تأثير درجة الحرارة الركيزة على بعض الخصائص التركيبية والكهربائية للشرائح الرقيقة للمركب (CdTe)

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الملخص :

أُعـــدت شرائـــح رقيقة من المركب CdTe في درجات حـــرارة الركيزة المختلفة (T_{sub} = 473-623 K) على الزجاج بواسطة الطريقة التقليدية فراغ التبخر، وأظهرت الأفـــلام وجود مرحلة مكعب مركـــزي الوجه للمركب CdTe مع التوجـــه المفضل إلـــى (111) مســـتوى parallelto الركيزة. ارتفعت درجة التوجه المفضل وكذلك التوصيل المظلم من أفـــلام المركب CdTe مع زيادة تشير الدراسات T_{sub}.Electrical آليات التوصيل اثنين ، خارجي في المنطقة درجة حـــرارة منخفضة، تليها التوصيل جوهري في ارتفاع درجة الحرارة المنطقة . والقيم المحسوبة من طاقات التنشيط في المنطقة التوصيل خارجي والجوهرية تعطى . كما أنها وجدت أن التحـــوّل بين آليات التوصيل اثنين يحدث قريبا جدا من درجات حـــرارة تتراوح بين (330-345 K). أظهر الاعتماد من الظـــلام والضوئية على درجة حرارة الركيزة لشرائح الرقيقة للمركب أن القيم الضوئية هي أمر واحد من حجم أعلى من ذلك من تلك المظلمة.

Effect of Substrate Temperature on the Structural and Electrical Properties of CdTe Thin Films

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Abstract

CdTe thin films were prepared at different substrate temperatures (T_{sub}=473-623k) on glass by conventional vacuum evaporation method. The films showed the existence of the face centered cubic CdTe phase with a preferred orientation of (111) plane parallelto the substrate. The degree of the preferred orientation as well as the dark conductivity of CdTe films increased with increasing T_{sub}.Electrical studies show two conduction mechanisms ,extrinsic in the low temperature region ,followed by intrinsic conduction in higher

temperature region.The calculated values of the activation energies in the extrinsic and intrinsic conduction region are given. It is found also that the transformation between the two conduction mechanisms occur very close to the temperature range of (330 – 345 K). The dependence of the dark and photoconductivity on the substrate temperature for CdTe thin films showed that photoconductivity values are one order of magnitude higher than that of the dark ones.

Index Terms- CdTe thin films, effect of substrate temperature, structural properties ,electrical properties

1-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).

2-EXPERIMENTAL PROCEDURE

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).

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 resistance of CdTe film under illumination was used to calculate the photo-conductivity.

3-Results and Discussion

3.1-Structural Study

Typical X-ray diffraction patterns of CdTe films deposited at three different substrate temperatures (T_{SUB} = 473,523 and 573K)are shown in figure (1a,band c) , respectively .The source temperature during evaporation was Tg= 973 k and the film thickness was t=924 nm .The existence of the face centered cubic phase is evident in all patterns .The identified peaks with its 'd' spacing and the values of the lattice parameter ,a, calculated from the spacing (a=0.647± 0.002nm) are in excellent agreement with both the bulk ASTM X-ray cards and the thin film data of Dharmadhikari (9) .The values of the interplanar spacing ,d, were calculated from the chart within error of ~0.2%. A remarkable oriented growth strongly preferentially orientation of (111) plane parallel to the substrate surface is seen. This preferential Orientation increases with increasing the substrate temperature as shown in fig.(Ia,b and c) and as indicated in table (I) by the following: :i)The increase of the sharpness (smaller half width)of (111) plane, with spacing ,d=0.373nm as the temperature of the substrate was increased.

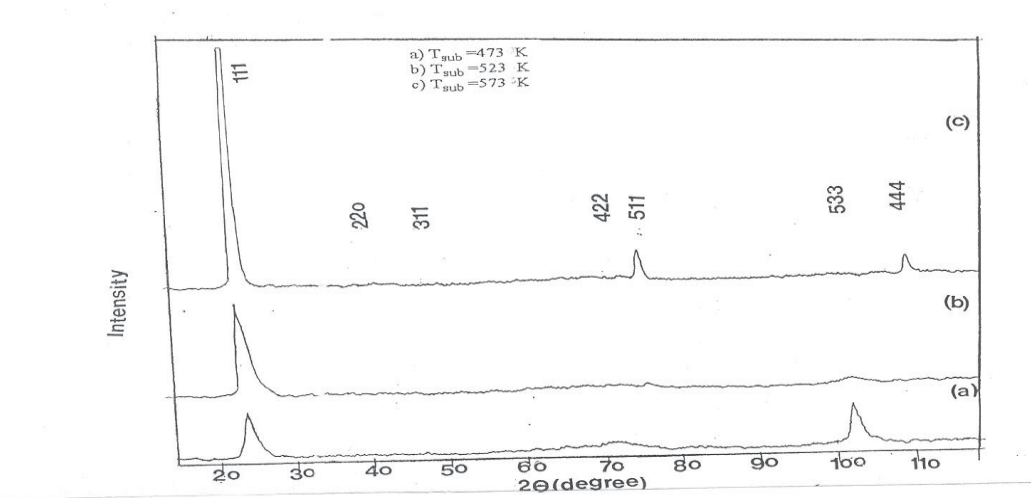
ii)The clear appearance of the fourth order cubic (444) peak at 'd' spacing = 0.0936 nm ,for the films deposited at the substrate temperature, T_{sub}= 5730 k, fig.(1c).

