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Effect of Substrate Temperature on the Optical Properties of CdTe Thin Films

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ABSTRACT

CdTe thin films were prepared at different substrate temperatures (Tsub=473-573K) on glass by conventional vacuum evaporation method. Optical transmission spectra as a function of substrate temperature were studied. The optical band gap was determined at different isothermal temperatures .The results show that the optical gap decreases with increasing the specimen temperature according to: Eg (eV)=1.59-bTm (where b is a constant which depends on the substrate temperature and Tm in K), valid from 298 up to 423 k.

Key words: CdTe thin films , effect of substrate Temperature , Optical Properties

INTRODUCTION

The investigation of the physical properties of II-VI Compound semiconductor thin films , particularly CdSe, CdS and CdTe has attracted considerable interest because of their high potential in photovoltaic devices. A considerable number of publications have appeared in the literatures on structural (1,2) ,electrical (3,4) and optical properties (5,6) of CdTe thin films. Most of these studies deal with the influence of the various deposition parameters and the effect of ambient on the physical properties of the films. Although CdTe thin films have been grown by various techniques, the deviation in film composition and stoichiometry from bulk remains a problem. There are a few publication about the effect of the substrate temperature on the physical properties of CdTe thin films (7).

The study of the optical properties of CdTe thin films is important when they are to be used in solar cells, because they determine in part the efficiency of the devices .Moreover, the optical properties are closely related to the structure and composition of the films and study of the optical properties gives valuable information about the latter properties. Furthermore, there is no complete study of the optical properties in relation to the preparation process of the films.

In this work optical properties of CdTe thin films was studied under vacuum and the optical
gap was determined for different isothermal measuring temperatures.

MATERIALS AND METHODS

1-Sample preparation

Thin films of CdTe were prepared by thermal evaporation from a molybdenum boat in an Edwards coating unit (Model E 306 A) with ultimate pressure (1x10-5 torr). The films were deposited onto heated glass substrates (corning glass 7059). The boat is charged with CdTe in a granular form. The substrate temperature (473-623k) was controlled by a temperature controller using a thermocouple in contact to one of the substrates. Two different source temperature have been selected (773 and 973k). The film thickness was determined during evaporation by the use of quartz crystal monitor technique and was complemented by a multiple beam interferometric method outside the vacuum(8).

2-Measurements

X-ray diffractometer (Cu K-radiation) model (Diano PW 1390) was used to identify the crystal structure and to study the crystallographic preferred orientation of CdTe thin films. Indium thin film electrodes were deposited and the resistance of CdTe films was measured using a Keithley 610C electrometer. A calibrated Tp-30AL-crom thermocouple was attached to the sample for measuring its temperature A100 watt tungsten lamb was used to expose the films for white light for 0.5 hour.. The absorption coefficient(α) and the optical energy gap Eg were determined at various ambient temperatures by measuring the optical absorbance A in the wavelength range 300 nm up to 2000 nm wavelength , where measurements become impossible due to excessive absorption .All the absorbance measurements were carried out under vacuum 10-3 torr using (PERKIN ELMER) (Lamda I) spectrophotometer .

RESULTS AND DISCUSSION

Optical Study

The effect of substrate temperature on the optical properties of thermally evaporated CdTe films was studied. Three films of the same thickness, t=924nm were deposited at Ts =973 K. Figure (1) shows the spectral dependence of the transmittance of these CdTe films deposited at substrate temperature 473, 523 and 573 K respectively, in the wavelength range from 700 up to 2000 (nm). It is observed (figure 1) sharp optical absorption edges occurred at wavelengths of around 840, 835 and nm. The starting point of transmittance rise are shifted toward shorter wavelengths due to the increase of the substrate temperature.

