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Study the Annealing Effect on Electrical properties of ($As_{0.5}Se_{0.5}$) doped With Tellurium

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Abstract:

During this work, the study of electrical properties of (As0.5Se0.5 doped with 1%Te) thin films which prepared by thermal vacuum evaporation on glass substrate bases at room temperature with (100±20)nm thickness, deposition rate (1.6nm/s) and study effect of annealing at temperatures (Ta) (348,398 and448)K for (30min) on these properties. The X-ray diffraction pattern showed that all prepared films have amorphous structure. The electrical measurements explain that D.C. conductivity increases as annealing temperature (Ta) increases and all films have two values of activation energy (Ea1) and (Ea2) and found that it decrease when (Ta) increases. From study Hall effect, all samples showed (p-type) and carrier's concentration (p) increase while it's mobility decreases with increasing of (Ta). From measurements of thermoelectric power showed that the thermal activation energy (Es) smaller than the D.C. conductivity (Ea2) and (Es) decrease as (Ta) increase.

Key words: chalcogenide glass, D.C conductivity, Hall Effect, Seebeck effect, annealing.

دراسة تأثير التلدين على الخصائص الكهربائية لأغشية (As0.5Se0.5المشوبة ب 1% Te)

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الخلاصة:

تم في هذا البحث دراسة الخصائص الكهربائية لاغشية As0.5Se0.5) المشوبة بالتيليريوم بنسبة 1%) الرقيقة المحضرة بطريقة التبخير الحراري في الفراغ على قواعد زجاجية بدرجة حرارة الغرفة وبسمك (100±20)nm وبمعدل ترسيب (nm/s1.6)، ودراسة تاثير التلدين عند درجات حرارة (348,398,448)K (Ta ولمدة (min30) على الخصائص قيد البحث. تبيّن من خلال نتائج حيود الاشعة السينية (XRD) ان جميع الاغشية كانت عشوائية التركيب عند درجة حرارة الغرفة (R.T) والاغشية الملدنة ضمن المدى (348,398,448)K. اظهرت القياسات الكهربائية ان التوصيلية الكهربائية المستمرة تزداد بزيادة درجة حرارة التلدين (Ta) ضمن المدى (R.T,348,398,448)K وان الاغشية كافة تمتلك طاقتين للتنشيط (Ea1) و (Ea2) وتقل قيمتها بزيادة (Ta) وتبين من خلال دراسة تاثير هول ان جميع الاغشية هي من النوع الموجب (p-type) وان تركيز حاملات الشحنة (p) تزداد في حين تحركيتها تقل بزيادة (Ta). بالنسبة الى قياسات القدرة الكهروحرارية لوحظ ان طاقة التنشيط (Es) للاغشية المحضرة اقل مما هي عليه للتوصيلية المستمرة (Ea2)، كما ان (Es) تقل بزيادة (Ta).

الكلمات المفتاحية : زجاج الجالكوجينات، التوصيلية بالتيار المستمر، تأثير هول، سيبك، التلدين.

Introduction:

The glasses (As-Se-Te) is a great significance in terms represent a new classification for semiconductor and its thin films used in many technological and scientific applications, where used in optical memory devices, photographic printing to the advantage of its high sensitivity when exposed to a wavelength identical to the energy gap, and (Popescu) [1] found that most chalcogenide glasses films that doped with (Te) uses in medical diagnosis and in pollution monitoring. The common feature of these glasses is the presence of localized states in the mobility gap because that absence of long-range orders as well as various inherent defects. Recently, the investigation of electron transport in disordered system has gradually been developed and the investigation of gap states is of particular interest because of their effect on the electrical properties of semiconductors [2]. The effect of impurity in an amorphous semiconductor may be widely different, depending upon the conduction mechanism and the structure of the material while in crystalline semiconductors the effect of a suitable impurity is always to provide a new donor and or acceptor states, this is not essential in amorphous semiconductor[3,4].

