ELECTRICAL PROPERTIES OF Cd_xSe_{1-x} FILMS
AT DIFFERENT THICKNESS AND ANNEALING TEMPERATURES

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Cd_xSe_{1-x} alloy has been prepared successfully. The prepared alloy were used to produce Cd_xSe_{1-x} films. Cd_xSe_{1-x} films with different thickness (0.5, 1, 1.5, 2)μm have been prepared by thermal evaporation on glass substrates. The deposited films have been annealed at different temperatures (373, 423 and 473)K. From studying the electrical properties of Cd_xSe_{1-x} films deposited on glass with different thickness and annealing temperature, we found that D.C conductivity increases from 1.511×10^{-5} to 67.6×10^{-5} $(\Omega.cm)^{-1}$ at R.T with thickness increasing (0.5–2)μm and decreases from 1.511×10^{-5} to $1.4 \times 10^{-7}(\Omega.cm)^{-1}$ with increasing of annealing temperatures (R.T–473)K for 0.5μm thick. There are two activation energies for D.C conductivity E_{a1} and E_{a2} decrease from 0.151 to 0.107 eV and from 0.446 to 0.188 eV at R.T, respectively, with increasing of thickness form 0.5 to 2μm. E_{a1} and E_{a2} increase from 0.151 to 0.231 eV and from 0.446 to 0.570 eV at 0.5 μm thick, respectively, with increasing of annealing temperatures (R.T–473)K. Hall measurements confirmed that all the intrinsic films are n-type, carriers concentration decreases from 11.16×10^{14} cm^{-3} to 8.333×10^{14} cm^{-3} at R.T with increasing of thickness (0.5–2)μm, and decrease form 1.116×10^{15} cm^{-3} to 0.096×10^{14} cm^{-3} for 0.5μm thick with increasing of annealing temperatures (R.T– 473)K. The mobility is found to increase with increasing of thickness and annealing temperatures. The drift velocity (V_d), carrier life-time (τ) and mean free path (ℓ) increase with increasing of annealing temperatures and thickness. A.C conductivity measurements for Cd_xSe_{1-x} films with different thickness and annealing temperatures consistent with correlated barrier hopping model (CBH).

1. Introduction

Cadmium selenide is an important member of this group of binary compounds. It has a direct intrinsic band gap of 1.74 eV and high photosensitivity in the visible region of the electromagnetic spectrum, which make it an interesting material for various applications[1,2]. Cd_xSe_{1-x} often possesses n-type conductivity in bulk as well as in thin film form. The native defects in excess Cd and Se vacancies thus, play an important role in the determination of conduction processes in Cd_xSe_{1-x} thin films[3]. The very high transmittance of the films in the visible region, and the brilliant orange colour of the films make Cd_xSe_{1-x} films useful aesthetic window glaze material[5]. Cd_xSe_{1-x} is an important material for solid-state devices such as, solar cells, high-efficiency thin-film transistors, and light-emitting diodes[4]. Other areas of successful applications include: photo-detectors, light amplifiers, lasers, photo electrochemical cells, and gas sensors for the detection of oxygen[2,5]. The lattice structure of Cd_xSe_{1-x} can be found in the forms of sphalerite (cubic) and wurtzite (hexagonal). The former is a metastable phase constituting the almost exclusive product of an electrochemical formation process, while the latter is the thermodynamically stable structure obtained either by annealing the cubic phase or directly by various, electroless, preparation techniques[6].

The D. C conductivity in crystalline semiconductors depends on the presence of free electrons and free positive holes. At (0K), the valence band is regarded as filled and the conduction band is empty. As the temperature is raised bonds are broken and the effect is that free electrons are excited into the conduction band, and this leaves behind holes in valence band[7]. The electrical conductivity (σ) is given by Ohm's law

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$$\vec{J} = \sigma\vec{E} \tag{1}$$

where:J: is the current density.E: is the electric field.

$$\sigma = nq\mu \tag{2}$$

or

$$\sigma = (nq^2\tau)/m^* \tag{3}$$

whereμ: is the mobility,τ: is the carrier's lifetime,n: is the carrier's concentration,m^*: is the effective mass of the carrier, and$q$: is the electron charge

In semiconductors, the relation between the current density and electric field is given by:

$$\vec{J} = q(n\mu_n + p\mu_p)\vec{E} \tag{4}$$

where$n$ & p are the electron and hole concentration and μn &μp are the mobility of electron and hole, respectively,

$$\mu = \frac{\vec{V_d}}{\vec{E}} \tag{5}$$

Where V_d is the drift velocity. So that:

$$\sigma = q(n\mu_n + p\mu_p) \tag{6}$$

This important relationship is connecting the conductivity with the electron and hole concentrations and mobility[7,8].The change of electrical conductivity with temperature for most cases of intrinsic semiconductors are given by:

$$\sigma = \sigma_o\exp(-E_a/k_BT) \tag{7}$$

Where :E_a: is the thermal activation energy, T: is the absolute temperature, k_B: is the Boltzmann constant, σ_o: is the minimum electrical conductivity at 0K

