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Effect of heat treatment on optical properties of Cadmium Zinc Telluride thin films grown by cathodic radiofrequency sputtering

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ABSTRACT: Cadmium zinc telluride thin films were prepared by cathodic radio frequency sputtering from cadmium telluride and zinc telluride targets. The films deposited on glass substrates were annealed in vacuum at different temperatures (300 °C – 400 °C). Structural properties of Cadmium zinc telluride were studied using X-ray diffraction; the effects of heat treatment temperature on the optical properties were investigated through optical transmission. It was found that all annealed films were polycrystalline with preferential (111) orientation. The grain size increases as the annealing temperature increases. The optical transmission data showed that annealed films exhibit high transmission. The band gap and the refractive index changed with increase in annealing temperature.

KEYWORDS: $Cd_{1-x}Zn_xTe$ thin films, CdTe, ZnTe, Cathodic rf-sputtering, annealing temperature.

1 INTRODUCTION

The ternary compounds cadmium zinc telluride, with the chemical formula $Cd_{1-x}Zn_xTe$, are II-VI semiconductors which have attracted increasing interest for their wide application in a variety of optoelectronic devices such as photovoltaic cells [1], [2], [3], light emitting diodes [4], radiation detector [5], [6], [7], infrared, X-ray imaging [8], gamma rays detectors [9]. The band gap of $Cd_{1-x}Zn_xTe$ can be tailored in the range of 1.45 to 2.26 eV by controlling its composition, therefore, $Cd_{1-x}Zn_xTe$ has emerged as a leading candidate for tandem solar cells [10].

$Cd_{1-x}Zn_xTe$ thin films have been successfully grown by a variety of techniques such as radio frequency sputtering [11], chemical vapour deposition [12], molecular beam epitaxy [13], vacuum thermal evaporation [14], tow-stage process [15], and electrodeposition [16]. All of these methods of film preparation have their inherent advantages and disadvantages. In the last decade, there has been an increased interest in the study of physical properties of Cd1-xZnxTe thin films for the above mentioned applications [17], [18], [19], [20].

In this paper we focus on the preparation and characterization of $Cd_{1-x}Zn_xTe$ thin films for optoelectronic device. Attention was paid to the influence of heat treatment temperature on optical properties of $Cd_{1-x}Zn_xTe$ thin films grown by sequential radio frequency sputtering.

2 EXPERIMENT

The Cd1-xZnxTe thin films were prepared by cathodic radio frequency sputtering from a cadmium telluride (CdTe) and zinc telluride (ZnTe) commercial targets of high purity (99.99 %) in a vacuum chamber and onto corning glass substrates degreased and ultrasonically cleaned.

The glass substrates were maintained at ambient temperature during the growth. The vacuum chamber was evacuated to a final pressure of 10^{-6} Torr. During sputtering, the argon pressure was 2 x 10^{-2} Torr and the incident radio frequency power was maintained at 100 W (CdTe) and 300 W (ZnTe). Under these conditions, the deposition rate was 300 Å/min and 630 Å/min for CdTe and ZnTe respectively. The targets were pre-sputtered for 10 min. The films were subsequently annealed in vacuum at 300, 350 and 400 °C for 2 hours.

The structural properties of Cd1-xZnxTe thin films were investigated by X-ray diffraction technique (XRD) by means of an Xpert MPD Difractometer system with CuKα radiation. Optical transmittance measurements were performed using a Shimadzu UV-PC spectrophotometer in the 200 – 3200 nm wavelength range.

3 RESULTS AND DISCUSSION

X-ray diffraction carried out on as-deposited films show two phases assigned to the binary CdTe and ZnTe (Fig. 1.a).When the samples undergo an annealing at 300, 350 and 400 °C in vacuum during 2 hours, we note on the spectra the absence of the CdTe and ZnTe phases and the appearance of diffraction peaks associated with (111), (220) and (311) reflections of Cd1-xZnxTe of orientation (Fig. 1.b-d). All annealed films have a preferential growth in the (111) direction with cubic structure.