The exposing process of film to a certain temperature in a specific period of time called the annealing has been carried out either in vacuum or in presence of a particular gas or in air. The thermal treatment granted atoms kinetic energy that necessary to rearrange itself in the crystalline lattice that is lead to organization of the crystal structure of the material and reduces the defects; also annealing the thin film may sometimes cause reduced resistance as a result to form localized states within the energy gap and then increase the conductivity, (Hsiuang and Wang)[5] found the effect of thermal treatment on amorphous semiconductors will be in two phases: the first includes the reduction in the disordered of atoms (at low temperature), the second phase include reducing the dangling bonds(at high temperature).

In this work, the effect of thermal annealing on the electrical properties have studied provides a better understanding of disorder mechanism and defect formation in the chalcogenide films.

Experimental:

The glassy alloys of (As0.5Se0.5 doped with 1%Te) were prepared by applying melt quenching technique. The exact proportions of high purity (99.999%) arsenic (As), Selenium (Se) and tellurium (Te) elements, in according with their atomic percentages, these elements were put within the quartz tube sealed at ($\mathbf{10^{-2}}$torr). The tube was heated to (823k) for (4-5 hours) and shaken it in several times during the course of heating to attain uniformity. The molten samples were then rapidly quenched in cold water. The films of (As0.5Se0.5 doped with 1%Te) of thickness (100±20)nm were prepared by vacuum evaporation technique using molybdenum boat according to low [6] ($\mathbf{m = 2\pi\rho_0 r^2 t}$) where : weight of alloy. : the distance from boat to a substrate. : thickness of film. the density of alloy ($\mathbf{\rho_0 = \frac{m_T}{V_T}}$) where $\mathbf{m_T}$: the alloy mass, $\mathbf{V_T}$: the alloy volume, for the purpose of study the electrical properties (d.c conductivity, Hall and Seebek effects) requires deposited the film on conduction poles were prepared by evaporate wire of aluminum (by using tungsten boat) on the glass substrate covered with makes for poles. The films of (As0.5Se0.5 doped with 1%Te) were annealed at (Ta) (348,398 and 448) K by using oven type of (Griffin Incubator) which reaches the great degree of temperature at (473K).

Results and Discussion:

D.C conductivity and activation energy

Non-crystalline was tested of the film (As0.5Se0.5 doped with 1%Te) by x-ray diffraction even after annealing films at ($\mathbf{T_a = 348, 398\ and\ 448}$) K. The well-defined peaks characteristic of crystalline materials were absent, Fig. (1).

