INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

EFFECT OF THICKNESS FOR ($Bi_xSb_{2-x}Te_3$) THIN FILMS ON THE ELECTRICAL PROPERTIES

Hussain. M. Selman and Salma. M. Shaban
University of Baghdad, College of Science, Dept. of Physics

ABSTRACT
In this study ($Bi_xSb_{2-x}Te_3$) alloys with different values of percentage of (Bi) (x=0, 0.1, 0.3, 0.5 and 2) and different thickness have been prepared. Thin films of these alloys are prepared using thermal evaporation technique under vacuum of (1×10^{-5}) torr on glass substrates, at R.T. The D.C measurements showed that there are two stages of activation energy (E_{a1}) and (E_{a2}), hence two conducting mechanisms for thin films under study, in the temperature range, (Ea_1) occurs within range (298-373)K were as (Ea_2) within range (373-433) K. We found the values of activation energy E_{a1} and Ea_2 increase with increase the Bi percentage and decrease with increase the thickness. The hall measurements show that all thin films have p-type conductivity and The carrier concentrations n_H decrease with increasing of and mobility μ_H while the mobility μ_H decreases with increasing Bi percentage for different thickness.

KEYWORDS: Activation energy, thin films, thermal evaporation, mobility.

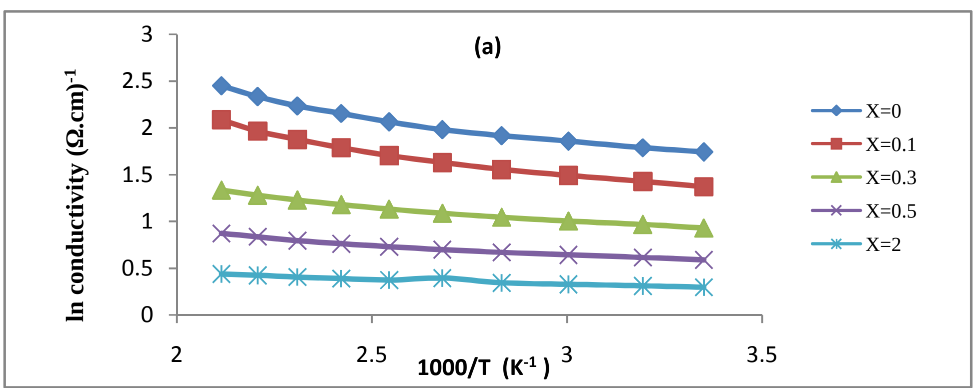
INTRODUCTION
In this research the purpose of measurement electrical properties of semiconductor thin films is to permit identifying impurities of the materials and energy levels. Electrical properties depend on the nature of semiconductors, if they are pure or doped and crystalline or amorphous. These factors have very importance to use in many electronic and photovoltaic applications. we can be defined the electrical conductivity (σ) as a relative factor between current density (J) and the electric field (E), can be found from ; $J=\sigma E$ ohm'law[1], where; $\sigma= n_H q\mu$, $\sigma=nq^2\tau/m*$ where (μ) is the mobility, (τ)is the relaxation time of carrier's, n_H is the carrier's concentration, (m*) is the effective mass of the carrier ,(q) is the electron charge. The relation between the current density and electric field in semiconductors is $J=q(n\mu_n+p\mu_p)E$, Where (n & p) are the electron and hole concentration and (μ_n & μ_p) are the mobility of electron and hole. The drift velocity is given by ($V_d=-\mu_nE$) for electrons and ($V_d=\mu_pE$) for holes. Then the relation between the conductivity and electron concentration –hole concentration is: $\sigma = q(n\mu_n+p\mu_p)$ Practically, the material will be either n-type or p-type, and then equation will be: $\sigma n = q(n\mu_n)$ for n-type $\sigma_p = q(p\mu_p)$ for p-type. The following equation gives the electrical conductivity changing with temperature for most semiconductor cases: ($\sigma= \sigma_\circ \exp(\frac{-E_a}{K_B T})$ Where:
($\sigma_\circ$) is the minimum electrical conductivity at (0)K, (E_a) is the activation energy which corresponds to ($E_g/2$) for intrinsic conduction, (T) is the temperature and (k_B) is the Boltzmann's constant [2].
In (1879) The scientist "Hall"discovered this method, Hall Effect is the direct measurements to infers the charge carrier's quality (electrons or holes) and to measure the concentration and mobility in semiconducting materials and the difference in the current distribution in the metal slice by a magnetic field. This technique is based on the practical found at ions that a magnetic field is applied in the direction of Z axis (B_z), perpendicular to the electric current passing in the x-axis (I_x), this current deflect derailed the original impact of the Lorentz force (F_L) as resulting from the effect of the magnetic field that is given in eq; $F_L=eV_xB_z$ where (V_x) is drift Speed of charge carriers[3,4].
We can determined Hall's coefficient (R_H) by measuring the Hall voltage (V_H) that generates the Hall field across the thickness sample (t) which given by the equation[4]: ($R_H= \frac{V_H}{I} * (\frac{t}{B})$), the "Lorentz" force leads to the negative charge carriers (electrons) collating in view of the semiconductor that collated positive charge carriers on the other side because of the fewness of the electrons number which leads to the potential difference between the semiconductor edges and the effort appearing difference. Charge carriers are collected at the semiconductor edges and continue until it reaches to an equilibrium state. Then force generated by Hall which is equal to the Lorentz force (F_L), ($F_L=F_H$), $eV_xB_z = e(E_H)_y$, $(E_H) = B_zV_x$. In case of hole a current density (Jp) as resulting from the holes movement, the following equation be ($J_p = epv_x$) Substitute of (V_x) we can be got: ($(E_H)_y = (\frac{1}{ep})J_PB_z$).We can be noticed from the above eq. that the Hall's fields directly proportional to current density multiplied by the magnetic field, and the proportionality constant (1/ep) is defined by Hall factor that is symbolize by the (R_H) for the semiconductor positive (p-type) and For the negative semiconductor (n-type)[59]. The Hall's coefficient should be (-1/ne). The charge carriers' concentration can be presented as the following: ($p_H = \frac{1}{R_H}.ep$>>n); ($n_H = -\frac{1}{R_H}.en$>>p) ;Hall mobility (μ_h), can be calculated from the relation, ($\mu_H = \sigma|R_H|$) [3] .