The Hall effect is a widely used method to distinguish between the type of the carriers, the concentration, and determining the mobility in the semiconductors[8].When a constant current (I) follows along the x-axis from left to right in the presence of a z-directional magnetic field (B); electrons are subjected to the Lorentz force initially, and they drift toward the negative y-axis, resulting an excess surface electrical charge on the side of the sample and causing a transverse voltage; this transverse voltage is known the Hall voltage (V_H).The hall coefficient (R_H) is determined by measuring the Hall voltage that generates the Hall field across the sample of thickness (t), by[9]:

$$\mathbf{R_H} = \frac{\mathbf{V_H}}{\mathbf{I}} \cdot \frac{\mathbf{t}}{\mathbf{B}} \tag{8}$$

Carriers concentration can be determined by using the relation[8]

$$\mathbf{n_H} = \frac{-1}{\mathbf{qR_H}} \text{ for electrons,} \qquad \mathbf{p_H} = \frac{+1}{\mathbf{qR_H}} \text{ for holes} \tag{9}$$

Hall's mobility (μ_H) can be written in the form[10]

$$\mu_H = \frac{\sigma}{n.q}$$

(10)

$$\mu_H = \sigma \ |R_H|$$

(11)

1.1. A.C. Conductivity

Information about the nature of the conduction mechanism in material can be obtained from a.c conductivity. In these experiments, the electrical conductivity is measured as a function of the frequency (ω) where $\omega = 2\pi f$ is the angular frequency and f is the frequency of an alternating electric field[9]. The total conductivity σtot at a certain frequency and temperature is defined as[9,10]

$$\sigma_{tot} = \sigma_{a.c}(\omega) + \sigma_{d.c}$$

(12)

where$\sigma_{d.c}$ is the D.C conductivity which depends strongly on temperature and dominate at low frequencies; while $\sigma_{a.c}$ is the A.C conductivity which is weaker temperature dependence than $\sigma_{d.c}$ and dominate at high frequency and nondependent temperature, then the empirical relation for the frequency dependence A.C conductivity is given by[10]

$$\sigma_{a.c}(\omega) \propto \omega^s$$

(13)

or

$$\sigma_{a.c}(\omega) = B\omega^s$$

(14)

where:B is constant, then we can re-write the eq. (14) as follows:

$$\sigma_{total}(\omega) = A_1 \ \omega^s + \sigma_{d.c}$$

(15)

The exponent (s) is a function of frequency and is determined from the slope of a plot ln $\sigma_{a.c}(\omega)$ versus ln (ω) then[9-11]:

$$S = \frac{d\left[\ln\sigma_{a.c}(\omega)\right]}{d\left[\ln(\omega)\right]}$$

(16)

s is not constant, but decreases with increasing of temperature and approaching unity at low temperatures and decreasing to 0.5 or less at high temperatures[10].

1.2. Models of A.C Conductivity
1.2.1. Quantum Mechanical Tunneling Model (QMT)

QMT model is usually observed in amorphous semiconductors that have large density of states in the middle of the gap (near E_F) and distribute randomly in space energy and the transport is by electrons or holes tunneling between states close to Fermi level. In this model, the $\sigma_{a.c}(\omega)$ is given by[9-11]:

$$\sigma_{a.c}(\omega) = \frac{Cq^2 k_B T N^2(E_F)\omega R_\omega^4}{\alpha'}$$

(17)

Where: C: is $1/12 \ \pi^2$, N(E_F): is the density of states (eV^{-1}. cm^{-3}) at Fermi level R_ω: is the tunneling distance.

α': is the decay of localized wave function and the exponent (s) is given by[9-11]:

$$s = 1 - \left[\frac{4}{\ln\left(1/\omega\tau_o\right)} \right]$$

(18)

where: τ_o: is the relaxation time. From last equation, we observe that (s) is temperature independent but frequency dependent and decreases with increasing frequency.

1.2.2. Correlation Barrier Hopping Model (CBH)

In this model, the charge carrier is assumed to hop between defect D+ and D- which are called bipolaron. The $\sigma_{a.c}(\omega)$ conductivity is given by[9-11]:

$$\sigma_{a.c}(\omega) = \left[\left(\pi^2 N(E_F)\right)^2 \varepsilon_1 / 24 \right] \omega R_\omega^6$$

(19)

where: N(EF): is the density of state at Fermi level and the exponent (s) is given by[10]:

$$s = 1 - \left[\frac{6 k_B T}{W_m} \right]$$

(20)

where (W_m): is the energy required to take two electrons from D site into C.B and equal to optical gap. In this model, the exponent (s) is temperature dependence and approaches unity when the temperature approaches zero.

1.2.3. Small Polaron Tunneling (SP)

When addition of charge carrier to the covalent solid causes a large degree of local lattice distortion; this may form small polaron have total energy (electronic + distortion) of the system is lowered by an amount (w_p), the polaron energy. The A.C conductivity may be represented by equation (19) and the exponent (s) may be given as[10]:

$$s = 1 - \left[\frac{4}{\ln\left(1/\omega\tau_o\right)} - \frac{W_H}{k_B T} \right]$$

(21)

where W_H: is the activation energy of polaron transfer and is given by:

$$W_H \approx \frac{1}{2} W_p$$

(22)

1.2.4. Large Polaron Tunneling (LP)

In this model, A.C conductivity occurs by forming an extended polaron which is large compared with the interatomic distance; therefore, it is called large polaron, and the A.C conductivity is given by[10]:

$$\sigma_{a.c}(\omega) = \left(\pi^4 / 12\right) q^2 \left(k_B T\right)^2 N^2 E_F \cdot \left[\frac{\omega R_\omega^2}{\left\{2\alpha k_B T + W_{Ho} r_o \left| R_\omega^2 \right|\right\}} \right]$$

(23)

Where r_o is the polaron radius, and W_{Ho} is a function of atomic positions and the relaxation time. The exponent (s) is temperature and frequency dependent.