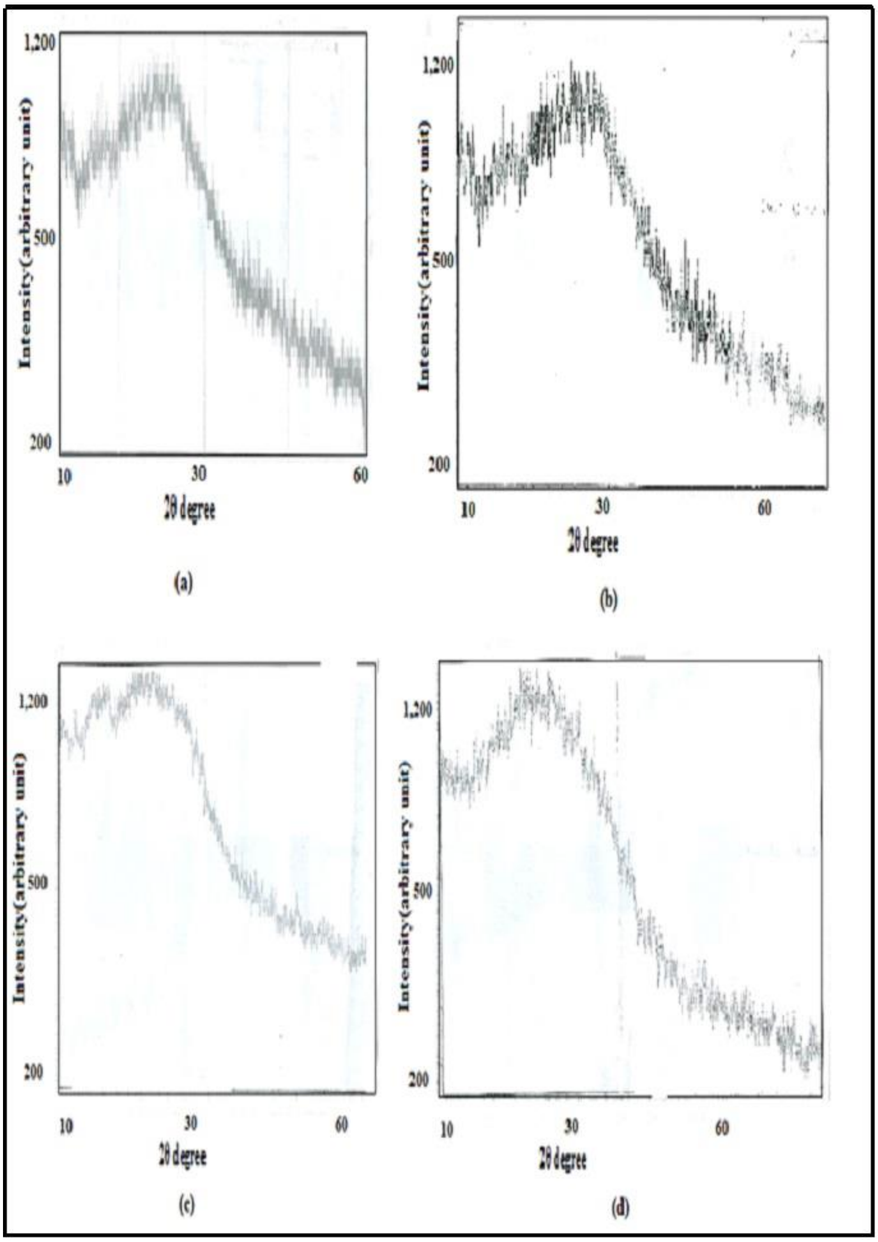


Figure (1): x-ray diffraction patterns for the films ($As_{0.5}Se_{0.5}$ doped with 1%Te): (a) at room temperature. (b)at 348k. (c) at 398k. (d) at 448k.

D.C conductivity and activation energy were measured of this film by using the eq. (1):

$$\sigma_{d.c} = \frac{1}{\rho} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

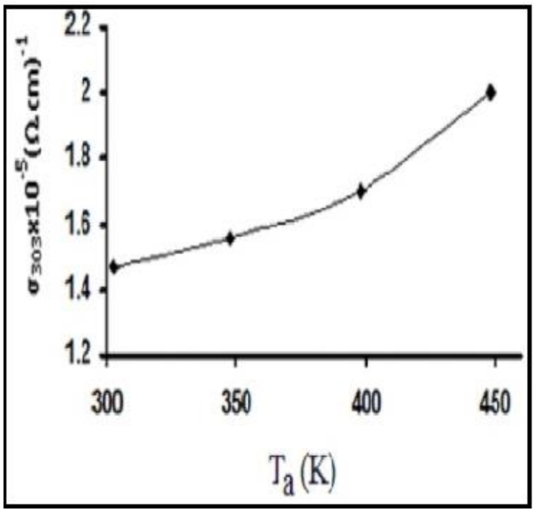
Where $\sigma_{d.c}$: dc conductivity, and ρ: The resistivity

$$\rho = R\frac{b.t}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Where R: the resistance, b: pole display, t: Film thickness and l: The distance between the poles of aluminum. The activation energy was measured through plotting the relationship between ($\ln\sigma_{d.c}$) and inverted temperature ($\frac{1000}{T}$) and calculate the tendency multiplied by Boltzmann's constant (K_B) according to *Arhinu's* relationship [7]:

$$\sigma_{d.c} = \sigma_0 \exp\left[-\left(\frac{E_a}{K_B T}\right)\right] \qquad \ldots\ldots.(3)$$

Fig. (2) Depicts change the d.c conductivity at room temperature (303k) (σ_{303}) with (T_a) for ($As_{0.5}Se_{0.5}$ doped with 1%Te) with different annealing temperature (T_a = 348,398 and 448) K. It was found that (σ_{303}) increases with the increasing (T_a)[8].



Figure(2):Variation of (σ303) with (T_a) for prepared and annealed films of (As0.5Se0.5 doped with 1%Te).