EXPERIMENTAL

This research includes an explanation of the preparation method of ($Bi_x Sb_{2-x} Te_3$) alloys with x= (0, 0.1, 0.3, 0.5, 2), and thin films, the mechanism of measurement to the structural and electrical properties with nearby electric circuits which is used in this measurement. In the beginning raw materials are obtained as powder to prepare the alloys, these raw materials are (Bi with purity 99.9%, Sb purity 99.96% and Te purity 99.999%) powders. Alloys have been prepared from these raw materials in the magnitude which is mentioned above, by melting them in the quartz ampoules under vacuum with pressure about (10^{-3}) Torr. By using thermal evaporation method Thin films are prepared, the vaporized material is deposited on the glass substrate to investigate the electrical properties (Hall Effect and D.C.) at room temperature[8]. Electrical measurements have been used to examine the prepared thin films on a glass substrate at room temperture with aluminum electrodes. We will study Hall Effectiveness and (D.C) conductivity for ($Bi_xSb_{2-x}Te_3$). The chemical compounds (Bismuth Telluride antimony) can be considered the best thermoelectric material which can be used in applications and devices working at room temperature. The electrical conductivity has been measured as a function of temperature for $Bi_xSb_{2-x}Te_3$; therefore the relation between the ohmic resistance and temperature (room temperature to 280ºC) will be studied. This measurement will also be described as the electrical efficiency to prepared thin film with the temperature's increasing. By using sensitive digital electrometer type keithley device (616) and electrical oven the measurements have been finished. The resistivity (ρ) of the films is measure by using the equation [5]; ($\rho = R.\frac{A}{l}$) Where (R) is the sample resistance (A): is the cross section area of the films, (l) is the distance between the electrodes. The films conductivity (σ) was determined from the relation: $\left(\sigma = \frac{1}{\rho}\right)$, The activation energies could be found from the plot of lnσ versus (1000/T) according to this equation: ($\sigma = \sigma_\circ \exp\left(\frac{-E_a}{K_B T}\right)$). Where is ($\sigma_\circ$) the minimum electrical conductivity at (0)K. Hall effect was carried by using (HMS-3000 Hall Measurement System) to measure the current and voltage. When the magnetic field (B=0.55 Tesla) is applied perpendicular to the applied electrical field, a transverse Electric motive force (e.m.f.) that is called Hall voltage (V_H) is set up across the sample, so the Hall coefficients can be obtained by using Eq., ($R_H = \frac{V_H}{I} * \left(\frac{t}{B}\right)$) The signs of hall coefficient can show the charge carrier type. The carrier concentration (n_H) can be calculated by using the equation ($p_H = \frac{1}{R_H}.ep$>>n); ($n_H = -\frac{1}{R_H}.en$>>p), Hall mobility (μ_H) could be calculated from the conductivity product and the Hall coefficient according to equation; , ($\mu_H = \sigma|R_H|$).