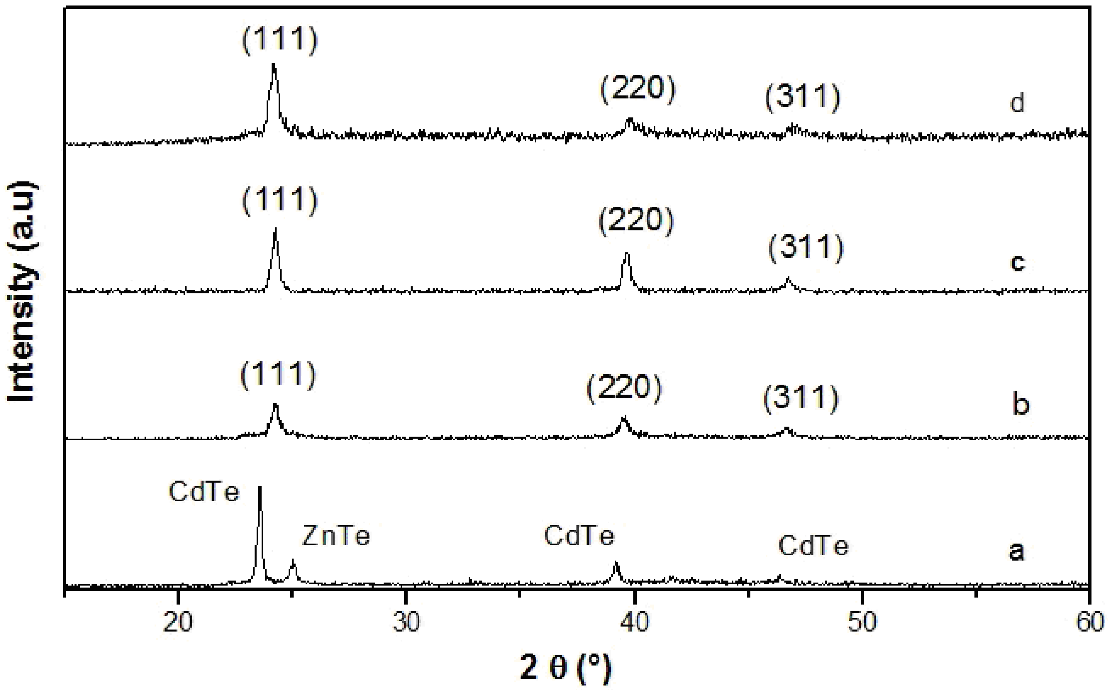

Fig.1. XRD patterns of: (a) as-deposited films; (b-d) annealed at 300; 350 and 400 °C respectively for 2 hours.

Table 1 shows the full width at half maximum (FWHM) of the (111) peaks, and crystallite size calculated from Sherrer's relationship for the cubic system [21]. The composition of Zn in the film is determined from Vegard's law [12].We note on this table that the crystallite size increases as the annealing temperature increases.

Table 1. full width at half maximum (FWHM), crystallite size and alloy composition of $Cd_{1-x}Zn_xTe$ annealed at different temperatures

Annealing temperature	Composition (x)	FWHM (111) (°)	Crystallite size (Å)
300 ° C	0.3	0.3764	27.77
350 ° C	0,26	0.3640	28.74
400 ° C	0,18	0 .3149	34.64

Figure 2 shows the normalised transmittance spectra of $Cd_{1-x}Zn_xTe$ films annealed at different temperatures. The measurements show that the $Cd_{1-x}Zn_xTe$ films exhibit a high transmission with a sharp drop at the end of the strip which indicates a good crystallinity of these layers. From these spectra the absorption coefficient α and refractive index were obtained as a function of the photon energy hυ and the wavelength λ.