Fig. (3) shows the resistivity as a function of (***T***) for a prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with 1%Te), it has been observed that resistivity decreases with increasing the annealing temperature, it is common feature of semiconductor back to increasing of density of localized states that is due to increasing the concentration of charge carriers [9]. This means that the increasing in temperature leads to a negative thermal coefficient of resistance by the eq. (1).

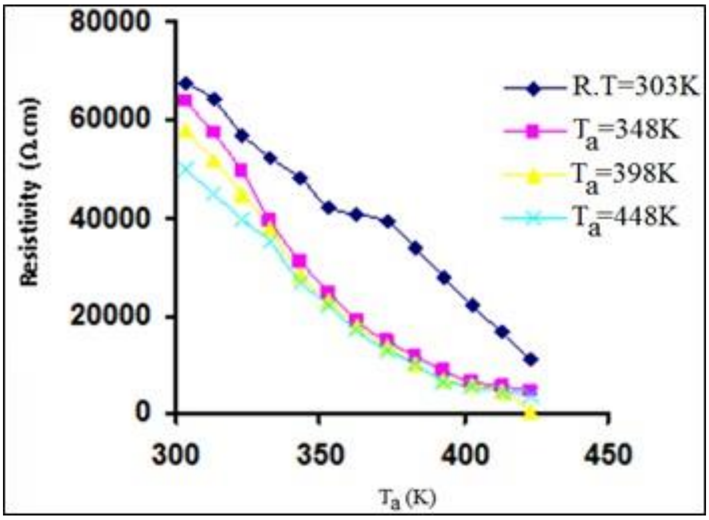


Fig. (3) Variation of resistivity with (T) for prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with 1%Te).

Table (1) depicts that presence of more than one value for activation energy, in other words, electrical conductivity has occurred by two mechanisms; the first way: by tunneling the charge carriers raised between confined levels in gap at low temperature, but at high temperature, the conductivity occur by charge carriers above and below the mobility edge. These results were consistent with *(Davis &Mott)* [10], also found from Table (1) that the values of these activation energies (E_{a1}) and (E_{a2}) decrease for prepared and annealed samples, these results were consistent with (*Bhuiyan and AlAzad*) [8], *(Khan and Adler)* [11]and *(Varghese and*

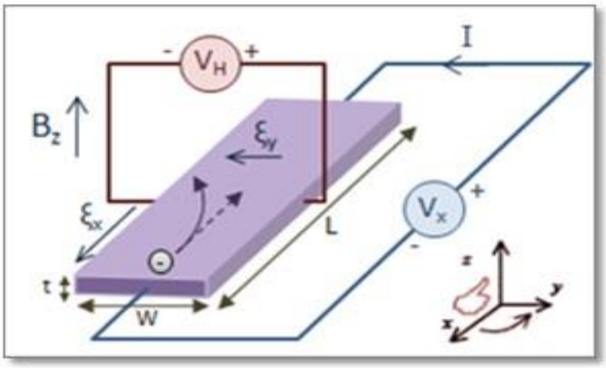
Iype)[12], that the interpretation of what is happening is that when increasing the degree of annealing temperature (T_a) it cause increased density of localized states i.e. increase the defects states inside the gap due to decrease the optical energy gap (E_g^{opt}) and increase the concentration of charge carriers and the transition between the converging enegy levels within the energy gap, which it needs to activate less energy to move and electrical conductivity events.

Table (1) The D.C conductivity and activation energy of ($As_{0.5}Se_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$As_{0.5}Se_{0.5}Te_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
$\sigma(\Omega.cm)^{-1}$ at 303K	$1.47x10^{-5}$	$1.56x10^{-5}$	$1.7x10^{-5}$	$2x10^{-5}$
$\sigma(\Omega.cm)^{-1}$ at 423K	$18.9x10^{-5}$	$22x10^{-5}$	$25x10^{-5}$	$25x10^{-5}$
E_{a1}(eV)	0.090	0.086	0.082	0.078
E_{a2}(eV)	0.430	0.369	0.313	0.273