The structure and optical properties of these films have been studied in earliest paper[12]. They found that the structure is hexagonal crystalline and the prepared films have direct energy gab and also they effected by variation thickness and annealing temperatures. In this paper the

effect of thickness and annealing temperature on the electrical properties (d.c and a.c conductivity and Hall effect) have been studied.

2. Experimental

The Cd_xSe_{1-x} with(x=0.5) compound was prepared as alloy by using stoichiometric and high purity (99.999%) cadmium metal packed under argon, obtained from Certified Chemicals, UK and high purity (99.999%) selenium metal obtained from Balzers, Switzerland. The element weighted according to its atomic weight and then mixing in quartz tube evacuated at pressureof (10^{-3}mbar). The tube was sealed and heated in electrical program controller furnace of type (Nabertherm), Germany, at a rate of 120K per hour in steps up to 773K, and balanced at the temperature for (2) hours and then raised to 1173K, and also balanced at the temperature for (2) hours and then cooled at 25 C, then ampoule was broken and the prepared compound of $Cd_xSe_{1-x}$was taken out and powdered to a fine grain powder. The powder of the compounds was used as a source of the evaporation to prepare the films. The used films are prepared by vacuum evaporation methods at 25 C with deposition rate (R_d) of about (1.5×10^{-3}µm/sec) and thickness (0.5, 1, 1.5 and 2)µm and annealing temperature (373, 423, and 473)K. The substrates were cleaned by different methods depending on the type used.

Glass slides substrates were cleaned by using detergent with water, and then they were rinsed by ultrasonic cleaner's bath filled with distilled water for 15 minutes. After that the substrates were rinsed by ultrasonic cleaner's bath filled with a pure alcohol for 15 minutes also. Finally, the slides were dried by blowing air and wiped with soft paper. The mask is a piece of aluminum foil having thickness 0.25mm with the same size of the substrate. Various shapes of masks were used to determine the shape of films and electrodes for different measurements as shown in Fig. (1).The masks were cleaned according to the following stages: rinsed in HCl (5%) for five min, and then washed in distilled water, after that immersed in a pure alcohol. Finally dried by blowing with hot dry air. Edwards coating unit system type E306A has been used for deposition Al electrodes for ohmic contact on glass substrate for electrical measurement with thickness of (0.2)µm.
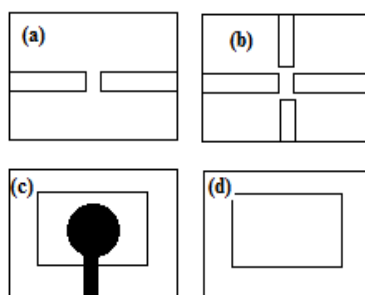

Fig.1.Masks of (a) D.C conductivity electrodes.(b) Hall effect electrodes,
(c)A.C conductivity electrodes, (d) Material deposition.

2.1.The Electrical Measurement

The electrical measurements include D.C conductivity, Hall effect and A.C conductivity for samples deposited on glass substrate with aluminum electrodes for Cd_xSe_{1-x}films with different thicknesses and annealing temperatures at constant substrate temperature (300K).The electrical resistance has been measured as a function of temperature for Cd_xSe_{1-x}films in the range (303 – 483)K by using the electrical circuit as shown in Fig. (2). The measurements have been done using sensitive digital electrometer type Keithley 616 and electrical oven.
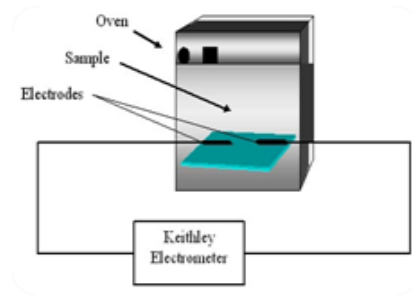
Fig.2.The circuit for measuring D.C. conductivity.

The resistivity (ρ) of the film was calculated by using the following equation:

$$\rho = \frac{R'.A}{L}$$

(24)

where: R': is the resistance of the film, A: is the area of the film. L: is the distance between the electrodes. The conductivity (σ) of the films was obtained from the reciprocal of the resistivity:

$$\sigma = \frac{1}{\rho}$$

(25)

The activation energies could be calculated from the plot of $Ln\sigma$ versus $10^3/T$ according to equation (7).

2.2.Hall Effect Measurements

Hall effect has been measured by using the electrical circuit as shown in Fig.(3), which contains D.C power supply (0-40) volt and two digital electrometers (type Keithley 616) to measure the current and voltage. When the samples carrying a current are exposed to a constant magnetic field (B = 0.257 tesla) perpendicular to the electric field, then Hall voltage (V_H) is set up across the sample. The Hall coefficient (R_H) can be found from equation (9). The sign of Hall coefficient determines the type of charge carriers. From the value of R_H the charge carrier concentrations (n_H) and (p_H) by can be calculating by using the relations (9), Hall mobility (μ_H) can be obtained according to the equation (10) and (11).

