Annealing effect on the optical energy gap of (CdTe) thin films

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Abstract

Cadmium telluride thin films deposited by Co-evaporation technique on glass substrates.

UV-VIS absorption data of films grown at room substrate temperature, as well as to the annealing thin films at the temperatures (373,473,573) K.

The absorption coefficient α and optical energy gap Eg of the films obtained from the absorption data are measured in the strong absorption regime (300-1100) nm. Both the allowed direct and indirect optical transitions occur in CdTe thin films. The optical energy gaps for thin films deposited at room temperature that are associated with allowed direct and indirect interband transitions are 2.75 and 1.45 eV respectively. It observed that there is an increase in optical energy gap with increase in annealing temperatures.

Introduction

Semiconductor thin films have produced and studied in polycrystalline form for many decades. Indeed, most new semiconducting materials produced in polycrystalline form before techniques developed for producing single crystals [1].

II-VI compound semiconductors have drawn considerable insert due to their use in the fabrication of photoconductors, space charge limited diodes, photovoltaic devices, transistors and γ-ray detectors .Efforts have been made by many workers to produce good quality polycrystalline cadmium telluride thin films for their effective use in photovoltaic devices[2].

The CdTe thin films have a " zincblende" crystal structure, this structure also called "zinc sulfide(ZnS)" structure. A great many important semiconductors have diamond or zincblende lattice structure which belong to the tetrahedral phases, that is, each atom is surrounded by four equidistant nearest neighbors which lie at the corners of a tetrahedron.

In a zincblende lattice, such as cadmium telluride (CdTe) , one sub lattice is cadmium and the other is tellurium[3].

Experimental Part

In the work we used a coating unit manufactured by "Edwards" type (E306A), the ultimate pressure, which can be obtainable from this vacuum system, is about 10^{-5} pa (10^{-7} mb). This can achieve by two stages; a mechanical (Rotary) pump does the first stage where the vacuum can reach

10^{-3} mb, the second stage is a complementary stage, which is, contains the diffusion pump. The open and closed operations of valves do manually.

films are obtained through co-evaporation of Cd grains (99.99%) pure, obtained from Balzers, Switzerland) and Te powder (99.999%) pure obtained from Aldrich Chemical company Inc, USA) and deposited onto glass substrates under a high vacuum $5x10^{-4}$ pa (5 x 10^{-6}mb).

The glass substrates (size 76 x 26 mm, thickness 1-1.2 mm) which used in this work must cleaned before deposition.

The deposition of thin films on any substrates by the direct combination of the elements vapors in a vacuum system called the "Co-evaporation".

Equal weights taken from Cd and Te materials by using sensitive electric balance type (Mettler H35AR) and we put each material in a molybdenum boat, which selected to have a cover with small holes to prevent material spattering during evaporation process.

Post deposition annealing of the films was done in a muffle furnace type (Memmert 715065) in which the films could be heated up to 573 K.The annealing temperature was controlled to within ± 10K.

Films grown on glass substrates used for X-ray diffraction studies using a Phillips X-ray Diffractometer.

The interference-fringe methods had developed to a remarkable degree by Tolansky and now accepted as the absolute-standard methods [6].

If the fringes on each side of the dividing line are equidistant (as in figure 2.4b), then it is called " Fizeau fringes". The film thickness can give as [7]:

$$t = \frac{a}{2}\frac{\Delta x}{x} \quad ....(7)$$

Where λ: the wavelength of the light used, which is sodium (Na) light (589.3nm). Δ x :The fringe displacement. x:The distance between two successive fringes.

The absorptance spectra was obtained for each sample using (Perkin-Elmer Lambda 9 , UV-VIS-NIR Spectrophotometer).

The absorption coefficient measurements reported for the strong absorption regime (300-1100nm).

When light of intensity (I0) incident on the film sample, the intensity of the transmitted light (I) through a thickness t according to the exponential low of absorption [8].

$I=I0 \exp(-\alpha t)$ ....(8)

This law, which has been attributed to both Bouguer and Lambert; therefore it is sometimes called Bouguer – Lambert relation.

Since the absorptance A is

A=log (Io/I) …………… (9)

α =2.3 (A/t) …………… (10)

Therefore, the absorption coefficient as a function of the wavelength λ for each specimen was determined. The energy of the incident photons can be determined by:

$$E(eV) = h\nu = \frac{1240}{a\,(nm)} \quad \text{…………(11)}$$

Where h:Planck`s constant

Frequency of incident light.ν:

From equations (4 & 6) the direct and indirect optical energy gaps can be determined from the intersection of $(\alpha h\nu)^2$ and $(\alpha h\nu)^{1/2}$ respectively as a function of photon energy (hν) when α=0.

Results & Discussion

UV-VIS absorptance data were obtained for each sample under study in the strong absorption regime (300-1100)nm.