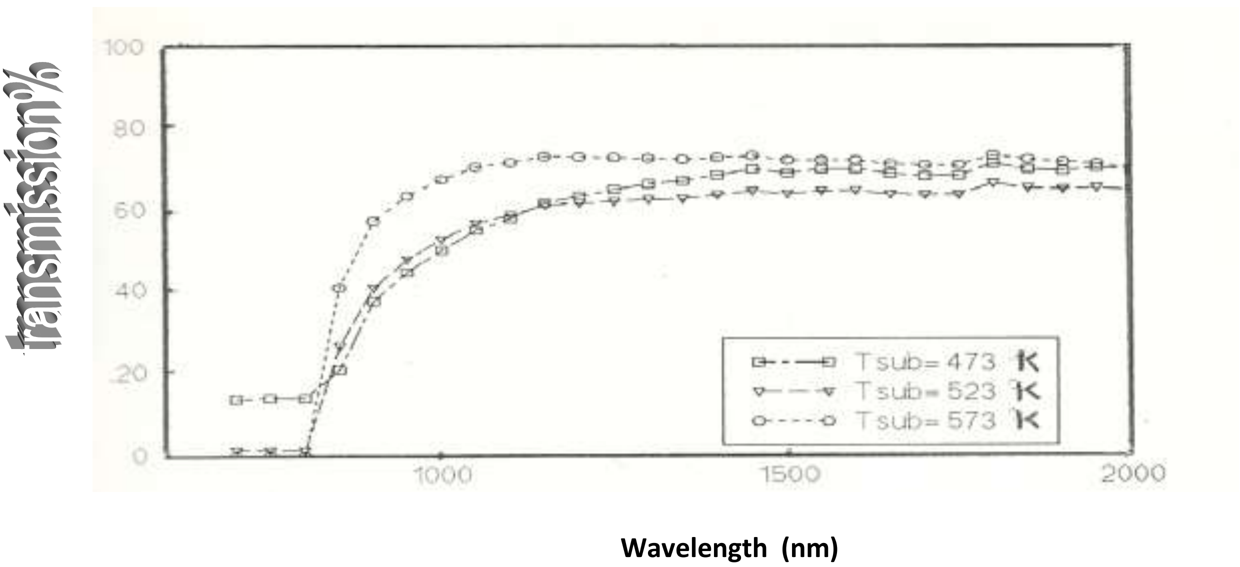


Fig. (1) : The spectral behavior of transmittance of CdTe films for different substrate temperatures at a constant film thickness, t= 924 nm, and the source temperature, T_s =973 K.

Figure(2) shows the spectral behavior of the transmittance of CdTe films deposited at Ts=773 K with three different substrate temperatures, Tsub = 473, 523 and 573 K respectively, but at another film thickness, t=436nm. It is seen that as the substrate temperature increases, the absorption edge were also shifted toward shorter wavelength (823,816 and 810 nm respectively).

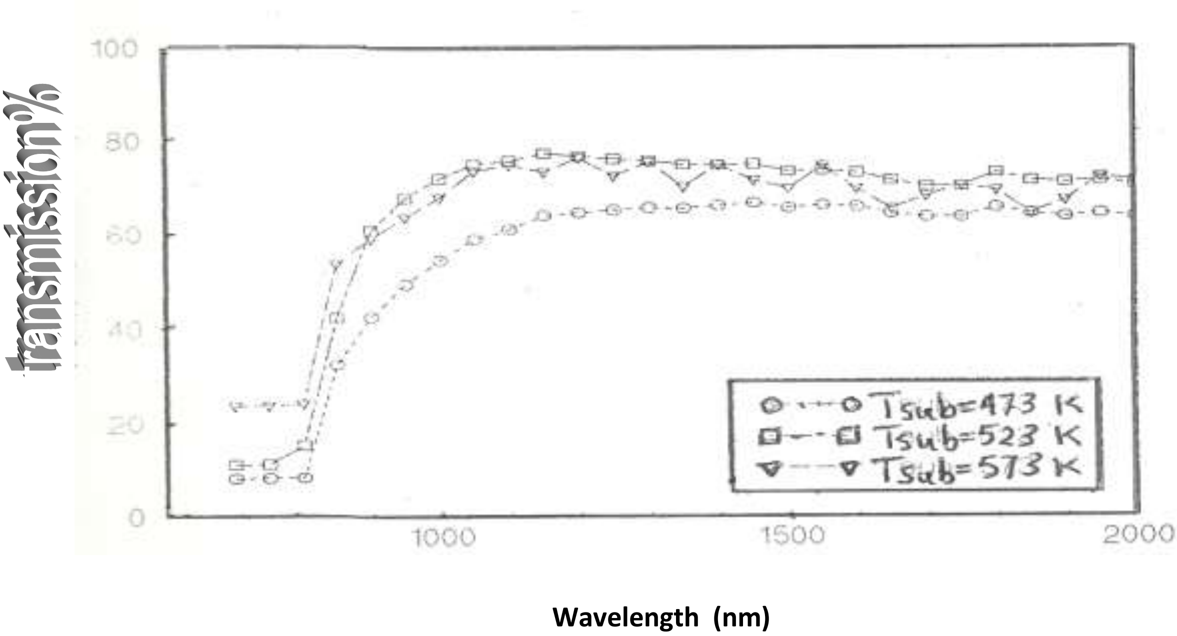


Fig. (2) : the spectral behavior of transmittance of CdTe films for different substrate temperatures at a constant film thickness, t= 436 nm, and the source temperature, T_s =773 K.