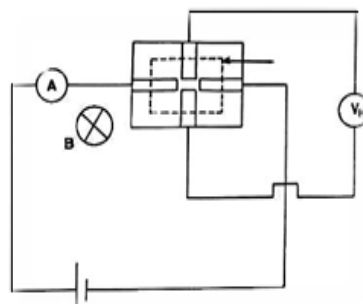*Fig. 3. The circuit diagram for Hall measurements.*

The carrier life-time (τ)can be calculated from the mobility values by using the equation:

$$\tau = \left(\mu.m^*\right)/e \tag{26}$$

Where m* is the effective mass.The drift velocity (V_d) could be calculated from the equation:

$$\vec{V_d} = \mu.\vec{E} \tag{27}$$

whereE is the applied electric field. The main free path (ℓ) could be calculated using the equation:

$$\ell = V_d.\tau \tag{28}$$

2.3.A.C Conductivity Measurement

The metal-semiconductor-metal film was prepared on glass substrate by using thermal evaporation method for multilayer from aluminum, Cd_xSe_{1-x} film for different thickness(0.5,1,1.5,2) µm, then aluminum, with (0.2) µm thickness. The resistance of alternating current was measured by using the circuit diagram as shown in Fig. (4). This circuit contains (multi-frequency LCR meter model hp. 4274 A and 4275A, Hewlett. Packard) in the range of frequency ($10^2 - 10^9$)Hz and 0.08V, and by using the dimension of the sample, the alternating conductivity can be found.
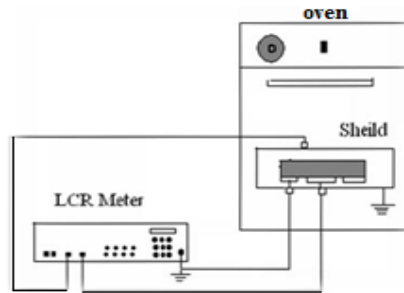

Fig.4.Schematic diagram of A.C conductivity measurement.

3. Results and discussions

3.1.D.C Electrical Conductivity

The D.C conductivity ($\sigma_{d.c}$) for Cd_xSe_{1-x}films, which has been studied as function of $10^3/T$ at different thicknesses and annealing temperatures for one hour are shown in Fig. (5 a, b, c, d) and Table (1) within the range of (300-483) K. The ($\sigma_{d.c}$) of the Cd_xSe_{1-x}films increases with increase of thickness. The observed lesser conductivity in thinner films can be explained due to lower degree of crystallinity and the small grain size. This result is in agreement with Al-Fwadi et al.[13]. The conductivity decreases with increase of annealing temperatures because of the rearrangement that may occur during annealing, which produce an irreversible process in conductivity, so annealing may be reduced the density of states, structural defects and eliminated tails in the band gap and improved the structure of films.

It is clear from the Fig.(5) that there are two transport mechanisms, giving rise to two activation energies E_{a1} and E_{a2}. The conduction mechanism of the activation energy (E_{a2}) at the higher temperatures range (333-483) K is due to carries excitation into the extended states beyond the mobility edge, and at the lower range of temperatures (300-443) K, the conduction mechanism of the activation energy (E_{a1}) is due to carriers excitation into localized states of the edge of the band. The values of E_{a1} and E_{a2} increase with increasing of annealing temperatures due to the elimination of some defects from the films and the improvement in crystallinity during annealing. also its observed that the values of E_{a1} and E_{a2} decrease with increasing thickness and this may be

attributed to the increasing of the absorption and decreasing of the energy gap. These results are in agreement with Naji et al.[14], Abdullah et al.[15].
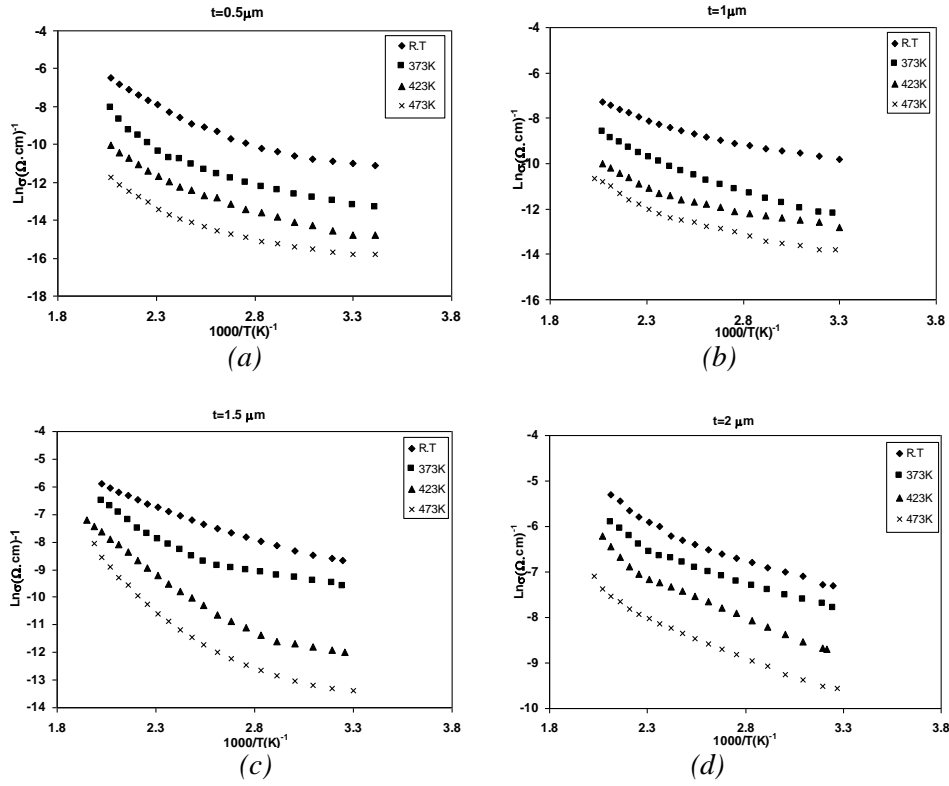