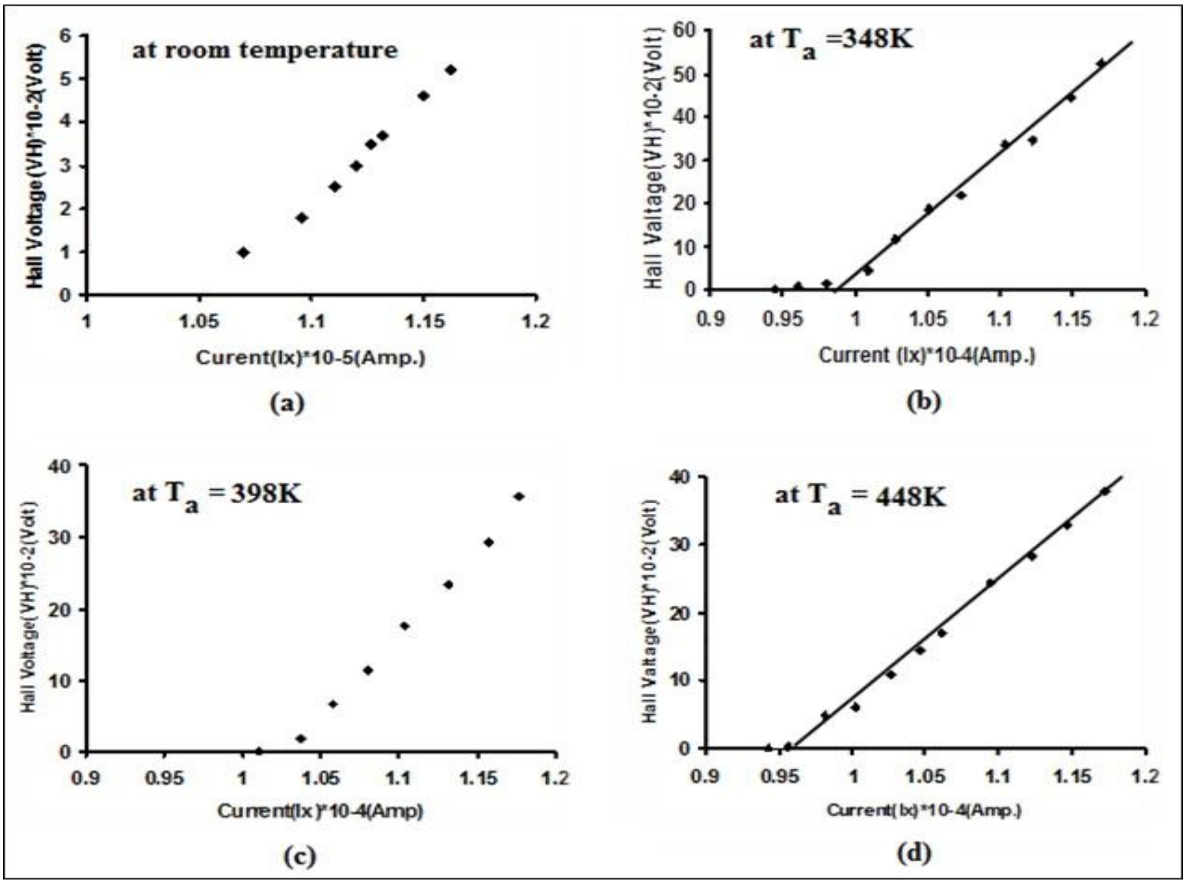
hall effect

To find out the type of charge carriers majority and calculate its density and its mobility of films ($As_{0.5}Se_{0.5}$ doped with Te at 1%) has been used Hall measurements technique as shown in Fig. (4) after placing the films perpendicular to the magnetic field (B_z) when changing the current (I_X) through the films recorded change in Hall voltage (V_H) when calculation the straight mail graphs of the relationship between that shape (I_X) and (V_H) the Hall coefficient was found (R_H), it was found that the relationship between (I_X) and (V_H) was positive, i.e. the films ($As_{0.5}Se_{0.5}$ doped with 1%Te) deposited at room temperature and annealed at (T_a = 348,398 and 448)K is the kind of (p-type), this result is consistent with (*Mahan and Bube*)[9]and (*Khan and Adler*)[11], (*C. Chen*)[13].



