(d.c) electrical conductivity of ($CdSe_{0.5}Te_{0.5}$) thin films which formed at different rates of deposition

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Abstract

The aim of this research is to prepare ($CdSe_{0.5}Te_{0.5}$) thin films by vacuum thermal evaporation method ,and study the direct electrical conductivity and calculating activation energy values of thin films which prepared at different rates of deposition (0.25,0.50,0.75) nm/s .

The study of relation ship between electrical conductivity and temperature has shown that the electrical conductivity increase with temperature increasing ,and the study of relation ship between electrical conductivity with rate of deposition has shown that the electrical conductivity increase with rate of deposition increasing ,while the activation energy values decrease.

INTRODUCTION

Films of solid solutions based on II-VI compounds ,particularly those of the $CdSe_xTe_{1-x}$ system ,are promising materials for semiconductor technology . [1]They are suitable for the manufacture of ,for example, variable gap structure ,vidcons,solar cells, and photo detectors . [2]

The full range of solid solutions between the II-VI compounds CdSe and CdTe has interesting implications for thin film electro-optic devices." Tunable" band gaps and lattice parameters, which depend on the relative amounts of chalcogenide in the compound $CdSe_xTe_{1-x}$ can be obtained .Both factors are important for photoconductive and photovoltaic applications ,especially if thin film hetrostructures are considered. [3]

II-VI compounds have a prominent place in modern semiconductor physics and technology ,as they show a high efficiency of radiative recombination, high absorption coefficients, and direct band gaps corresponding to a wide spectrum of wavelengths from the UV to IR region ,many of these systems form a continuous range of solid solutions that allow the physical properties to be controlled smoothly and the structural parameters to be optimized by changing their molar composition. [4] ,for example cadmium selsnide having suitable band gap (1.74)ev [5] ,and table (1) shows some of (II-VI) compounds[6]

Many researchers have been studied $CdSe_xTe_{1-x}$ films which prepared from CdSe and CdTe either from evaporation a solid solutions [7] or by a dual source evaporation of CdSe and CdTe [3] or by vacuum condensation[1], [8] has used the two –source vacuum evaporation method , [9] has used electro deposition technique in preparing films, and most other researchers have been followed the same methods ,in the present study we have not used CdSe and CdTe in preparing films, instead we have prepared at first the $CdSe_{0.5}Te_{0.5}$ alloy by gradual heating from the elements Cd , Se and Te ,then we have prepared films by thermal evaporation method.

The table (1) illustrates some of (II-VI) compounds[6] :

Group II elements	Group VI elements/ E_g of II-VI compounds (eV)		
	Sulfar	Selenium	Tellurium
Zinc	ZnS 3.6	ZnSe 2.6	ZnTe 2.2
Cadmium	CdS 2.6	CdSe 1.7	CdTe 1.6
Mercury	HgS 2.1	HgSe semimetal	HgTe semimetal

d.c ELECTRICAL CONDUCTIVITY:

The conductivity of semiconductors depends strongly on the ambient and the structure .In case of semiconductors the resistance rapidly decreases with increase of temperature .The empirical formula connecting the resistance and absolute temperature valid within a limited temperature range is given by: [10]

$$R(T)=R_o\, e^{\beta/T} \qquad \ldots\ldots\ldots\ldots(1)$$

Here R_o ,β are within that temperature range ,constants characteristic of each semi conducting material ;This formula may be written for conductivity:

$$\sigma = \sigma_o\, e^{-\beta/T} \qquad \ldots\ldots\ldots\ldots(2)$$

Multiplying the numerator and denominator for the exponent by the Boatman's constant K_B and denote $K_B\ \beta = E_a$,we will obtain: [10]

$$\sigma = \sigma_o \exp(-E_a / K_B T) \quad \ldots\ldots(3)$$

For a given semiconductor the quantity characteristic(E_a) is called its activation energy, and its physical meaning is different for different temperature ranges. The existence of activation energy means that in order to increase the conductivity of a semiconductor, one should supply energy to it.

The electrical conductivity is defined as the proportionality factor between the current and the electric field. In a semiconductor the basic equation for σ is given by : [11,12]

For intrinsic $\sigma = e(N\mu_n + P\mu_p)$
For n-type $\sigma = e\, N\mu_n$ …….(4)
For p-type $\sigma = e\, P\mu_p$

Where μ_n and μ_p are the electron and hole motilities respectively.