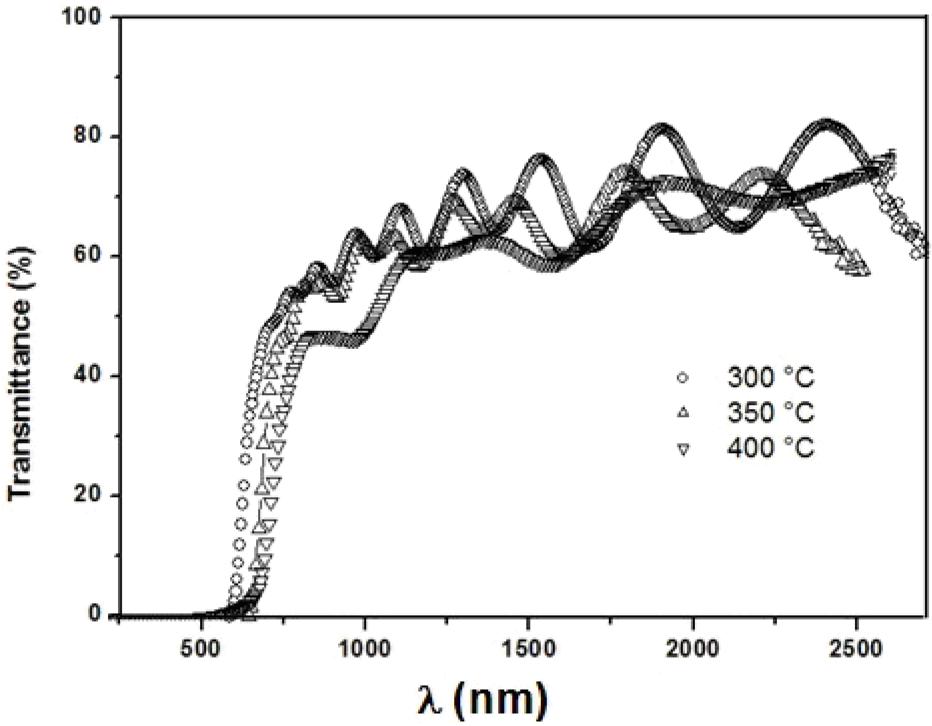

Fig.2. Normalized transmittance spectra of Cd1-xZnxTe films annealed at different temperatures

Figure 3 represents the variation of $(\alpha h\upsilon)^2$ as a function of the energy hυ. The value of the energy band gap is obtained from the extrapolation of the curve to the energy axis. The obtained band gap energies are 1.64, 1.61 and 1.53 eV, respectively for the films annealed at 300, 350 and 400 °C. We note from this figure that the value of the band gap energy decreases as the annealing temperature increases. This variation of the band gap energy can be explained by the increase in particle size due to the quantum effect of the size, a similar observation was made on thin films of CdTe and ZnTe [22].

