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Structural, Morphological and Electrical investigations of $Zn_{0.05}Cd_{0.95}Te$ thin films

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***Abstract**: Thin film of high purity (99.999 %) $Zn_xCd_{1-x}Te$ (where x =0.03, 0.05, 0.07, 0.09) wereprepared by high vacuum technique (HVT×10^{-6}Torr), on glass substrates at differentsubstrate temperatures. $Zn_{0.05}Cd_{0.95}$ Te, ($Zn_xCd_{1-x}Te$, where x =0.05)The film deposited at lower temperature was annealed for one hourin vacuum of $5x10^{-3}$torr at as-deposited to 300K. Structural investigation has been carriedout using the X-ray diffraction technique. Scanning electron microscopy have been usedto study the morphological behaviour of the thin films. At the lower depositiontemperature the film represents amorphous nature but with increasing value of x the filmexhibits polycrystalline nature. The SEM indicate that in amorphous state the surfaces arenon uniform but at higher annealing temperature the film surfaces are uniform. The built in voltage is estimated to be about 0.65 eV.*

1 Introduction:

In recent years, much attention has been paid to the II-VI group chalcogenide materials,mainly due to their wide range of applicability as solid state devices in scientific and technologicalfields. The study of $Zn_{0.05}Cd_{0.95}$ Tethin films is of great importance because it has many scientific andtechnological applications in the areas of optoelectronic devices, particularly in solar cells [1-7].$Zn_{0.05}Cd_{0.95}$ Teis a II-VI compound semiconductor with a direct optical band gap of 1.65-1.75 eV atroom temperature. In the present work the structure of $Zn_xCd_{1-x}Te$ (x = 0.03,0.05,0.07,0.09) havebeen investigated in both the annealed and as-deposited states. X-ray diffraction is used todetermine the crystal structure of the layers. Prepared samples are sometimes amorphous andsometimes crystalline, depending on evaporation rate about 2θ atomic planes of each constituentper layer. Amorphous phase has also been observed in case of $Zn_{0.05}Cd_{0.95}$ Tethin film. This has beenobserved in thin film pairs where the large atomic structure mismatch produces epitaxy betweenthe layers. Absence of large range crystalline order are observed even at smaller layer thicknessand low temperatures, whereas at large thickness and at higher temperature the interface iscrystalline [8-9]. Hence we report some of our results from as-deposited and annealing effect on$Zn_xCd_{1-x}Te$ thin films, which are prepared with equal numbers of closed packed planes ofCadmium telluride and Zinc telluride. Therefore these films are given a post deposition annealingtreatment at different temperatures in a vacuum of $5x10^{-3}$torr. X-ray diffraction is used tocharacterize the nature of the film [10-11]. Scanning electron microscopy were carried out to studythe effect of the deposition temperature and annealing temperature on the surface of the thin films.Generally clean and smooth surface crystalline films show clear detectable island in scanningelectron micrograph investigations [12]. The contrast of the different islands is produced by thedifferent orientations of the island with respect to the angle of the backscattered electrons.

2Experimental :

Thin film samples consist of alternate layers of $Zn_xCd_{1-x}Te$ (x = 0.03, 0.05, 0.07, 0.09).Thefilm of thickness 0.30 μm were prepared by electron beam evaporation of $Zn_xCd_{1-x}Te$ of 99.999%purity on optically plane transparent photographic pyrex glass substrate of dimensions 2.5cm x7.5cm under the vacuum of reduced pressure of 1 x 10^{-6}torr using 'HINDHIVAC 12' vacuumcoating unit (Model:12A4DM). The films were prepared at different substrate temperature of300K . An ultra high-cleaned graphite crucible was kept on water-cooled platform andthe material was placed in the crucible. A high power electron beam was made focused into thecrucible to evaporate the material. Power of the electron beam was carefully controlled andoptimized so that the dissociation of the material in its constituents could be prevented. In our caseoptimized beam power was 500 Watt. Rate of deposition was calculated from the thickness, andtotal time of deposition was 15 Å S-1. Films of $Zn_xCd_{1-x}Te$ deposited at room temperature wereannealed in vacuum (5 x 10^{-3}torr) at the temperatures as-deposited, 400, 500 and 600K for onehour each to observe polycrystallization of amorphous films. X-ray diffraction was performed insymmetric reflection geometry when the scattering vector is perpendicular to the plane of thesample, and symmetric transmission geometry when the scattering vector lies in the plane of thesample. In symmetric reflection geometry, the structure of the sample is probed in the direction ofthe growth. The layer structure of these films was determined by X-ray diffraction (PHILLIPS PW1700) using Ni-filterd Cu-Kα (λ= 1.54 Å) radiation [13-14]. Large angle (2θ =20°−90°) X-raydiffraction (XRD), in the Bragg-Brentano geometry was used to characterize crystallinity. Surfaceof the film has been studied by the scanning electron microscopy (SEM). SEM photographs aretaken in secondary electron emissive mode using ETECH AUTOSCAN scanning electronmicroscopy.