RESULTS & DISCUSSION

The electrical properties of ($Bi_2 Sb_{2-x} Te_3$) thin films which is deposited on the glass substrate at room temperature for different composition of X (0, 0.1, 0.3, 0.5, and 2) as well as different thickness, will be prepared. These properties involve the D.C. conductivity from which the conduction mechanism of the charge carries can be estimated and also the hall measurement which give the information regarding to the type of conductivity, density and mobility of carriers. Temperature dependence of the electrical conductivity has been used to get the information about the nature of transport mechanisms of the ($Bi_2 Sb_{2-x} Te_3$) thin films in within the range (298 K-473K),we calculated the activation energies to ($Bi_2 Sb_{2-x} Te_3$) thin films by using the equation ($\sigma = \sigma_\circ \exp\left(\frac{-E_a}{K_B T}\right)$). We observed that (lnσ) decreased with increasing of (1000/T), as shown in figure (1). we found two conductivity stages within the heating temperature range which indicating there are two conduction mechanism, in such case the first activation energy (Ea_1) happens at low temperature within the range (298-373) K is attributed to carriers transport to localized situations near the valence and conduction bands ,while the second activation energy (Ea_2) at higher temperature (383-433)K, it is attributed to transport of the carrier excited into the conduction band. These two transports mechanism explains that the D.C. conductivity is non-linear with temperature variation, in figure (1)[6 ,9]. The activation energies values (E_{a1}) and (E_{a2}) increase when (x) increases from (0 to 2) and decrease when increase the thickness. we can be concludes that the increasing in the percentage of (x) leads to increasing in the activation energies which in turn leads to satiate the appertaining bonds, it can be said that there is elevation in the density of state occurs at "Fermi" level, which caused conversion from conductivity near "Fermi"level to the thermal activation conductivity at band gap [6].



