the films on thermal treatment.

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1. Introduction

The ternary alloy $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$ (CZT) is a IIB-VIA compound semiconductor, in which Zn occupies Cd sites. Due to the wide range between the band gap energy of the binary compounds ($\text{CdTe} = 1.45\text{ eV}$ to $\text{ZnTe} = 2.3\text{ eV}$), this alloy has a great potential in opto-electronic devices, such as solar cells, optical windows, photodetectors, light emitting diodes, optical memory devices, X-ray and gamma ray detectors [1-4]. $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$ is mainly used as the substrate material for the growth of HgCdTe IR detectors and also it is used as the surface passivation layer to HgCdTe infrared focal plane arrays (IRFPAs) [5]. Raman spectroscopic technique is the most useful method to study the lattice vibrations and their interactions with other excitations [6]. In the present study the $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films were deposited onto well-cleaned glass substrates maintained at different substrate temperatures and are characterized by XRD, AFM and Raman scattering.

2. Experimental

The $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ alloy was prepared from its own constitutional elements. Appropriate weights of Cd, Zn and Te (purity 99.999%) were mixed together, charged in a quartz tube and sealed under a vacuum of 10^{-5} Torr. The sealed quartz ampoule with the charge was placed in a rotating furnace. The temperature of the furnace was raised gradually to 1373 K and left at this temperature for about 36 hours, after that the ampoule was slowly cooled to room temperature at a rate of 30° C/h [7]. The $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ ingot was taken out from the ampoule and made into fine powder and used for film preparation. Thin films of $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ were deposited onto well-cleaned glass substrates by vacuum evaporation. Tantalum boat containing the powder was used as the source and the pressure inside the chamber was maintained better than 10^{-5} Torr. The thickness and rate of evaporation of the films were monitored by a Quartz crystal thickness monitor. The composition and thickness of the

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films were evaluated by using Rutherford backscattering spectrometry (RBS). Structural analysis was made using a Philips X-ray diffractometer with $\text{CuK}\alpha$ radiation ($\lambda = 1.542 \text{ \AA}$) at 40 kV and 20 mA in the scanning angle (2θ) from 20° to 50° . The surface microstructure of the films was investigated by ex-situ atomic force microscopy (AFM) (PSI, Autoprobe CP model). Raman spectra of the films were recorded at room temperature using a 488 nm Ar^+ laser beam of power 200 mW over a $50 \mu\text{m}$ spot size. The scattered light was collected in the backscattering geometry using a double grating monochromator SPEX model 14018. The spectra were recorded using a microprocessor based automated data collection system with a step of 0.5 cm^{-1} and a collection time of 10 s.

3. Results and discussion

The vacuum evaporated $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films were uniform, smooth and exhibits good adhesion to the substrate surface. Fig. 1 shows the RBS spectrum of the room temperature deposited $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin film. The films were found to have a very good stoichiometry as analyzed by RBS simulations (GISA3) (Cd: 0.898, Zn: 0.102 and Te: 1.00). The thickness of the $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin film evaluated by RBS was $312 \pm 1 \text{ nm}$, which agrees well with the thickness $310 \pm 1 \text{ nm}$ determined by using a α -step surface profilometer (Tencor α -STEP Instrument).

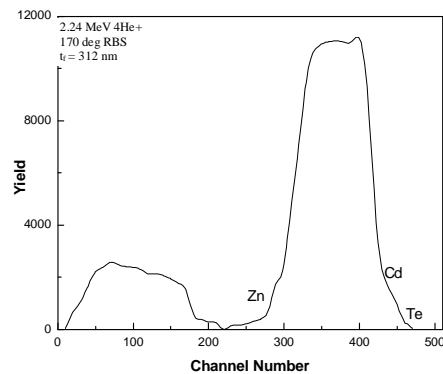


Fig. 1. Rutherford backscattering spectrum of $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin film ($t_f = 312 \text{ nm}$).

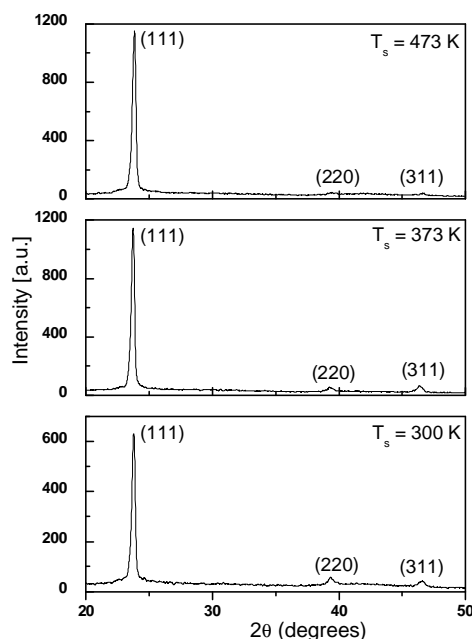


Fig. 2. XRD spectra of $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films.

Fig. 2 shows the XRD patterns Cd_{0.9}Zn_{0.1}Te films deposited at different temperatures. The films exhibited polycrystalline nature with zinc blende structure. Cd_{0.9}Zn_{0.1}Te films were found to exhibit three diffraction peaks associated with (111), (220) and (311) reflections, of which the intensity of the (111) orientation is very predominant [8]. The XRD patterns of the higher temperature deposited films clearly show an increase in peak intensity of the (111) peak. The increase in intensity and the decrease in FWHM of the (111) peak may be attributed to improvement of crystallinity on thermal treatment. The decrease in intensity of the (220) and (311) peaks may be due to increase of the preferential orientation along (111) direction upon heat treatment.