3 Structural and morphology propertiesAnalysis

3.1 Effect of substrate temperature and annealing temperature on X- ray diffraction

The structural properties of $Zn_{0.05}Cd_{0.95}Te$ thin films have been determined by alarge angle ($2\theta =20^0-90^0$, λ=1.54 Å) X-ray diffraction patterns. To study the effect of substratetemperature, the X-ray diffraction measurement are carried out on the $Zn_{0.05}Cd_{0.95}Te$ thin film ofthickness 0.30μm deposited at 300K is shown in Fig.1(a,b,c,d). Thefilms were found to be sometimes amorphous and sometimes crystalline, perhaps depending on thevalue of annealing temperature of the films. When the films are deposited at 300K as shown in Fig.1

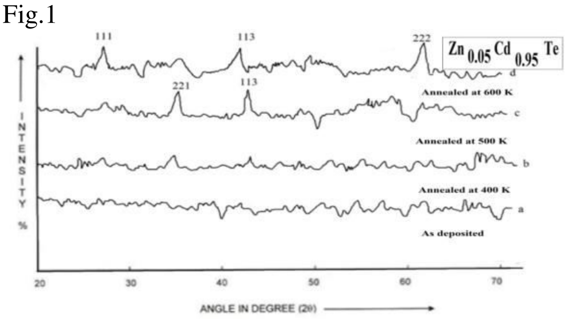

Figure.1. X-ray diffraction pattern of Zn0.05Cd0.95Te thin film of thickness 0.30 μm deposited at300K in vacuum of 2x10-5 torr at different temerature (a) As prepared (b) 400 K(c) 500 K and (d) 600 K.

The inner films tended to be amorphous at lower temperature. This statement is furthersupported by the observations of different workers [15-16]. Film deposited at 300K is found to beamorphous in nature and with the increasing value of annealing the films are found to be polycrystalline innature along the peak intensity direction as shown in Fig. 1 (a,b,c,d). We see that the depositedfilms are better polycrystalline in nature with increasing annealing temperature and value of annealing temperature. Theintensity for the various planes was estimated by measuring peak heights directly on thediffractometer chart. To identify the crystalline phase, as well as crystalline forms, films, weresubjected to annealing at as deposited, 400, 500 and 600K for one hour in vacuum of the order of 5x 10-3torr. The annealing temperatures were selected to be between glass transition (Tg) and thecrystalline temperature (Tc) as drawn out from DTA traces. After each step of annealing the X-raydiffraction was recorded with the diffraction angle (2θ) of range 200-900. Among obtained tracesof the sample, (a,b) is amorphous state as illustrated in Fig.3 (a,b). The growth ofthe peak, due to increase in annealing temperature, may be attributed to the growing up of thecrystalline phase of the virgin film [17]. The main crystalline phases obtained for Cd, Zn, Te, CdTe andZnTe were matched to the American Society for Testing and Material (ASTM) Cards.

3.2 Effect of substrate temperature and annealing temperature on surface morphologyanalysis

Thin films were prepared at different substrate temperature of 300K Afterpreparation, the surface uniformity of the films has been studied by scanning electron microscopy(SEM) for which photographs are taken with secondary electrons using a AUTOSCAN scanningelectron microscope. Scanning electron micrograph of the $Zn_xCd_{1-x}Te$ films are shown in Fig.4(a,b,c,d). From the Fig.4 (a,b,c,d) it can be seen that small nonuniform spherical grains aredistributed across the smooth glass substrate. It can be seen that spherical island density decreasesas the value of x increases and also the grain size increases. The reason for this is that the sphericalgrains can obtain enough energy to move at higher temperatures. Films prepared at 300K isannealed in vacuum of 5x10-3 torr at as deposited, 400, 500 and 600K respectively. Fig.2 (a,b,c,d)shows SEM image of annealed films,$Zn_{0.05}Cd_{0.095}Te$ deposited at 300K, observation have been madefor different values of x not shown here.