iii)The broadening of the pattern at spacing ,d=0.125 nm shown in figure (Ia) may be attributed to the amorphous part at this temperature .The increase of T_{sub}, Fig.(I b,c) causes the appearance of (511) peak of cubic CdTe .As well as the increase of the intensity ratio of (I/I_o)of (511) peak with increasing T_{sub} , where I_o is the intensity of the highest peak of (111) plane and I_o, the intensity of any peak appear.

iv)The sharp (533) peak at spacing ,d= 0.0986 nm ,of the cubic structure of CdTe fig. (Ia) ,is broadening in pattern figure (Ib) and then, vanishing in pattern fig .(Ic) as T_{sub} increases .This result could be in somehow supports the texture in the films .

Table (1) XRD of CdTe thin films annealed at different annealing temperatures.

Substrate Temperature(K)	hkl(cubic)	Intensity ratio(I/I_0) Theoretical (card)	Intensity ratio(I/I_0) Measured(chart)
473	111	100	100
	533	2	8
523	111	100	100
	511	4	5
	533	2	7
573	111	100	100
	511	4	8
	533	2	0
	444	<1	4



Figure(1) : Typical X-ray diffraction patterns of CdTe films deposited for different substrate temperatures T_{sub}, the source temperature T_s =973k and film thickness t=924 nm

3.2-Electrical Studies

Figures(2,3) show the temperature dependence and the dark conductivity ln(σ) of CdTe thin films versus reciprocal temperature for films deposited at different substrate temperature, T_{sub}= 473,523,573,and 623 k and film

thickness ,t=1080nm. The figure shows that the values of conductivity of the films are increasing with increasing the ambient temperature. It is found that all CdTe thin films obey the Arrehenious equation(10), which is given by:

$\sigma=\sigma_o \exp(-E_a/KT)$

Where σ_o is a constant ,K_B is the Boltzmanns constant and E_a is the activation energy.

Figure(2) shows two conduction mechanisms, impurity conduction (extrinisic) in the low temperature region followed by intrinsic conduction in higher temperature region .Two essential linear regions, i.e. two values of E_a, were obtained.The calculated values of the activation energies in the extrinsic and intrinsic conduction regionare given in table (2) .

Table(2) The calculated values of the activation energies in the extrinsic and intrinsic conduction region

T_{sub} (k)	E_{al}(eV)	Temperature range (k)	E_{a2}(eV)	Temperature range(k)
473	0.013	300-334	0.600	359-393
523	0.030	300-339	0.686	354-393
573	0.046	300-337	0.680	354-393
623	0.063	300-336	0.700	347-393

The activation energies E_{a1} due to the impurity conduction were estimated to be between (0.013-0.0063 eV) as indicated in table(2).The average value of $E_{a1}\approx0.036$ eV is in the range of the activation energy of the native donorof the CdTe crystal with excess of cadmium(Cd-rich(n-type))(11) The increase of the conductivity,σ with increasing ambient temperature is attributed to the growth of larger grain sizes which in turn increases the electron mean free path and reduces the scattering effect . In the mean time, the increase of values σ may be related to the increase of the carrier concentration with increasing the measuring temperature.

Furthermore it is observed that the conductivity increase with increasing the T_{sub} as shown in fig (3) .This behavior may reflect the improvement of the film crystallinity associated to the increase of the substrate temperature ,as shown in fig. (1c) .

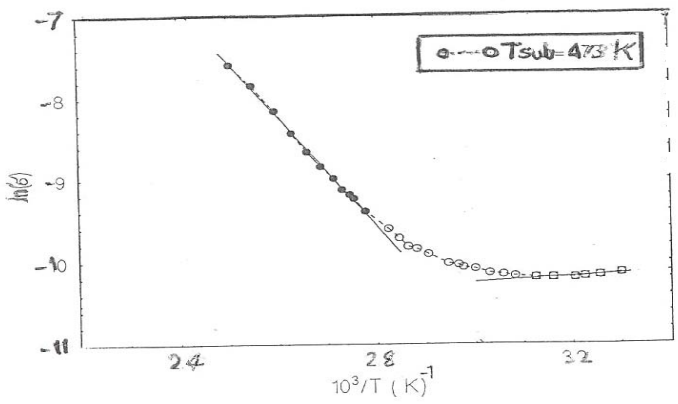


Figure (2): *The variation of the conductivity (ln σ) (ohm^{-1} cm^{-1}) of CdTe thin films with inverse temperature, at the source temperature, T_s =973 ^{0}K.*