The activation energy: the thermal activation energy E_a may be interpreted in terms of one of the following four possible excitation mechanisms: [12]

(a) E_a corresponds to the(E_g /2) for intrinsic conduction .(where E_g is the forbidden energy gap).

(b) E_a corresponds to the depth of traps.

(c) E_a may correspond to the energy required to raise the electrons from the ground state to an excited state ,so that they can tunnel the potential barrier efficiently to make a major contribution to electric conduction. Such a potential barrier is generally the barrier between molecules.

(d) E_a may correspond to the height of the potential barrier between the electrode and the material specimen which must be overcome for carrier injection from the electrode.

Experimental:

A: The preparation of ($CdSe_{0.5}Te_{0.5}$) alloy :

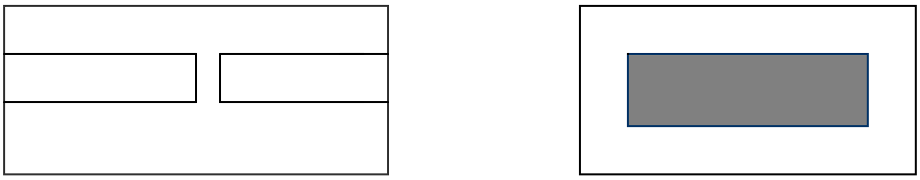
The alloy has been prepared by mixing a certain ratios of Cd ,Se and Te (99.999 %) purity elements with their atomic weight 78.96,112.40 and 127.60 respectively. The weight of each element ratio in the alloy was determined by the equation :
The weight of the total alloy = (the ratio of the first element in the alloy * its atomic weight) +(the ratio of the second element in the alloy * its atomic weight) +…….

$$W_{(total)} = r_1 * a.w_1 + r_2 * a.w_2 + \ldots \qquad \ldots\ldots\ldots\ldots..(5)$$

where $W_{(total)}$ is The weight of the total alloy , r_1 is the ratio of the first element in the alloy , $a.w_1$ is the atomic weight of the first element , r_2 is the ratio of the second element in the alloy, $a.w_2$ is the atomic weight of the second element ,……..etc.
the ratio of Cd =1, the ratio of Se=0.5, the ratio of Te =0.5
then the weight of each elements ratio determined by a sensitive balance (Mettler H 35 AR) and its sensitivity (10^{-4} gm) ,then these weights have been put in a clean quartz ampoule and it has been closed, the ampoule has been put in a furnace with temperature T=823 K for four hours ,then the temperature has been increased to 1023 K for three hours ,and finally the temperature has been increased to 1223 K for three hours too ,after that the mixed compound has been quenched in a cold water.

B:Thin films preparing:

A thermal evaporation method in high vacuum reaches to (10^{-6}mb) has been used to prepare ($CdSe_{0.5}Te_{0.5}$) films .The aluminum electrodes have been deposited on the glass substrate using a tungsten boat , ($CdSe_{0.5}Te_{0.5}$) films have been deposited using a molybdenum (Mo) boat, on Al electrodes .Thin films have been deposited at room temperature with different values of rates of deposition (0.25,0.5,0.75)nm /s ,thin films thickness was(3000±20)nm,a glass substrates have been used with dimensions (2.54*7.62)cm and with(1.2)cm thickness.



a-The mask used for Al -electrodes deposition

b-The mask used for film deposition.

Figure(1)The masks used in preparing the films

C:d.c Electrical conductivity measurements:

The d.c conductivity for ($CdSe_{0.5}Te_{0.5}$) thin films as a function of the temperature in the temperature range (298-513)K were measured .The samples were mounted in a conventional temperature regulator oven ,measurements of thin films resistance (R) with temperature were recorded ,and the resistivity is given by:

$$\rho = R.A/L \quad \ldots\ldots\ldots(6)$$

were A: cross sectional area **,**L :the distance between the electrodes
then the conductivity (σ)of the films were calculated using the equation :

$$\sigma_{d.c} = 1/\rho \quad \ldots\ldots\ldots\ldots(7)$$

The activation energy(E_a) were calculated from the plot of Ln σ versus (1/T) according to the formula (3).

The measurements have been taken by Kiethly Digital Electrometer 616,and Memert oven of range (523)K.