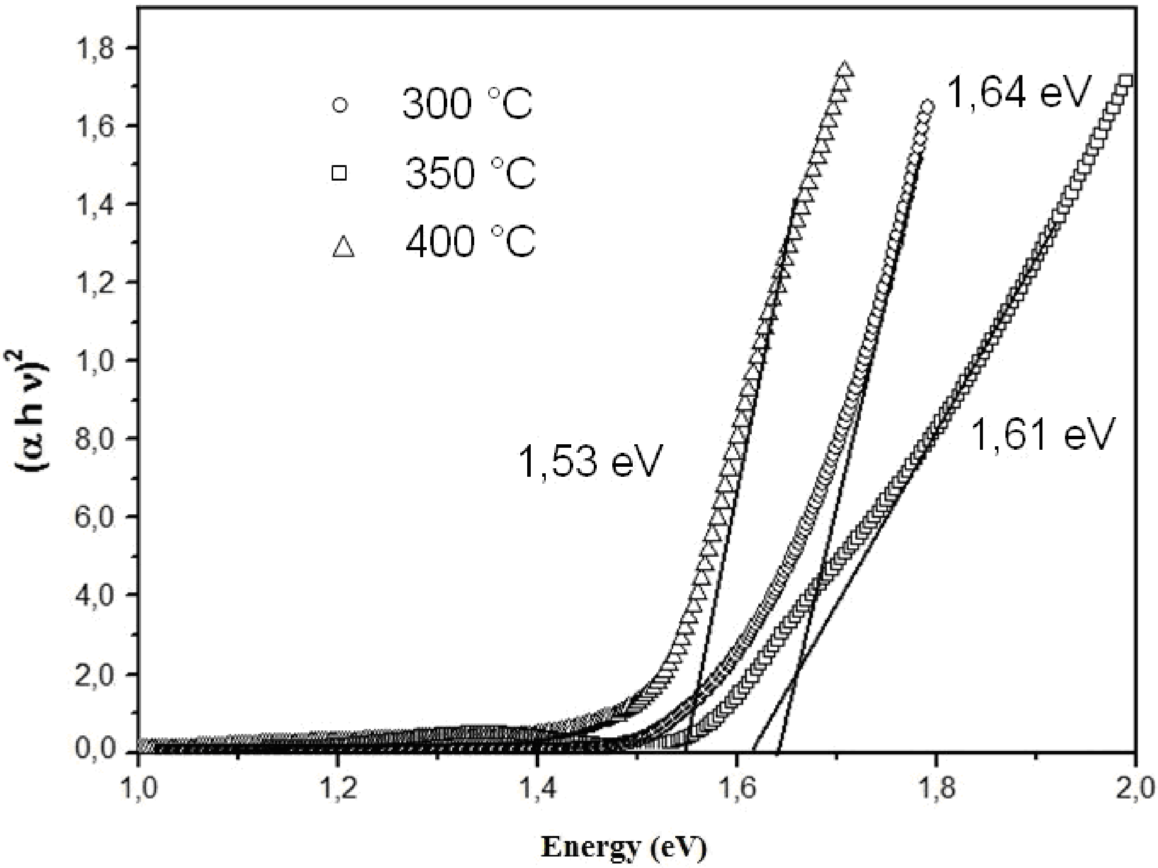

Fig.3. Variation of $(\alpha h\nu)^2$ as a function of photon energy (hν) for $Cd_{1-x}Zn_xTe$ thin films annealed at different temperatures

Figure 4 shows that the variation of the refractive index with the wavelength λ of $Cd_{1-x}Zn_xTe$ films annealed at different temperatures follows Sellmeier's law [23], and varies as the annealing temperature varies. This variation correlates well with observed changes in the crystallite size and the band gap energies of these films.

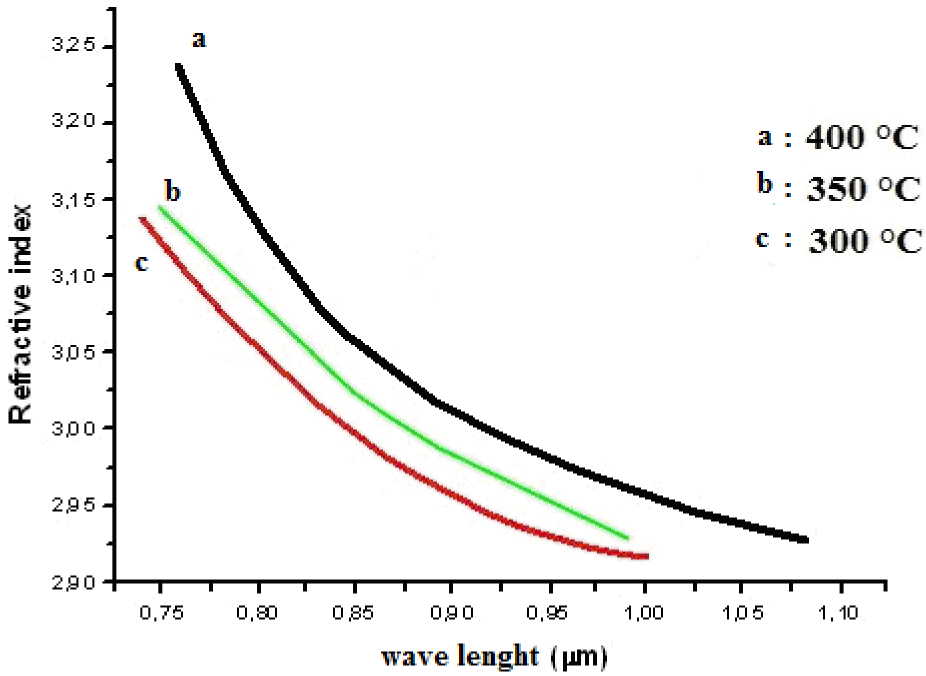

Fig.4. Variation of refractive index versus wavelength for Cd1-xZnxTe films annealed at different temperatures

4 CONCLUSION

In this work, we have investigated the effect of heat treatment on optical properties of Cadmium Zinc Telluride thin films grown on glass substrates by cathodic radio frequency sputtering from Cadmium telluride and Zinc telluride targets and then annealed in vacuum at 300, 350 and 400 °C for 2 hours. XRD characterization and optical transmission data show that crystallite size increases with annealing temperature increase, also direct band and refractive index varied with annealing temperature increase which can be explained by the increase in particle size due to the quantum effect of the size. However, all films remain strongly oriented along (111) direction with cubic structure.

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