The absorption coefficient α and the energy of the incident photons were calculated using equations (10) and (11) respectively:

$$\sim \; = \; 2.3 \frac{A}{t}$$

$$E(eV) = \frac{1240}{a\,(nm)}$$

Figure (2) shows the variation of the absorption coefficient with the wavelength λ for CdTe thin films deposited at room temperature. The absorption coefficient is of the order of 10^5 cm^{-1} in the visible region and higher than this value in the ultra-violet region of the spectrum. Figure (3) shows the absorption coefficient as a function of the photon energy hν. There are two sharp rises in the absorption coefficient, the first rise at around 1.45 eV,from 0.8×10^5 to

$2.7x10^5$ cm^{-1},and the second sharp rise at around 2.55eV from $2.7x10^5$ to $6.7x10^5 cm^{-1}$.The two rises indicates the onset of the allowed indirect and direct transitions respectively. The same trend of variation of α with hν is also observed by EL-Shazly et al.[10] and Aranda et al.[11].

In addition, the four kinds of transitions examine here. Both allowed (direct and indirect) transitions could obtain. Figure

(4 & 5)shows the variation of $(\alpha h\nu)^2$ and $(\alpha h\nu)^{1/2}$ with hν respectively for the films deposited at room temperature and annealed with different temperatures (373,473,573) K.

The measured values of the allowed direct and indirect band gaps of various annealing temperatures are given in table(1).Both Egd and Egi are found to increase due to increase of thermal annealing temperature as shown in figure (6 & 7) for CdTe thin film deposited at room temperature.

The increase in the energy gap may attribute to the increase in the average particle size, which causes the reduction of the native defect density.[12]

Table (1): The variation of allowed direct and indirect energy gaps (Egd & Egi) with annealing temperature.

TA (K)	With out TA	373	473	573
Egd (eV)	2.75	2.79	2.81	2.85
Egi (eV)	1.45	1.45	1.50	1.60

Conclusions

The effect of thermal annealing on the optical energy gap of CdTe thin films has investigated. The results of these investigations can summarize as follows:

1- From analysis of the absorption data, we conclude that both allowed (direct and indirect) optical transition occur in CdTe thin films. The films deposited at room temperature have optical energy gaps of 2.75 and 1.45 eV respectively.

2- The values of the direct and indirect energy gaps for these films observed to increase with thermal annealing temperature. The increase of substrate temperature observed by Rusu et al. gives stronger effect on optical parameters .

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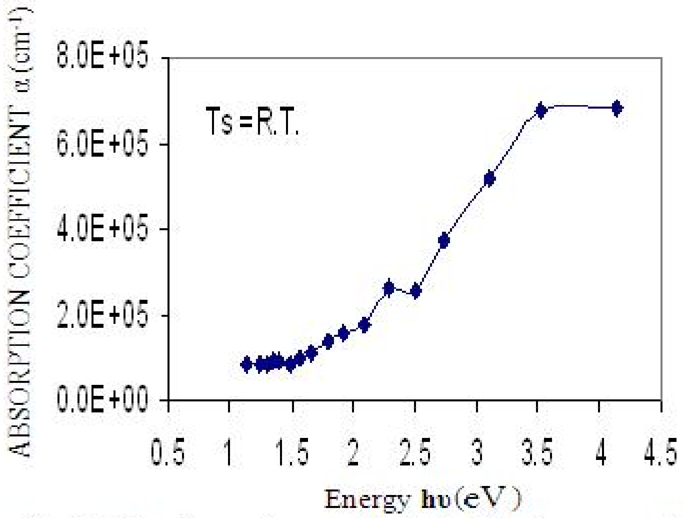

Fig.(1) The absorption coefficient α Vs. the energy hυ for **CdTe** film deposited at R.T

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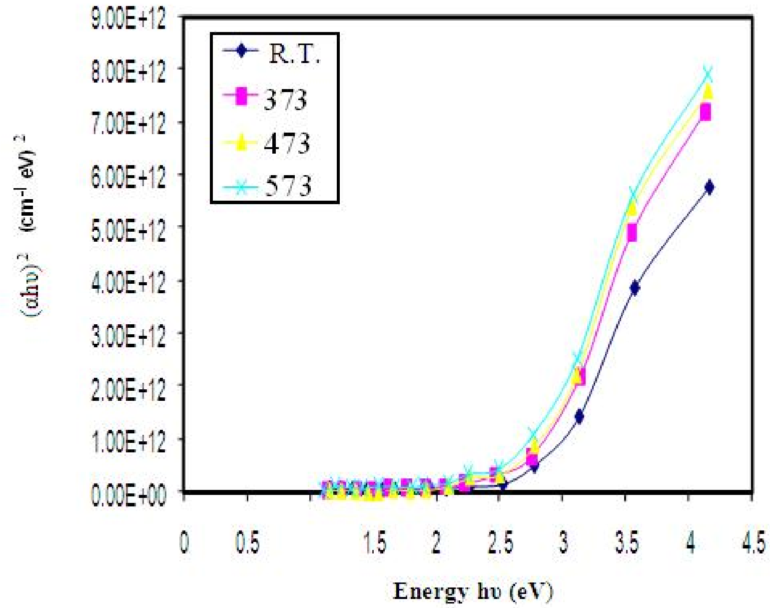

Fig.(2) $(\alpha h\nu)^2$ vs. hv plot for CdTe thin films deposited at R.T. and annealed with different temperatures.