Therefore, the shifting towards the shorter wavelengths leading to increase in the values of the optical gap this result may be to the improvement of structure of the films associating to the increase of the substrate temperature.

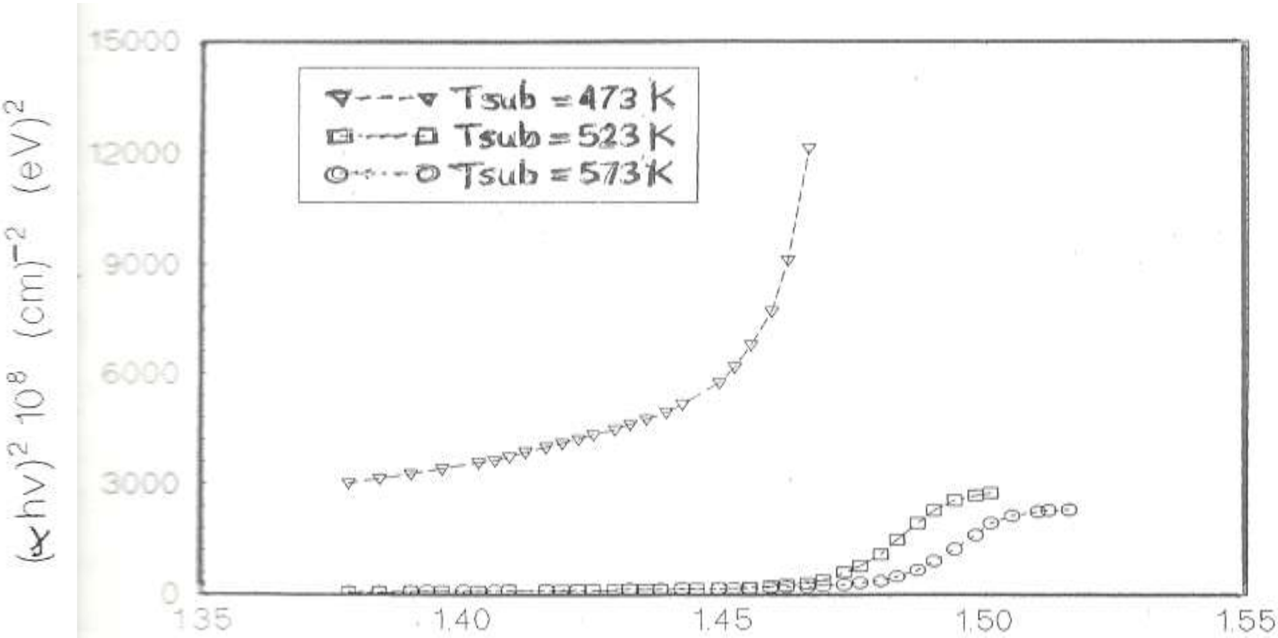
The dependence of the absorption coefficient, on the photon energy , at and near the absorption edge can give information about the electronic band structure of the film.

The optical gap Eg was determined from the absorption coefficient , α , using the expression:

The direct allowed transition $\alpha h\upsilon=A\{h\upsilon-Eg\}1/2$………………. (1)

For indirect allowed transition $\alpha h\upsilon=A\{h\upsilon-Eg\}2$ …………………..(2)

The extrapolation to zero of the linear part of the curves gives the optical gap. Figure (3) shows the variation of (αhυ)2 with hυ- for three different substrate temperature, Tsub =473,523 and 573 K with the same film thickness, (t-924nm) and source temperate Ts=973k at temperature of measurement.



E (eV)

Fig. (3): Variation of $(\alpha h\upsilon)^2$ with photon energy , E, for CdTe films for different substrate temperatures , at film thickness, t= 924 nm, and the temperatures of measurement T_m= 323 K.

It is seen that our films follow the direct allowed transition which assumes constant transition matrix elements and parabolic bands. The values of the optical gap Eg measured at different temperature s are given in the table (1) .These results are in good agreement with the optical gap values obtained directly from transmission measurements.