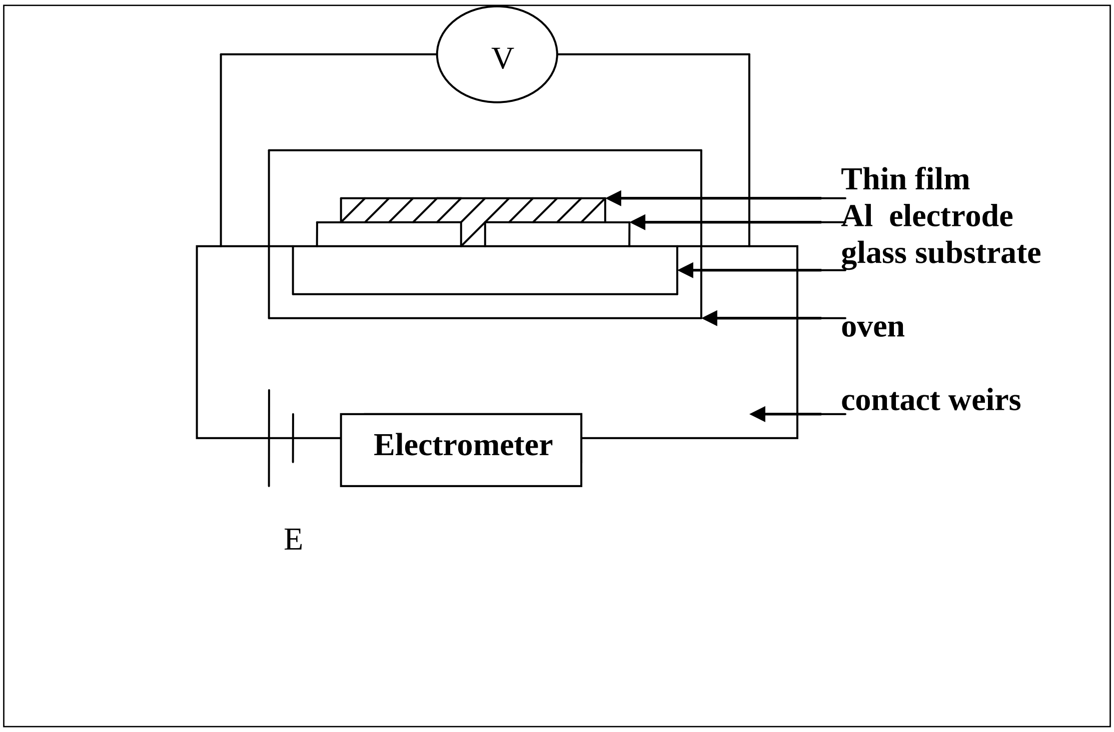


Figure (2) shows the electrical circuit of d.c conductivity measurements.

Results and Discussion:

Figure (3) shows the X-ray diffraction patterns for ($CdSe_{0.5}Te_{0.5}$) thin films which have been prepared with (0.25,0.50,0.75)nm/s rates of deposition.

The as- deposited films were polycrystalline and found to exhibit a cubic (Zinc blend) structure. The films are crystallized with a strong (111) direction, and this result was in agreement with(8,13) .As seen from figure(3 a,b,c) , figure(3-a) shows the X-ray diffraction pattern for ($CdSe_{0.5}Te_{0.5}$) thin films which has been prepared at 0.25nm/s rate of deposition , figure(3-b) shows the X-ray diffraction pattern for ($CdSe_{0.5}Te_{0.5}$) thin films which has been prepared at 0. 5nm/s rate of deposition , figure(3-c) shows the X-ray diffraction pattern for ($CdSe_{0.5}Te_{0.5}$) thin films which has been prepared at 0. 7nm/s rate of deposition ,it is obvious that films which prepared at (r.d =0.25,0.5)nm/s have a better structure than films which prepared at (r.d =0.7)nm/s ,because when there is along time to form the film ,the grain size will increase ,and the grain boundary will decrease ,and when the rate of deposition is high may be defects will be exist .

The omic contact for the prepared films were checked by the performance of the **I-V** characteristic for ($CdSe_{0.5}Te_{0.5}$) thin films as shown in figure (4).It was noted that **I-V** relation is linear.

Figure (5) shows the variation of Ln σ versus (1/T) for ($CdSe_{0.5}Te_{0.5}$) thin films which have been prepared with (0.25,0.50,0.75)nm/s rates of deposition on one plot.

As seen from figure, the direct electrical conductivity increases with temperature increasing and this is a feature of semiconductors ,where semiconductors have a resistance of negative thermal parameter ,where the charge carriers concentration increases with temperature increasing [14,15].