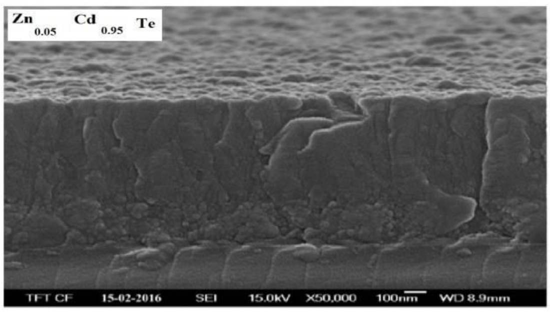

Figure.2 (a,b,c,d)shows SEM image of annealed films, Zn0.05Cd0.095Te deposited at 300K

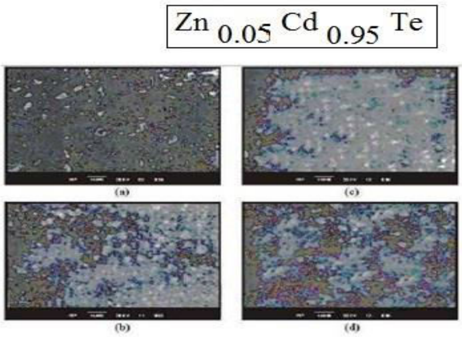

Figure. 3. SEM analysis of $Zn_xCd_{1-x}Te$ thin film of thickness 0.30 μm deposited at 300K invacuum of $2x10^{-5}$torr and annealed at different temperatures (a) As deposited (b) 400 K (c) 500 K and (d) 600 K.

It can be seen from fig.2 and fig.3 that the grain density decreases and grain size increases with increase in theannealing temperature and value of annealing temperature. At higher temperature the surface mobility increases [18-22]. Owing to an increase insurface mobility, the uniformity of the film is much improved [23-27].

4 Electrical properties (I-V characteristics)

Figure 4.3 shows the I-V characteristics of $Zn_{0.05}Cd_{0.95}Te$thin film measured by tuning bias voltage with the step of 0.1 V. At annealing temperature of 400K the crystallinity is not well, let the resistivity is very large so the rectifying behaviour is not clearly observed.The barrier height is found to be 0.79 eV. In the present work we have chossen the n- type CdTe with p type ZnTe to fabricate the transparent p-n and discussed the effect of annealing temperature on the electrical properties of the $Zn_{0.05}Cd_{0.95}Te$thin film. The $Zn_{0.05}Cd_{0.95}Te$in our work showed the rectifying properties which has potential applications in optoelectronic devices.

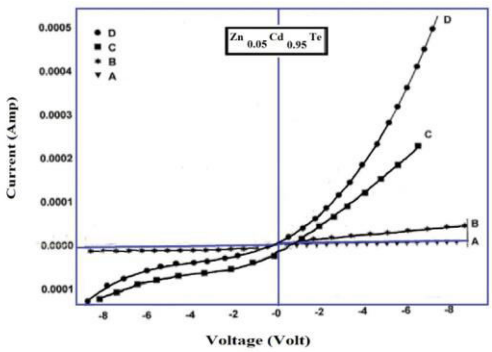

Figure.4 I-V characteristics of $Zn_{0.05}Cd_{0.95}Te$ thin film of thickness 0.30 μm deposited at 400 K annealed two hour in vacuum of $2x10^{-2}$torr at different temperature(A) as deposited (B) 400 K (C) 500 K (D) 600 K

5. Conclusion

Graph shows that X-ray peak roots start to grow at different angle within the selectedrange. The X-rays peak roots continue to grow as the temperature of annealing increases in thesuccessive annealing steps. The peaks were selected to investigate the crystallinity and crystallinestructure of each phase, as shown in Fig.3 (a,b,c,d).It is observed from figures that the peak heightincreases while the peak width decreases with higher annealing temperatures.

It is clear from the figure that with increase inannealing temperature, the surface morphology changes i.e. for the film of lower annealingtemperature the surface is nonuniform and the films at higher annealing temperature shows theuniform surfaces.

It shows SEM image at 600K annealing temperature, where largest grain size ispresent. The reason for this is that the grains can obtain enough energy to move and to go foraggregate on the substrate surface during annealing. The non-uniform surface indicates that the filmdeposited at 300K is amorphous in nature whereas after annealing it has become a clearcrystalline

The I-V characteristics clearly demonstrates the rectifying behavior in the range -8 to 8 V for sample annealed at 500K & 600K. The structure of $Zn_{0.05}Cd_{0.95}Te$can be treated as ZnTe/ amorphous CdTe/ZnTe, which is similar to the p-i-n structure. When CdTe and ZnTe film come into contact, a Schottky diode is formed which yields a new equilibrium of energy. The built in voltage is estimated to be about 0.65 eV.

6. References

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