Fig. (5 a, b, c, d): Ln $\sigma_{d.c}$ versus 1000/T for Cd_xSe_{1-x}films at different thickness and annealing temperatures.

Table 1. D.C. conductivity parameters for Cd_xSe_{1-x}films at different thicknesses and annealing temperature.

Thickness (μm)	T_a (K)	$\sigma_{d.cR.T}X10^{-5}$ $(\Omega.cm)^{-1}$	E_{a1} (eV)	Temp. Range (K)	E_{a2} (eV)	Temp. Range (K)
0.5	R.T	1.511	0.151	3035-363	0.446	373-483
	373	0.186	0.181	303-373	0.529	383-483
	423	0.038	0.230	303-403	0.541	413-483
	473	0.014	0.231	303-413	0.570	423-483
1	R.T	5.580	0.119	303-383	0.260	393-483
	373	0.503	0.124	303-323	0.284	333-483
	423	0.276	0.129	303-423	0.390	433-483
	473	0.099	0.160	303-403	0.400	413-483
1.5	R.T	17.301	0.122	303-333	0.217	434-483
	373	6.772	0.130	303-423	0.447	433-483
	423	0.614	0.157	303-373	0.450	383-483
	473	0.153	0.177	303-383	0.602	393-483
2	R.T	67.6	0.107	303-363	0.188	373-483
	373	41	0.108	303-403	0.193	413-483
	423	16.767	0.143	303-353	0.195	363-483
	473	7.032	0.144	303-443	0.328	453-483

3.2.Hall Effect of Cd_xSe_{1-x} films

The type of charge carriers, concentration (n_H), Hall mobility (μ_H), drift velocity (V_d), life-time (τ) and mean free path (ℓ) of charge carriers have been calculated from Hall coefficient (RH) data and D.C conductivity. The results are listed in Table (2). All Cd_xSe_{1-x} films with different thicknesses and annealing temperatures exhibit a negative Hall coefficient (n-type). The n-type conductivity of vacuum-deposited Cd_xSe_{1-x}films is normally attributed to the existence of excess Cd in the condensed films[13]. The n_H was calculated by using the equation (9). The carries concentration decreases with increase of annealing temperature due to improving the crystallite size, and the recrystallization occurring due this treatment leads to a growth of the main crystallite size. This result is in agreement with the result of Elahi et al.[16], also Its noticed that the carriers concentration decreases with increase of thickness due to higher degree of crystallinity and the big grain size[13-16]. Hall mobility increases with increase of annealing temperatures and thickness due to the decreasing of the carries concentration, τ,V_d and ℓ of the carriers have been calculated by using the equations (26), (27) and (28), respectively. Similar results were obtained by Odur and Gould[17] and [13].

Table 2.Hall parameters for Cd_xSe_{1-x}films at different thickness and annealing temperatures.

Thickness (μm)	Ta (K)	$\sigma_{R.T}X10^{-5}$ $(\Omega.cm)^{-1}$	n_HX10^{14} $(cm)^{-3}$	μ_H $(cm^2/V.s)$	V_d (cm/s)	$\tau x10^{-8}$ (s)	$\ell x10^{-8}$ (cm)
0.5	R.T	1.511	11.16	0.084	0.564	0.048	0.027
	373	0.186	1.296	0.089	0.599	0.051	0.030
	423	0.038	0.260	0.091	0.609	0.052	0.031
	473	0.014	0.096	0.092	0.610	0.053	0.032
1	R.T	5.580	8.915	0.391	2.607	0.222	0.580
	373	0.503	0.781	0.402	2.682	0.229	0.614
	423	0.276	0.255	0.676	4.507	0.384	1.735
	473	0.099	0.088	0.706	4.712	0.402	1.896
1.5	R.T	17.301	8.664	1.248	8.320	0.710	5.912
	373	6.772	0.735	5.576	37.174	3.174	118.019
	423	0.614	0.068	5.618	37.453	3.198	119.88
	473	0.153	0.016	5.737	38.249	3.266	124.946
2	R.T	67.6	8.333	5.07	33.799	2.886	97.565
	373	41	0.726	35.26	235.064	20.075	4718.929
	423	16.767	0.062	167.60	1117.322	95.422	106617.120
	473	7.032	0.016	264.78	1765.182	150.750	266102.643

3.3.A.C Conductivity

The A.C conductivity $\sigma_{a.c}(\omega)$ of Cd_xSe_{1-x} films with different thicknesses and annealing temperatures has been investigated.