As seen from the figures ,the function Ln σ versus (1/T) has an exponential dependence ,which may be attributed to the grain boundary width ,and are closed to linearity at relatively high temperatures ,but not exactly linear because we have considered(σ_o) is constant ,and in fact it depends on temperature ($T^{3/2}$) according to the equation : [14]

$$\sigma_o = constant\ (\mu_e + \mu_h)\ T^{3/2} \quad \ldots\ldots\ldots\ldots..(8)$$

where μ_e and μ_h are mobility's of electrons and holes respectively .
The activation energy (E_a) at room temperature was calculated and the observed values are shown in table (2),and many researchers like [5,1] have found an activation energies values near to our values although they have used a different techniques and circumstances in preparing films differ from our method in preparing films .

Figure (6) shows the variation of the activation energy with rate of deposition .

As seen from the Figures the conductivity increases with the rate of deposition increasing while the activation energies values decreases ,according to the inverse relation between the conductivity and the activation energy equation (3).
The increase in the electrical conductivity when the rate of deposition increases was probably due to the poor structure ,because when the time of preparing is became small defects may be established ,and defects increase conductivity[14,15], and when the rate of deposition increases may be impurities increase which they increase conductivity[13] and the conduction in ($CdSe_{0.5}Te_{0.5}$) thin films are affected by electrons excited from donor impurity levels to the percolation level ,which can be expressed as:

$$\sigma = \sigma_o \exp(E_p - E_f / K_B T) \quad \ldots\ldots\ldots(9)$$

where E_p is the percolation level and E_f is the Fermi level .
And may be there are different mechanisms of conduction refer to the thermal activation as well as the conduction by the defects

Conclusions:

From the results obtained in the present work ,a following points can be concluded :
1- A successive alloy can be obtained from Cd ,Se and Te pure materials by gradual heating ,and quenching the resultant mixed compound in cold water.
2- A successive thin films can be prepared from the alloy by thermal evaporation in vacuum method .
3-The conductivity increases with temperature increasing.
4- The conductivity increases with the rate of deposition increasing whereas the activation energy decreases.
5- There are conductivity

Table (2) illustrates the activation energy values and the rates of deposition

r.d (nm/s)	E_a (e.V)
0.25	0.46
0.50	0.42
0.75	0.38

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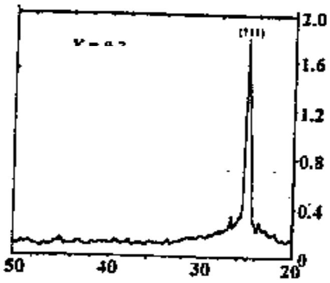

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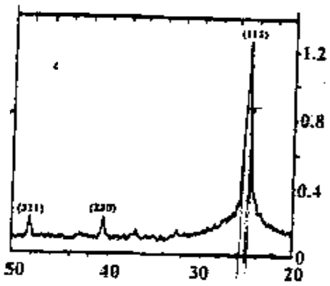

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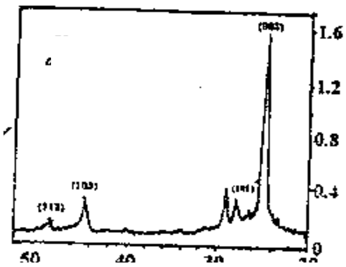


3-c

Figure (3) shows the X-ray diffraction patterns for ($CdSe_{0.5}Te_{0.5}$) thin films which have been prepared with (0.25,0.50,0.75)nm/s rates of deposition.