Figure(4):Show the Hall measurements circle.

Fig. (5) depicts the results of Hall effect for a prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with 1%Te) the positive relationship between (I_X) and (V_H), attributed to the Hall field generated as a result of charge carriers move from side to side in the films work to increase the movement of charge majority of holes that occur as a result of a linear increase with hanging on both sides of the semiconductor area increase. The Hall coefficient was calculated from the equation ($R_H = \frac{V_H}{I_x}\frac{t}{B_Z}$), and from the equation ($R_H = \frac{1}{pe}$) the carrier concentration was calculated, to calculate the Hall mobility was used the equation (μ_H) by ($\mu_H = \sigma_0|R_H|$).



Figure(5): Variation of (I_X) and (V_H) for a prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with 1%Te) with different annealing temperature.

Table (2) depicts values of (R_H), the carriers concentration (P) and (μ_H) for a prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with Te at 1%), from this table except note that annealing process did not effect on the type of charge carriers but they effect on decrease the values of (R_H) and thus an increase in the concentration of holes after annealing, this result matches with finding of research (*Sabah and Rasheed*) [14], the explanation for that is that annealing temperature increasing the localized states within the energy gap that lead to decrease in the optical energy gap (E_g^{opt}) and increase the charge carrier concentration, While the Hall mobility (μ_H) decrease with increase annealing temperature ($T_a = 348,398,448$) K of ($As_{0.5}Se_{0.5}$ doped with Te at 1%) film according to ($\mu \propto T^{-\frac{3}{2}}$)[7].

Table (2) the R_H , P and μ_H of ($As_{0.5}Se_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$As_{0.5}Se_{0.5}Te_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
$R_H(cm^3.Col^{-1})$	$1.42x10^4$	$1.07x10^4$	$9.33x10^3$	$7.29x10^3$
$P(cm)^{-3}$	$4.38x10^{14}$	$5.84x10^{14}$	$6.69x10^{14}$	$8.56x10^{14}$
$\mu_H(cm^2.V^{-1}.s^{-1})$	0.209	0.166	0.158	0.145

thermoelectric power

To find out the type of majority charge carriers of films (As0.5Se0.5 doped with Te at 1%) has been used Seebeck effect. Fig. (6) shows the relationship between Seebeck coefficient (S) and inverted temperature ($\frac{1000}{T}$) for a prepared and annealed films of (As0.5Se0.5 doped with Te at 1%) with different annealing temperature ($\frac{1000}{T}$) K, it has been observed the Seebeck coefficient is positive i.e. the conductivity is the kind of p-type, this result is consistent with (Bhuiyan and AlAzad)[8], (Hurst and Davis) [15]and (Vanderplas and Bube)[16] the activation energy for thermoelectric power ($\mathbf{E_S}$) was measured from calculate the tendency between Seebeck coefficient (S) and inverted temperature ($\frac{1000}{T}$) multiplied by electron charge, it has been observed that ($\mathbf{E_S}$) decrease with increase annealing temperature while the hopping activation energy (ω1) was calculated from (Ea2-ES) as shown in Table (3).

Table (3) the E_{a2}, E_s and ω_1 of ($As_{0.5}Se_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$As_{0.5}Se_{0.5}Te_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
E_{a2}(eV)	0.430	0.369	0.313	0.273
E_s (eV)	0.133	0.1	0.091	0.085
$\omega_1=E_{a2}-E_S$(eV)	0.297	0.269	0.222	0.188