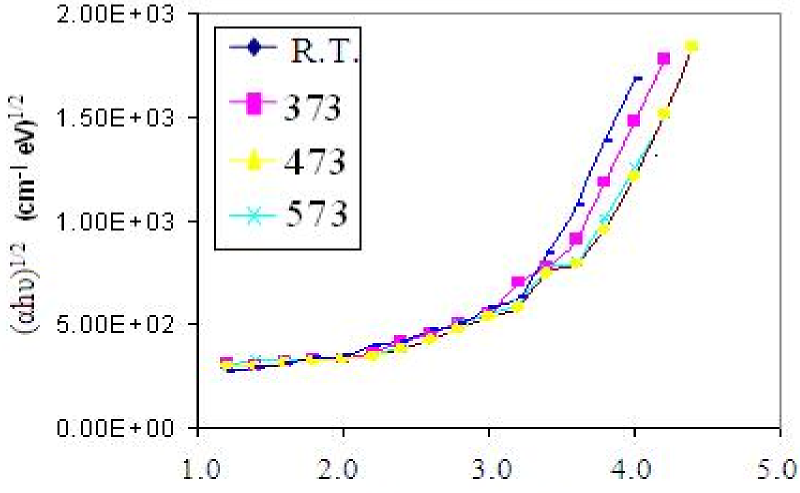

Fig.(3) $(\alpha h\upsilon)^{1/2}$ vs .hυ plot for CdTe thin films deposited at R.T. and annealed with different temperatures.

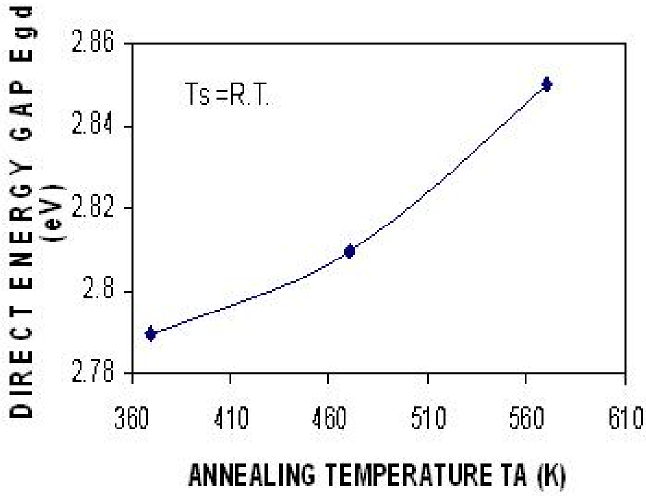

Fig.(4): The allowed direct energy gap Egd vs. annealing temperature TA for CdTe thin films deposited at R.T.

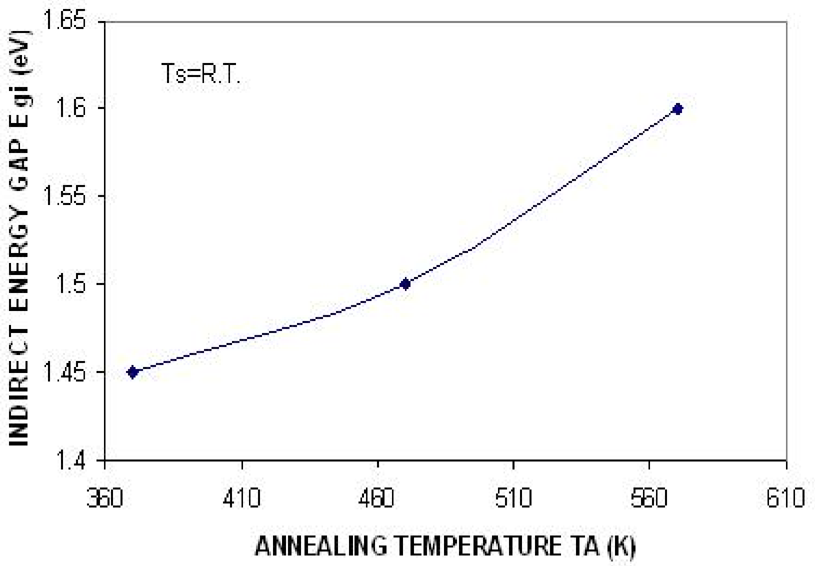

Fig.(5): The allowed indirect energy gap Egi vs. annealing temperature TA for CdTe thin films deposited at R.T.