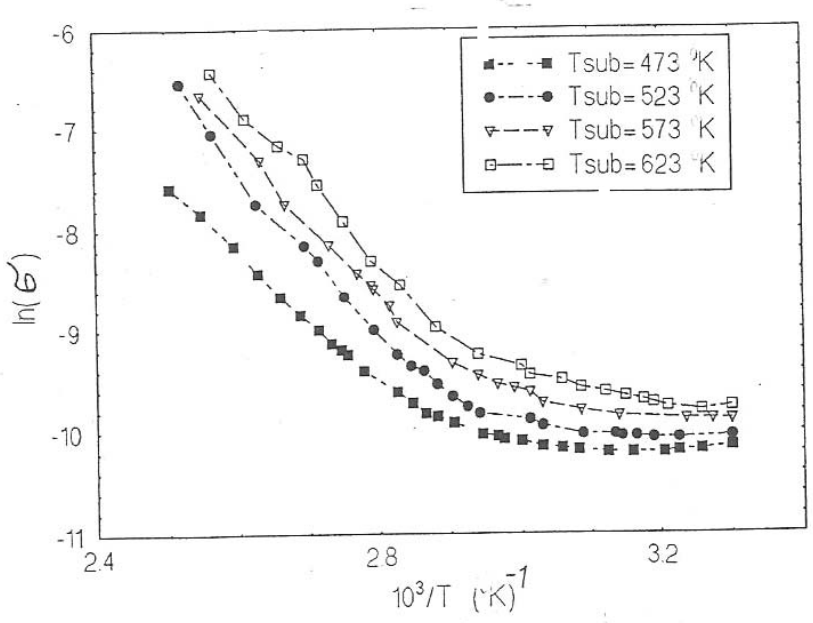


Figure (3): *Dark conductivity (lnσ) of CdTe films versus reciprocal temperature characteristics for films deposited at different substrate temperatures, and at T_s = 973 ^{0}K.*

Figure (4) shows the variation of the dark and photoconductivity (measured at room temperature) ,with substrate temperatures for CdTe films of the same thickness, t=1080 nm .It is clear that the CdTe thin films deposited at T_{sub} between 473 and 623 K have photoconductivity, of one order of magnitude higher than that of the dark conductivity. This result may be related to the increase of the carrier concentration when the films illuminated

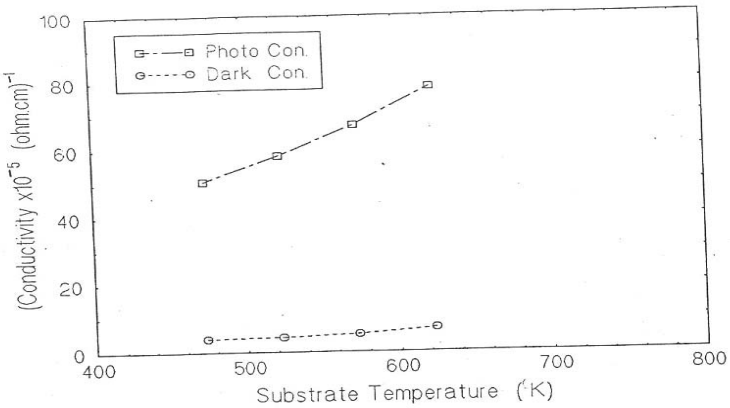


Figure (4): *Dependence of the dark and photoconductivities on the substrate temperatures, at film thickness, t =1080 nm, and the source temperature, T_s =973 ^{0}K.*

It is seen from table (2) that the values of the activation energies E_{a1}, (extrinsic region) and the activation energy E_{a2} (intrinsic region) increase with increasing the substrate temperature Increasing the activation energies in the two regions may be due to the improvement of film structure with rising T_{sub} from 473 to 623 K. This could be due to the decrease in the trapping levels density in the band gap as the substrate temperature increases.It is interesting also to indicate that the transformation between the two conduction mechanisms occur very close to the temperature range of Tm ≈ 330-345k.

Conclusion

CdTe thin films were prepared at different substrate temperatures (T_{sub}=473-623k) on glass 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.

Structure characterization is to be undertaken by X-ray diffraction and a remarkable oriented growth with strongly preferentially orientation of (111) plane parallel to the substrate surface is seen. This preferential orientation increases with increasing the substrate temperature.

Electrical studies show two conduction mechanisms of CdTe thin films .Therefore, the activation energies in the extrinsic and intrinsic conduction regions are calculated. The average value of E_{a1} 0.036 eV is in the range of the activation energy of the native donor of the crystal with excess of cadmium (Cd- rich(n-type)(11).

The increase of the conductivity, σ with increasing ambient temperature is attributed to the growth of larger grain sizes which in turn increases the electron mean free path and reduces the scattering effect .In the mean time , the increase of Values σ may be related to the increase of the carrier concentration with increasing the measuring temperature. Furthermore, it is observed that the conductivity increases with increasing the $T_{SUB.}$.

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