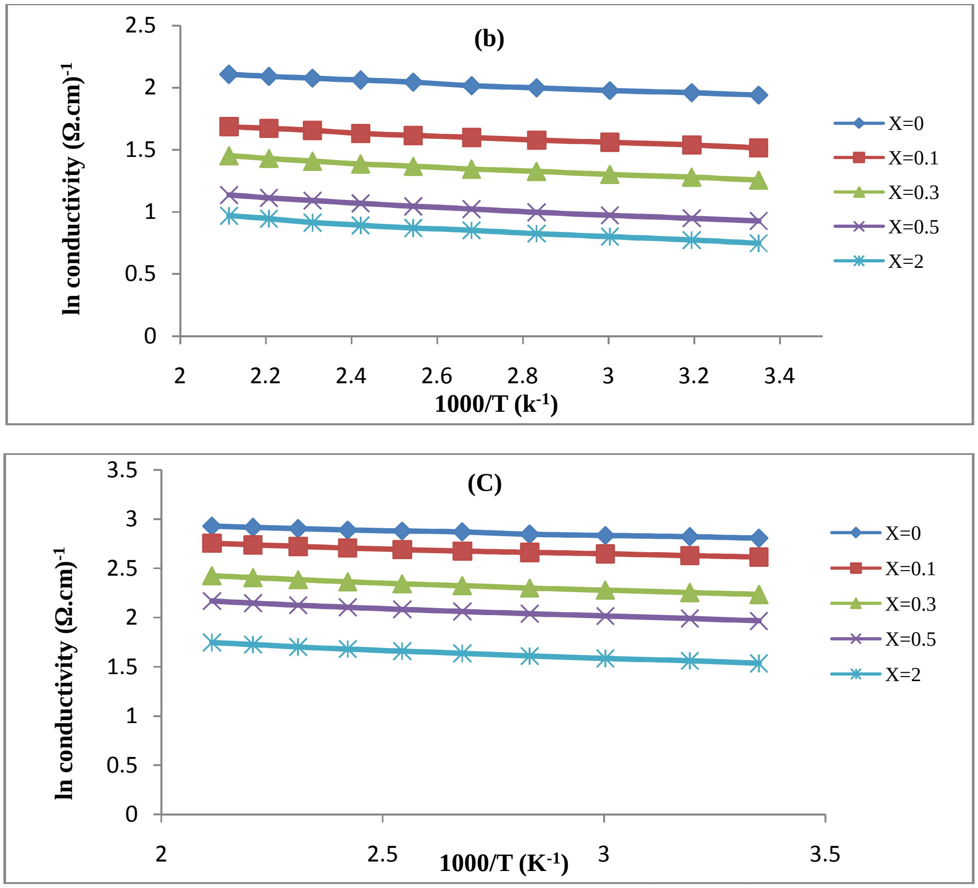
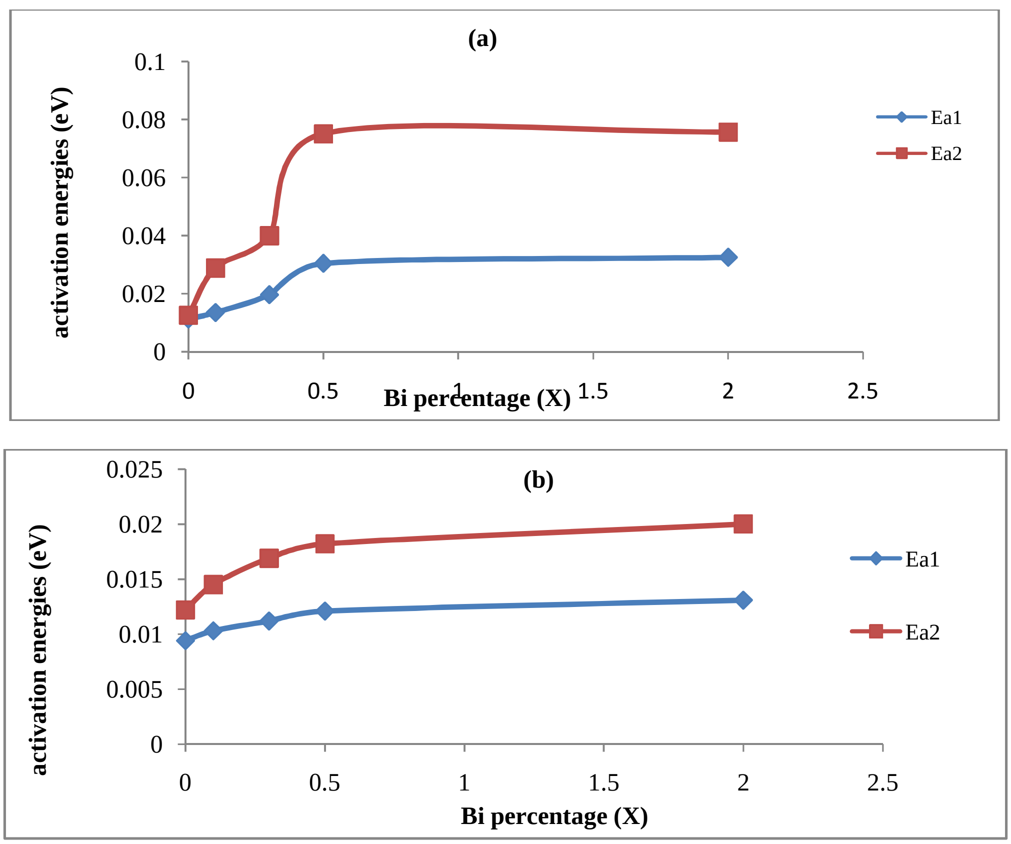


FIGURE 1 : The nature logarithm of electrical conductivity as a function of 1000/T for($Bi_xSb_{2-x}Te_3$) thin films for : a-(100nm) ,b-(300nm), and c-(500nm)