3.3.1 Frequency Dependence on A.C Conductivity

The $\sigma_{a.c}(\omega)$ for all films increases with increasing the frequency according to equation. (15) as shown in Fig. (6a, b, c, d). In this case, $\sigma a.c(\omega)$ is proportional to ωs which means that $\sigma_{a.c}(\omega)$ dominates at higher frequency, in the range of (103 – 105)Hz. For lower frequency in the range of $(10^2 – 10^3)$Hz $\sigma_{a.c}(\omega)$ becomes independent of the frequency because D.C conductivity dominate in this frequency range.

The values of exponent (s) are estimated from the slope of the curves plotted between $Ln\sigma_{a.c}(\omega)$ versus Ln (ω) declared in Fig. (6a, b, c, d) and listed in Table (3) found to be less than unity for all prepared films and decreases with increasing of annealing temperature, whereas the value increases as the film thickness increases.

The behaviour of $\sigma_{a.c}(\omega)$ with frequency can be explained in terms of polarization effect and hopping i.e, polarization effect in low frequency region where polarization is slightly changed

and $\sigma_{d.c}$ is dominated, and at higher frequency region the hopping takes place. That means the exponent (s) fits C.B.H. model given by [16,18] from which A.C conductivity occurs between two sites over the barrier separating between D^+D^- defect centers in the band gap. This leads to greater loss in the dielectric and $\sigma_{a.c}(\omega)$ is dominating.
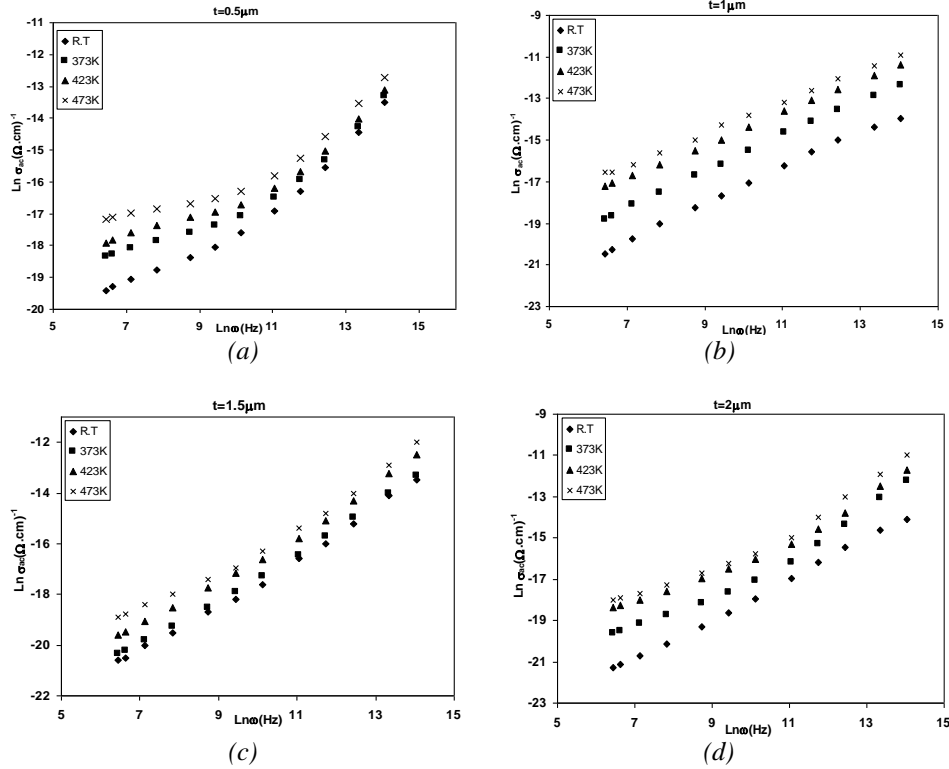

Fig.6. (a, b, c, d): $Ln\sigma_{a.c}$ as a function of $Ln(\omega)$ for Cd_xSe_{1-x}films at different thickness and annealing temperatures.

Table 3. Exponent (s) value of Cd_xSe_{1-x}films at different thickness and annealing temperatures.

Thickness (μm)	0.5	1	1.5	2
$T_a(k)$	S	S	S	S
R.T	0.728	0.869	0.932	0.971
373	0.600	0.855	0.906	0.949
423	0.560	0.774	0.898	0.903
473	0.529	0.759	0.878	0.897

3.3.2.Temperature Dependence on A.C Conductivity

The variation of $Ln\sigma_{a.c}(\omega)$ with reciprocal temperature $(10^3/T)$ for Cd_xSe_{1-x}films for two fixed frequencies $(10^3$ and $10^5)$ Hz at different thicknesses and annealing temperatures are shown in Fig. (7 a, b, c, d).
A linear behavior of $\sigma_{a.c}(\omega)$ of one stage has been observed over the entire temperature range (303 – 473) K indicating a thermal activated conduction mechanism. There is one activation energy for each film less than the activation energy in the D.C conductivity because the dependences of A.C conductivity on the temperature being less than in the D.C conductivity.