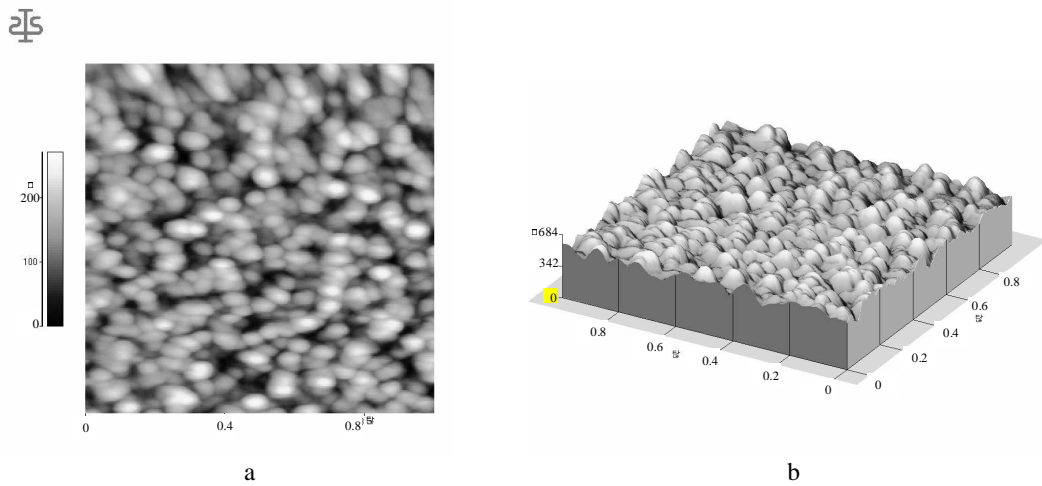


Fig. 3. Two-dimensional (a) and three-dimensional (b) AFM images of room temperature deposited Cd_{0.9}Zn_{0.1}Te thin film (1 μm × 1 μm).

Ex-situ atomic force microscope (AFM) has been used independently to access surface quality of the vacuum evaporated Cd_{0.9}Zn_{0.1}Te thin films. Fig. 3 shows the two-dimensional and three-dimensional AFM images of the room temperature deposited film (1 μm × 1 μm). The root mean square (rms) roughness evaluated from AFM measurement of the vacuum evaporated Cd_{0.9}Zn_{0.1}Te thin film at room temperature is 3.1 nm. The rms roughness of the 373 and 473 K deposited films were 2.9 nm and 2.8 nm respectively (error ± 0.1 nm). This may be due to the removal of surface defects at the higher substrate temperature. The average surface roughness evaluated by AFM measurements of the 300, 373 and 473 K deposited films were 3.3 nm, 3.1 nm and 3.0 nm respectively (error ± 0.1 nm).

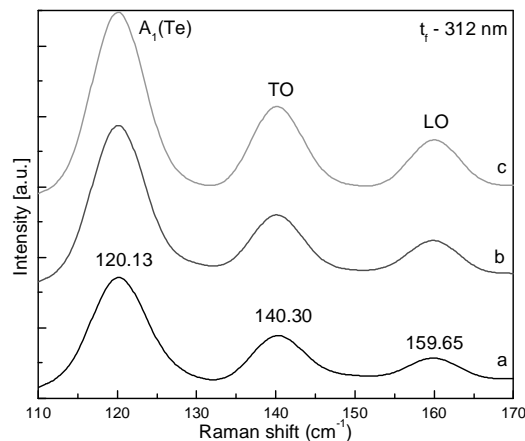


Fig. 4. Raman scattering spectra of Cd_{0.9}Zn_{0.1}Te thin films. (a) T_s = 300 K (b) T_s = 373 K and (c) T_s = 473 K.

In ternary compounds an excellent illustration of lattice dynamics can be obtained by using Raman scattering spectroscopy. Fig. 4 shows the typical Raman spectra of the 300, 373 and 473 K deposited $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films. The Raman peaks are identified at 140.30 cm^{-1} and 159.65 cm^{-1} for the transverse optic (TO) and the longitudinal optic (LO) phonons respectively in $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$ [9]. The peak at 120.13 cm^{-1} is the phonon with A_1 symmetry of the Te precipitates in CdTe [10]. Similar longitudinal and transverse optical (LO, TO) modes in $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$, which arise from CdTe- and ZnTe-like vibrations were reported by Harada and Narita [11]. We can observe from Fig. 4 that the peak position remains more or less the same, but the peak intensity and the area under the LO and TO peaks increases and the FWHM values decreases with substrate temperature, which is due to the improvement of crystallinity of the films on higher temperature deposition [12]. Similar results were obtained for the vacuum evaporated $\text{Cd}_{0.96}\text{Zn}_{0.04}\text{Te}$ thin films [13].

4. Conclusions

$\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$ thin films prepared by vacuum evaporation exhibited zinc blende structure with predominant (111) orientation. The rms roughness and the average roughness of the films deposited at room temperature, evaluated by atomic force microscopy were 3.1 nm and 3.3 nm respectively. The Raman spectra of the films exhibited longitudinal optic (LO) and transverse-optic (TO) modes, which arise from CdTe- and ZnTe- like vibrations. At higher substrate temperatures, the intensity of the (111) peak increases and the FWHM decreases. The rms roughness and the average roughness of the films decrease with increase of substrate temperature, which may be due to the removal of surface defects on higher substrate temperature deposition. The Raman peak positions of the higher substrate temperature deposited films remained more or less the same, whereas the peak intensity and the area under the LO and TO peaks increases and the FWHM values decreases with substrate temperature, which is due to the improvement of crystallinity of the films on higher temperature deposition.

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