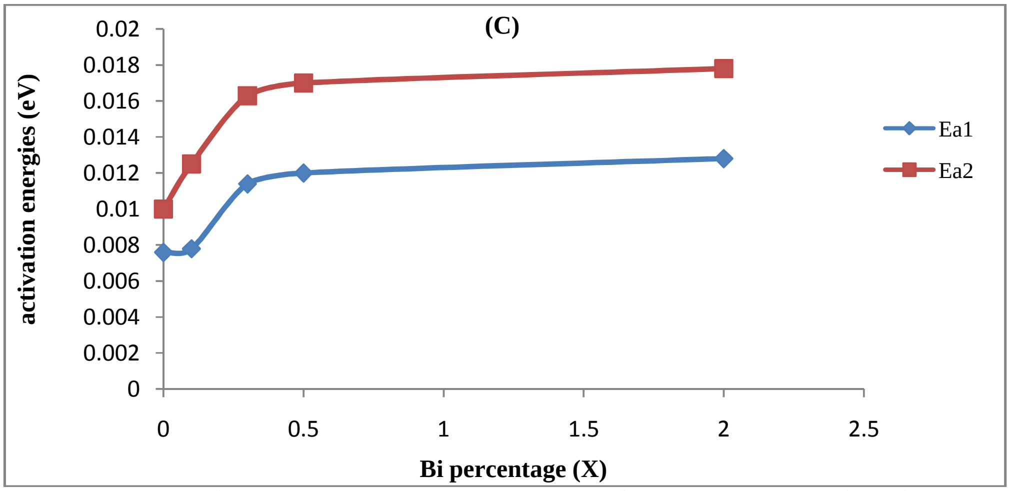
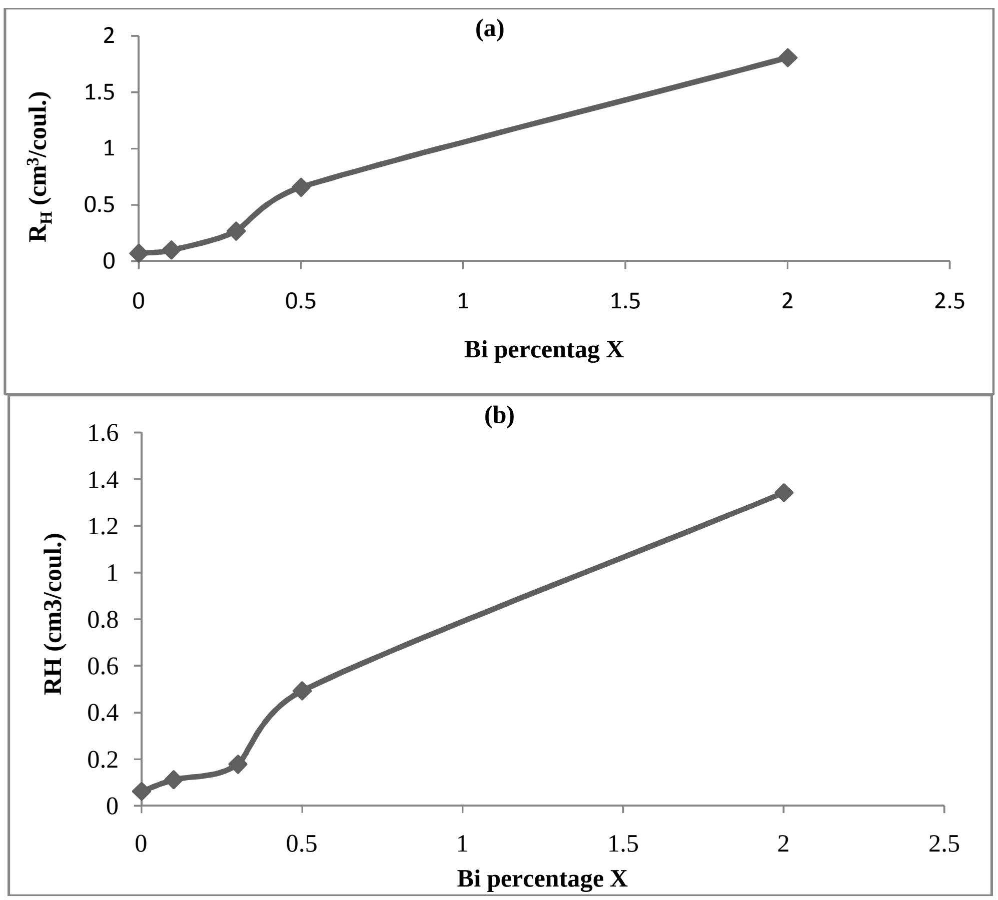


FIGURE 2: The variation of activation energies with Bi percentage for ($Bi_xSb_{2-x}Te_3$) thin films for: a-(100nm) ,b-(300nm), and c-(500nm)

The Hall measurements invloves Hall coefficient, Hall mobility carrier concentration and type of the conductivity. The results show that the thin films have p-type conductivity in Figure (2), show that the hall coefficient of ($Bi_x Sb_{2-x} Te_3$) thin films as a function of (Bi) percentage which appoints that hall coefficient increases with increasing of (Bi) percentage for different thickness (100nm, 300nm and 500nm)[8].The carrier concentrations n_H decrease with increasing of (Bi) percentage for different thickness (100, 300 and 500) nm as shown in figure (3). The carrier mobility (μ_H) increases with increasing of (Bi)[8]. Percentage for different thickness (100nm, 300nm, and 500nm) as shown in figure (4), it can be see that All these results are listed in Table (1).