Table (1) The values of the optical gap Eg measured at different temperatures.

T_{sub} (k)	T_s (k)	t (nm)	Direct band gap Eg (eV)			
			Tm=300(k)	Tm323(k)	Tm=373(k)	423(k)
473	793	924	1.452	1.449	1.416	1.378
523	793	924	1.487	1.466	1.435	1.418
573	793	924	1.500	1.481	1.449	1.426

It is seen from table (1) that the optical gap increases with rising the substrate temperature. The narrowing of the optical gap in the films grown at temperature lower than 573k may be related to the existence of high density of levels within the band gap which can give rise to band tailing as supposed for other polycrystalline materials. These levels would be associated with the electronic states at the grain boundaries .While rising the measuring temperature, Tm , from 300 to 423 k decreases the values of the optical gap. This result can be attributed to the increase of the carrier concentration with increasing the measuring temperature.

The optical band gap Eg was determined at different temperature 300,323,373, and 423k for CdTe films prepared at substrate temperature of 473,523 and 573 K.

Figures (4a,b) shows the relation between $(\alpha h\upsilon)2$ and $h\upsilon$ for CdTe films (Tsub = 573K) and one can finds a direct band gap for all the films .Table (1) gives the values of Eg for CdTe thin films according to the equation referred in (1).

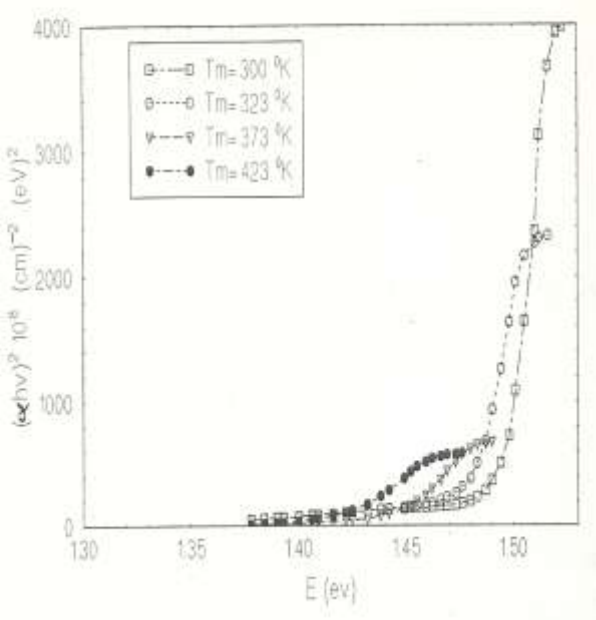


Figure (4.a): $(\alpha h\upsilon)^2$ versus photon energy ,E ,for CdTe films for different temperatures of the measurements T_m at the substrate temperature ,T sub =573 K ,and film thickness ,t =924 nm.

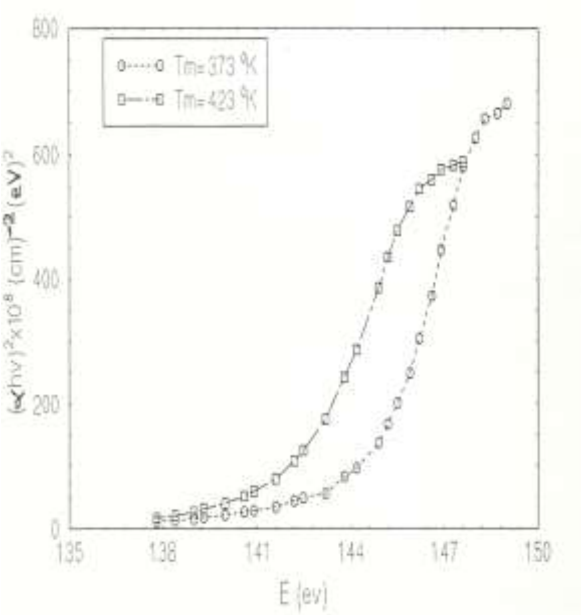


Figure (4.b):The same relation but extended for the above curves at the measuring temperature T_m= 373 and 423K.

All the films show that the optical gap decreases with increasing the isothermal measuring temperature according to the relation reported by Poelman et al(11) as follows:

$Eg=1.628-5.5\ x10^{-4}\ Tm$………………………… (3)

Where ,Tm is the temperature in K (valid from 300 up to 423k) and the temperature coefficient of optical absorption thus deduced is about (-5.5x10-4) (eV/K) in good agreement with that found (by Y.F.Tsay et al) for crystalline CdTe (12), and it is observed that this coefficient depends on the substrate temperature.