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The A.C activation energy E_ω decreases as the film thickness increases as shown in Table (4) and this may be attributed to increase of the absorption and decreasing the energy gap. It can be seen also that E_ω increases with the increasing of T_a due to the annealing process near Fermi level. It is obvious that there is a decrease in E_ω with frequency increasing and such result complies with the theory of CBH model[16,18].
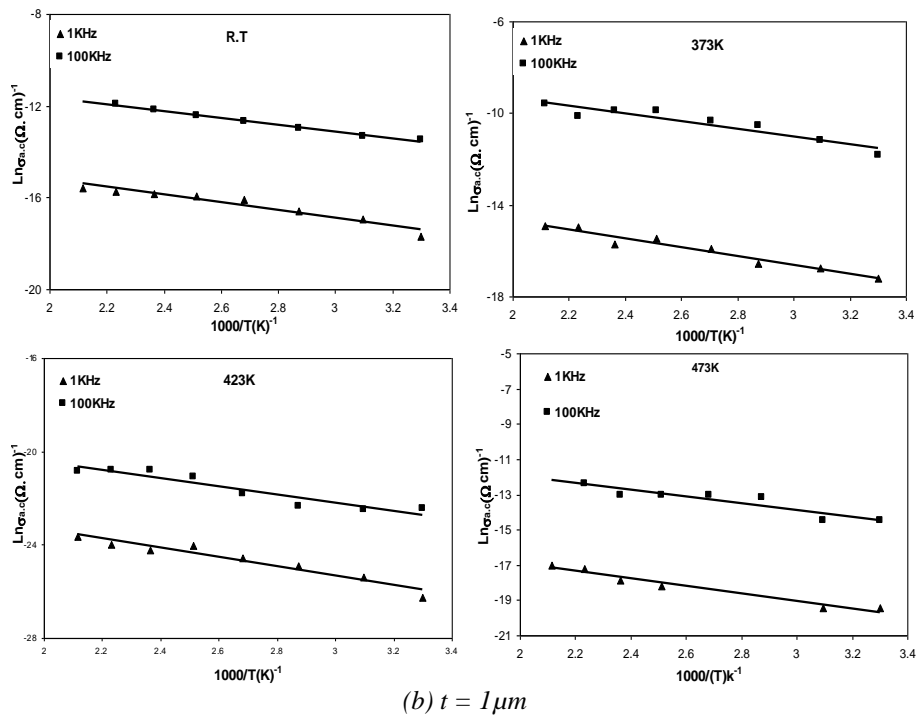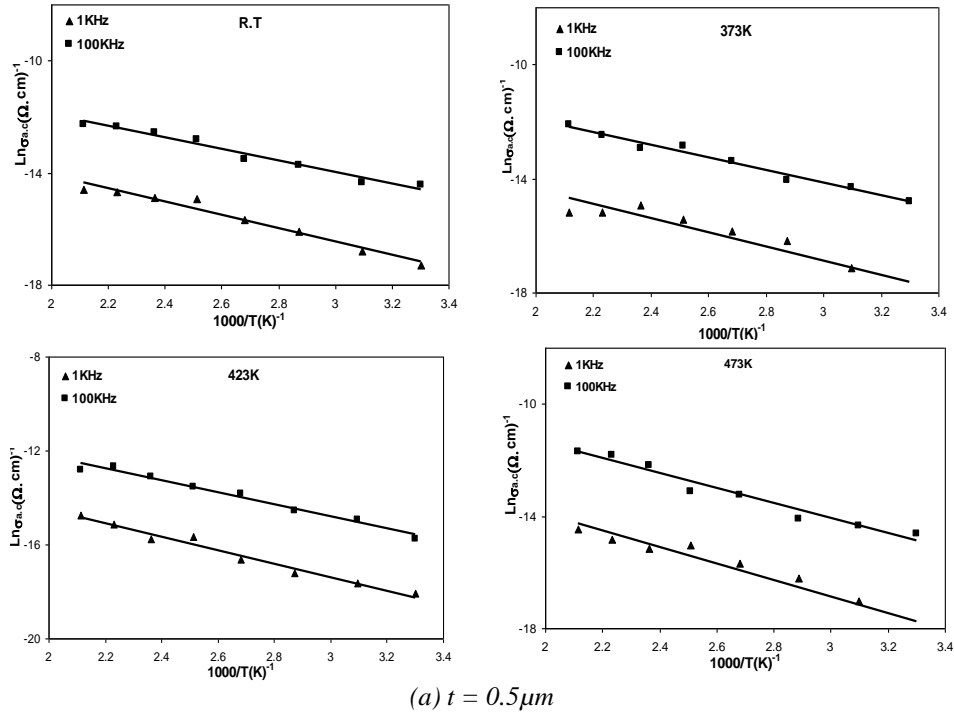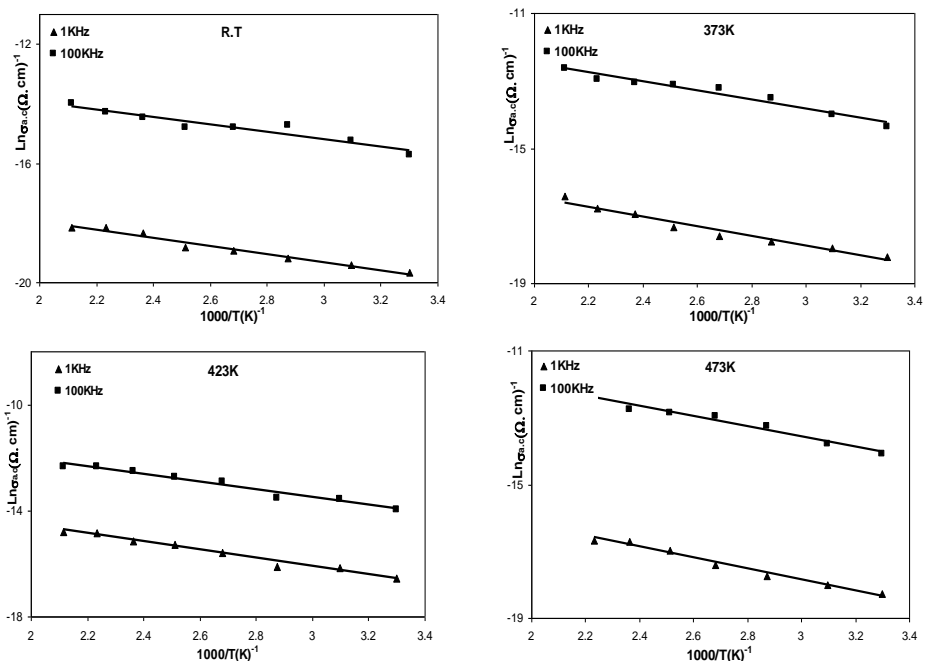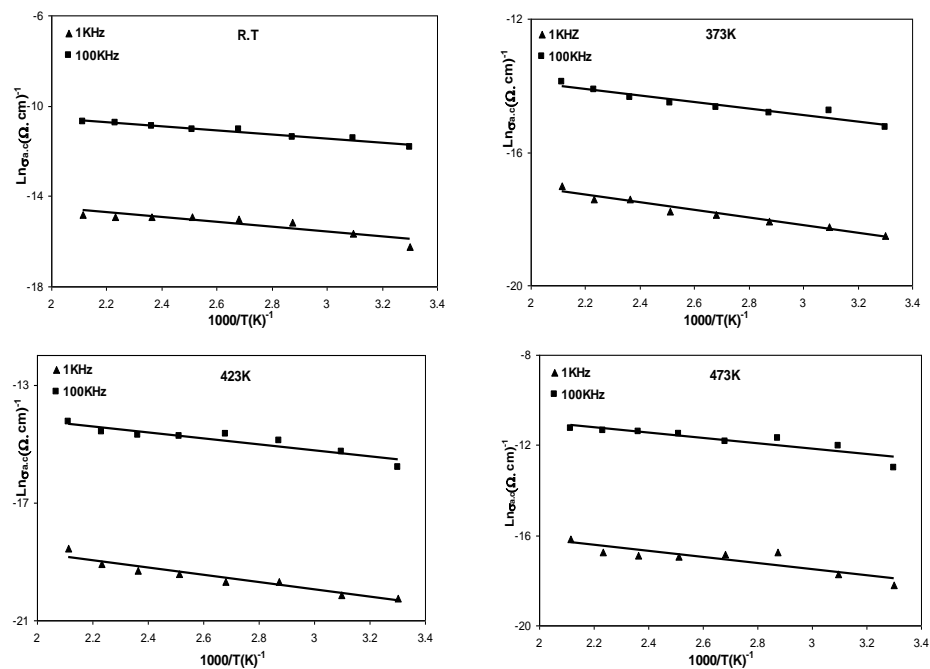