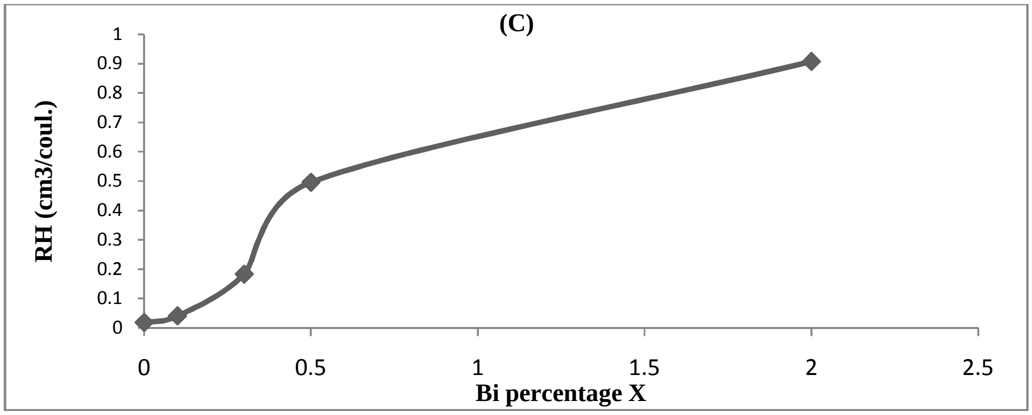


FIGURE 3: The relation between Hall coefficient R_H as a function of (Bi) percentage(X) of **($Bi_2Sb_{2-x}Te_3$)** thin films for the : a-(100nm),b-(300nm), and c- (500nm).