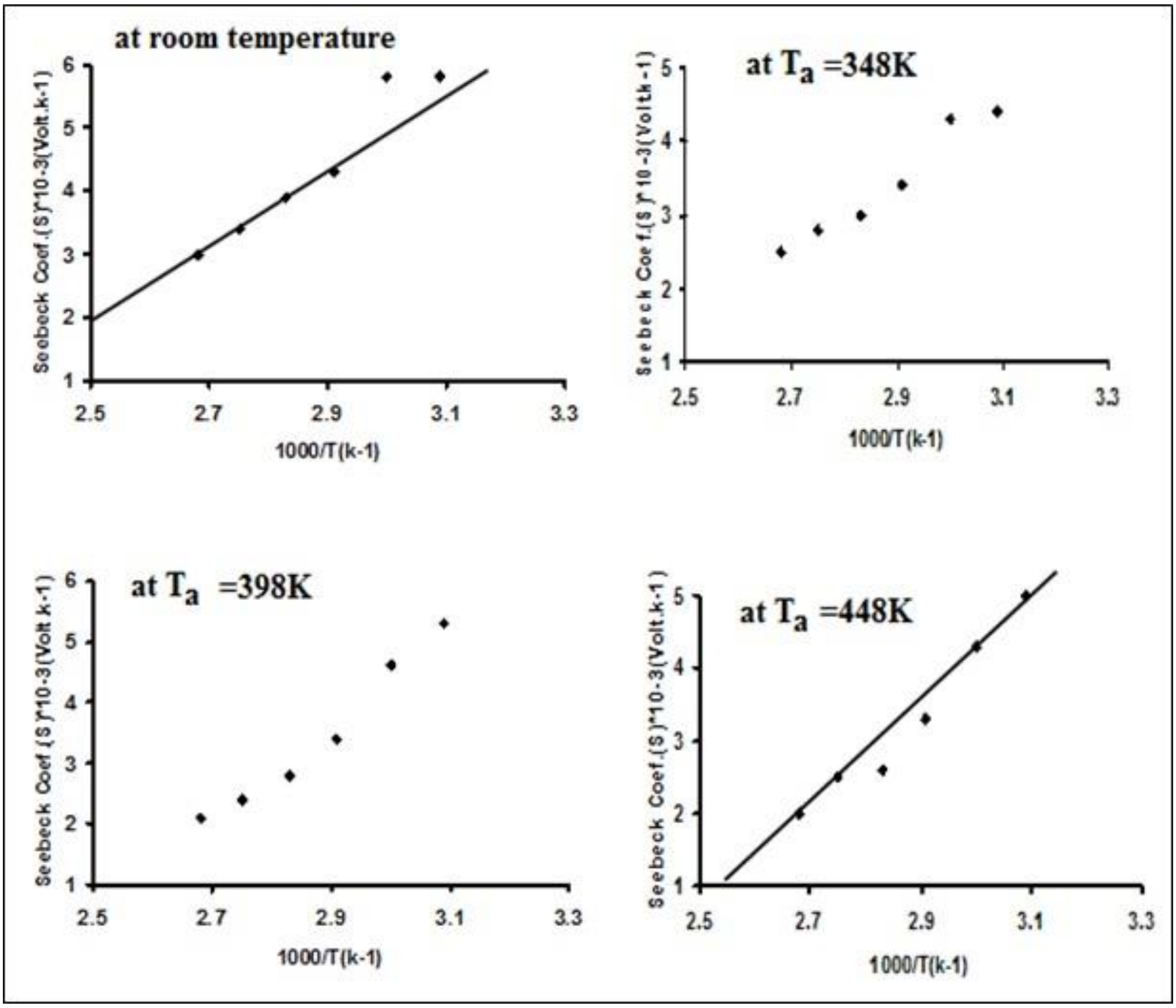


Figure (6):Variation of (S) and ($\frac{1000}{T}$) for a prepared and annealed films of ($As_{0.5}Se_{0.5}$ doped with 1%Te) with different annealing temperature.

Conclusions

We have prepared amorphous thin films of (As0.5Se0.5 doped with 1%Te) by thermal evaporation technique on glass substrates and effect of thermal annealing is interpreted on this film; it has been observed that increase d.c electrical conductivity with increasing annealing temperature and appears two values of activation energies that decrease with increase annealing temperature. Hall and Seebeck effects have also been studied for prepared and annealed films. It has been observed that holes were the majority of charge carriers for these films and observed that increasing of annealing temperature due to decrease both of Hall coefficient and mobility while increase on charge carriers. The difference between activation energies of electrical conductivity and thermoelectric power have been studied and showed that decrease with increase annealing temperature. (As0.5Se0.5 doped with Te at 1%) thin films provide a promising alternative for solar cell.

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