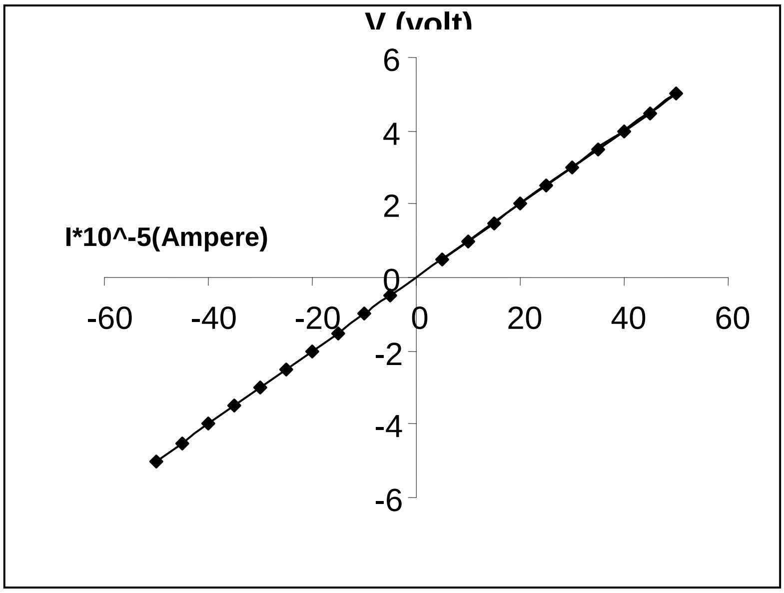
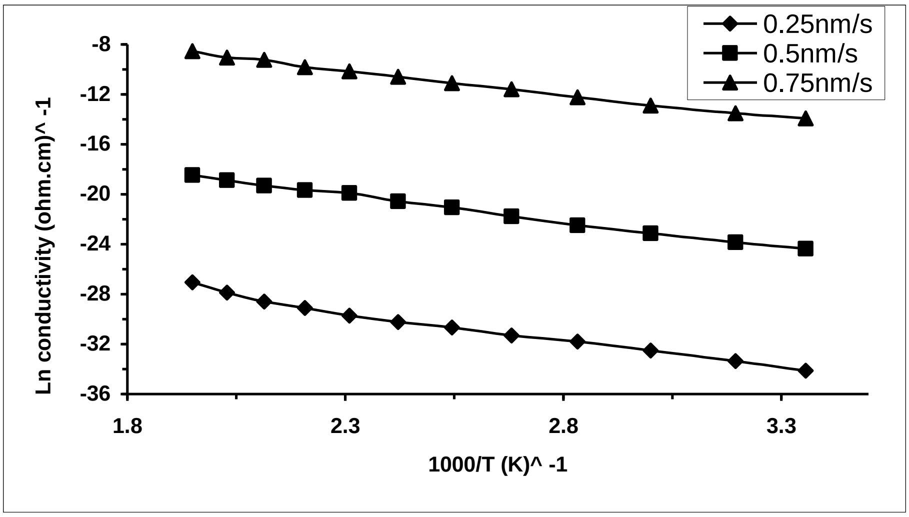


Figure (4) the **I-V** characteristic for ($CdSe_{0.5}Te_{0.5}$) thin films which have been prepared with (0.25nm/s) rate of deposition.



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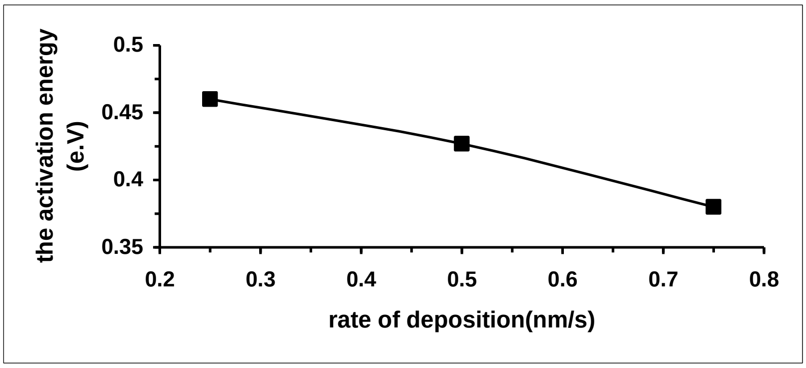

Figure (6) shows the variation of the activation energy with rate of deposition .

التوصيلية الكهربائية المستمرة لأغشية ($CdSe_{0.5}Te_{0.5}$) الرقيقة المحضرة عند معدلات ترسيب مختلفة

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الخلاصة

يهدف هذا البحث إلى تحضير أغشية ($CdSe_{0.5}Te_{0.5}$) الرقيقة بطريقة التبخير الحراري في الفراغ ،ودراسة علاقة التوصيلية الكهربائية المستمرة بدرجة الحرارة وحساب قيم طاقات التنشيط بمعدلات ترسيب مختلفة nm/s (0.25,0.50,0.75).

أوضحت الدراسة أن التوصيلية الكهربائية المستمرة تزداد بزيادة درجة الحرارة، وأوضحت دراسة العلاقة بين التوصيلية الكهربائية المستمرة ومعدل الترسيب أن التوصيلية الكهربائية المستمرة تزداد بزيادة معدل الترسيب ، فيما أظهرت دراسة العلاقة بين قيم طاقات التنشيط ومعدل الترسيب أن قيم طاقات التنشيط تقل بزيادة معدل الترسيب