Figure (5) shows the variation of Eg with absolute temperature for CdTe films(Tsub =573K) and the constants of the above equation (3) are obtained from the figure. The same results were obtained from the obtained figures for CdTe thin films (Tsub =473 ,523 K).

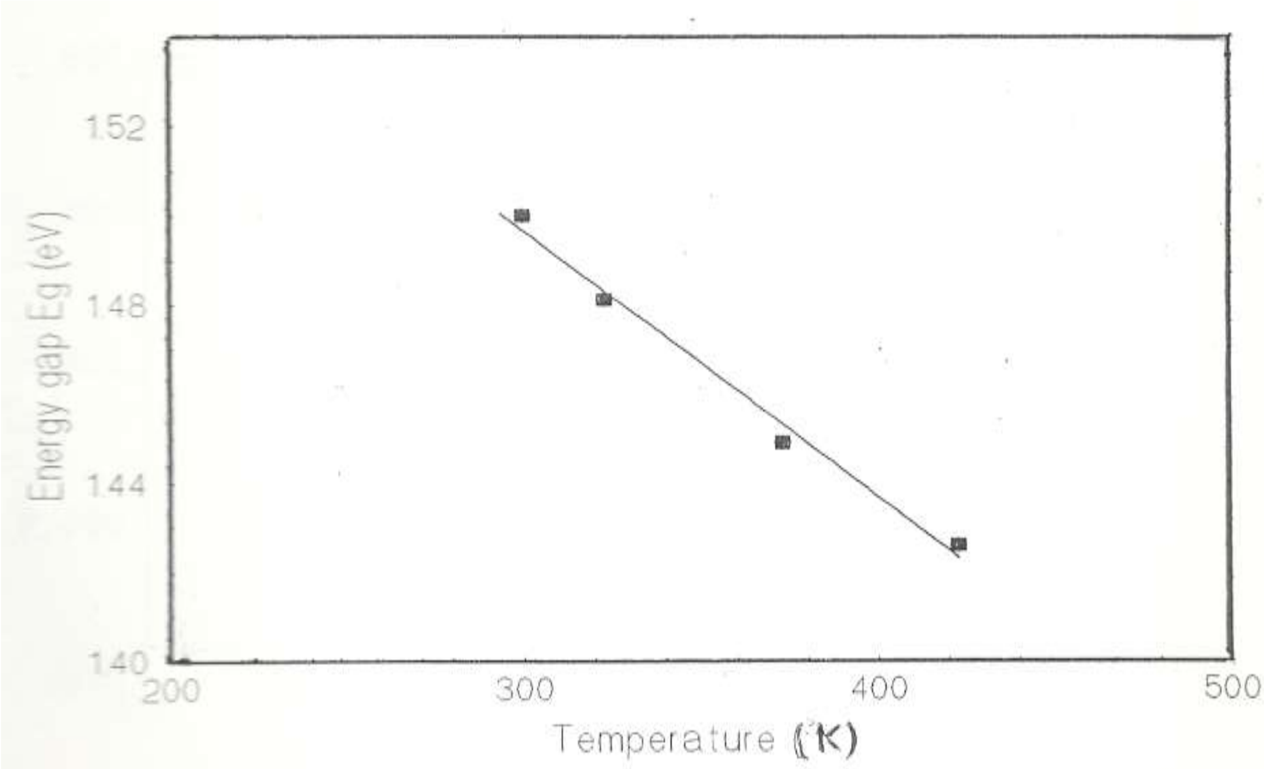


Fig. (5): The relation between optical energy gap ,Eg , and the temperature ,at the film thickness, t =924 nm, the substrate temperature ,T_{sub} =573 K ,and source temperature T_s=973K .

Conclusion

CdTe thin films were prepared at different substrate temperatures (Tsub=473-573K) on glass substrate by conventional vacuum evaporation method. The film thickness were controlled during the evaporation by a quartz thickness monitor. Michleson interferometer were used to determine the film thickness.

Optical transmission spectra as a function of substrate temperature were studied. The optical band gap was determined at different isothermal temperatures. The results show that the optical gap decreases with increasing the specimen temperature according to: Eg (Ev)= 1.59- bTm (Where, b is a constant which depends on the substrate temperature and Tm in K), valid from 298 up to 423K.

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