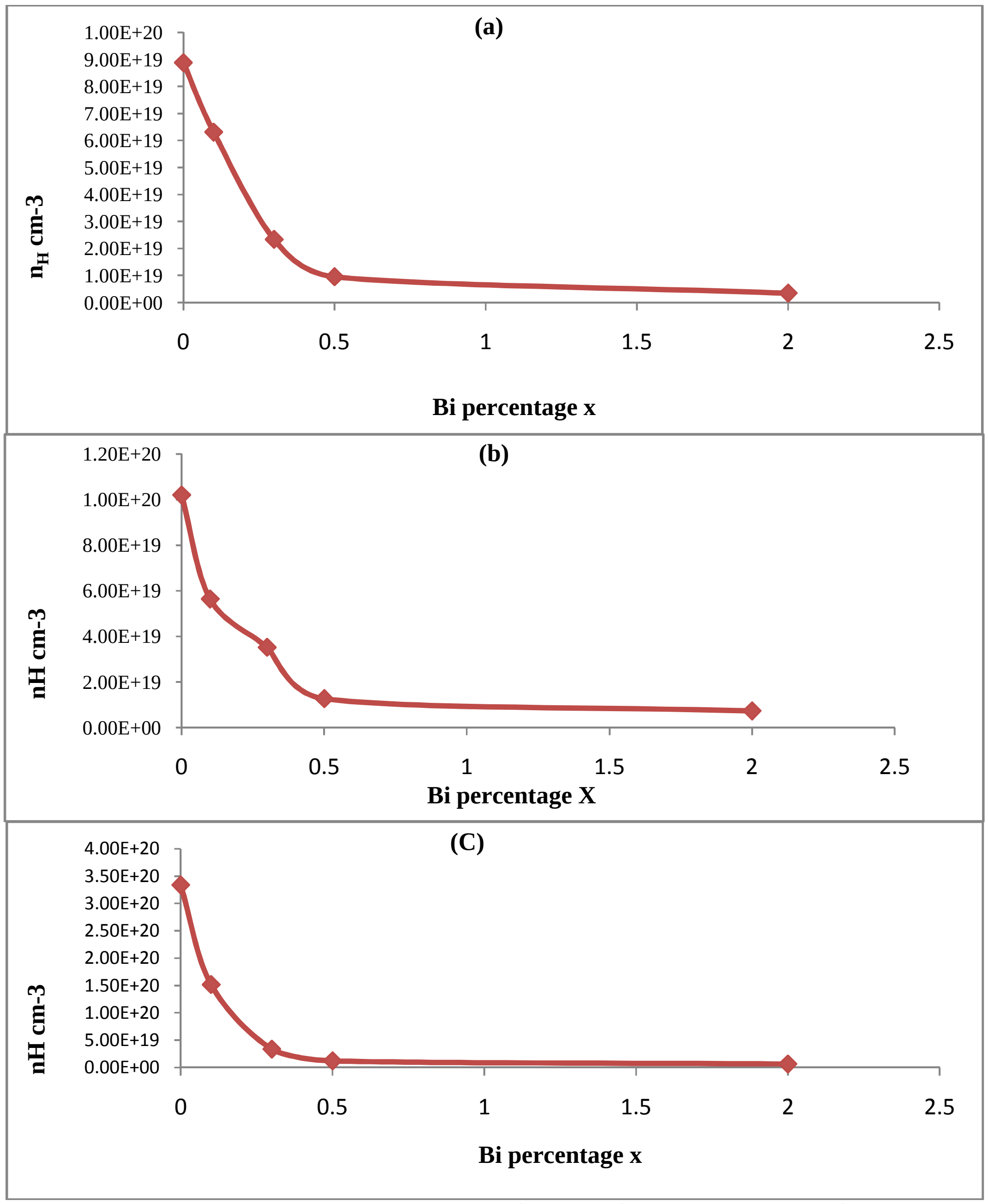


FIGURE 4: the relation between carrier concentration n_H as a function of (Bi) percentage(X) of **($Bi_2Sb_{2-x}Te_3$)** thin films for the : a-(100nm),b-(300nm), and c- (500nm).