(a) t = 0.5μm

(b) t = 1μm

Fig.7.1.(a, b): Ln $\sigma_{a.c}$ as a function of 1000/T for Cd_xSe_{1-x} films at different thickness and annealing temperatures at 1kHz and 100kHz.

(c) t = 1.5µm

(d) t = 2µm

Fig.7.2. (c, d): Ln σ$_{a.c}$ as a function of 1000/T for Cd$_x$Se$_{1-x}$ films at different thickness and annealing temperatures at 1kHz and 100kHz.

Table 4. A.C activation energies for Cd_xSe_{1-x}films at different thicknesses and annealing temperatures at 1kHz and 100 kHz.

Thickness (µm)	T_a(K)	E_w (eV)	
		1 kHz	100 kHz
0.5	R.T	0.206	0.176
	373	0.213	0.190
	423	0.248	0.221
	473	0.252	0.231
1	R.T	0.144	0.128
	373	0.167	0.144
	423	0.170	0.151
	473	0.183	0.164
1.5	R.T	0.117	0.106
	373	0.125	0.115
	423	0.133	0.124
	473	0.140	0.131
2	R.T	0.091	0.077
	373	0.098	0.082
	423	0.108	0.088
	473	0.113	0.102

4. Conclusions

The alloys and films of Cd_xSe_{1-x} have been prepared successfully and from electrical properties, it's found that the D.C conductivity for all films increases as the thickness increases and decreases with increasing the annealing temperatures. There are two transport mechanisms of the charge carriers in the range of (303-483)K. In general, the activation energies decrease with increasing the thickness and increase with increasing the annealing temperatures. Also from Hall measurements showed that all the intrinsic films are n-type.

The charge carriers concentration decreases with increasing the annealing temperatures and thickness, and Hall mobility increases with increasing the annealing temperatures and thickness. Finally Drift velocity, carrier life-time and mean free path increase with increasing of annealing temperatures and thickness, and the factor (s) of the A.C conductivity decreases with increasing of annealing temperatures and thickness .The experimental results for the mechanism of A.C conductivity are consistent with CBH model.

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