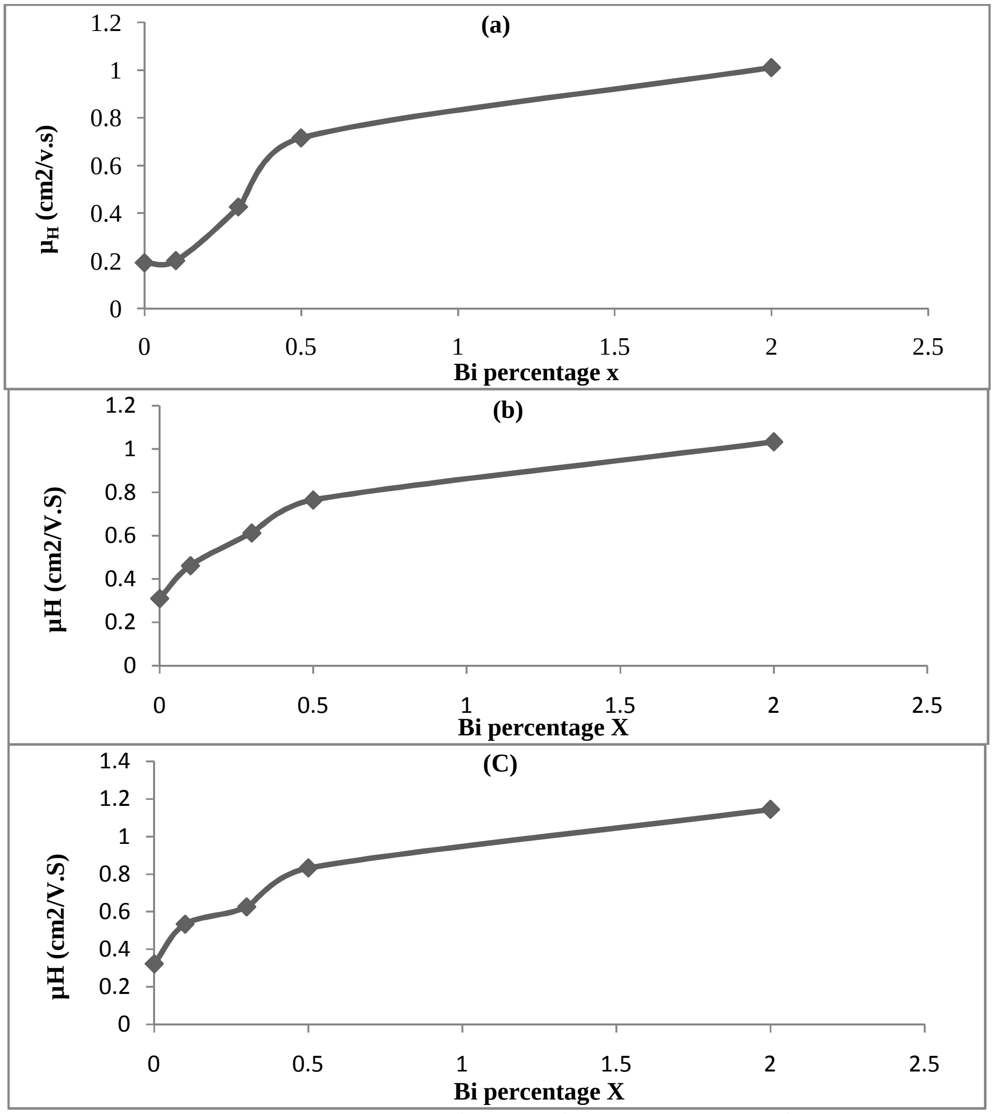


FIGURE 5: The relation between hall mobility (μ_H) as a function of (Bi) percentage(X) of **($Bi_2 Sb_{2-x} Te_3$)** thin films for the : a-(100nm),b-(300nm), and c- (500nm).

TABLE 1: Carrier concentration (n_H) ,Hall coefficient (R_H), Hall mobility(μ_H) of $Bi_xSb_{x-2}Te_3$ for different compositions (X=0, 0.1, 0.3, 0.5, and 2) and different thickness.

thickness t(nm)	X Percentage of (Bi)	Electrical conductivity (σ)at R.T. $(\Omega.cm)^{-1}$	Carrier concentration n_H (cm^{-3})	Hallcoefficient R_H $(cm^3/coul.)$	Hallmobility μ_H $(cm^3/v.s)$
100	0	2.727	$8.88*10^{19}$	0.0703	0.192
	0.1	2.029	$6.31*10^{19}$	0.0990	0.201
	0.3	1.594	$2.34*10^{19}$	0.2670	0.426
	0.5	1.091	$9.53*10^{18}$	0.6558	0.716
	2	0.559	$3.46*10^{18}$	1.806	1.011
300	0	5.075	$1.02*10^{20}$	0.0612	0.311
	0.1	4.169	$5.64*10^{19}$	0.1108	0.462
	0.3	3.452	$3.52*10^{19}$	0.1775	0.613
	0.5	1.676	$1.27*10^{19}$	0.4921	0.765
	2	1.214	$7.35*10^{18}$	1.342	1.033
500	0	17.207	$3.34*10^{20}$	0.0187	0.322
	0.1	12.962	$1.52*10^{20}$	0.0411	0.533
	0.3	3.410	$3.41*10^{19}$	0.1832	0.625
	0.5	1.677	$1.26*10^{19}$	0.4960	0.832
	2	1.261	$6.89*10^{18}$	0.9071	1.144

CONCLUSION

From the study of electrical properties for ($Bi_2Sb_{2-x}Te_3$) thin films with different (Bi) percentage (0, 0.1, 0.3, 0.5, and 2) and different thickness (100nm, 300nm, and 500 nm) which deposited by thermal evaporation technique at R.T.

1- All the thin films have a p- type conductivity as the Hall effect results for all thickness.

2- The electrical conductivity for all thin films have behavior of the semiconductors as the relation between the electrical conductivity (σ) as a function of (1000/T), we studied the effect of the (Bi) percentage on the electrical conductivity, for different thickness and we found that the electrical conductivity increasing with increasing the (Bi) percentage, also we found there are two activation energies E_{a1} and E_{a2}, which they are increasing with increasing of the (Bi) percentage.

3- The carrier concentration decreases with increasing the (Bi) percentage, but the Hall coefficient and Hall mobility increases with increasing the (Bi) percentage.

REFERENCES

[1]. Busch, G. and Schade, H. (1976) Lectures on Solid State Physics", Pergamon press London

[2]. Shahane, G.S. and Deshmukh, L.P. (2001) Mater. Chem. Phys., Vol. 70, No.12.574-581.

[3]. Islam, A., Islam M., Choudhury, M. and Hossan M. (1998)"Recent Development in Condenced Matter Physics and Nuclear Science", Rajshahi University, Bangladesh.

[4]. Edwin Hall (1879) "On a New Action of the Magnet on Electric Currents". *American Journal of Mathematics* Vol. 2: pp287–92. Retrieved on (2008).

[5]. Piprek, J. (2003) Semiconductor optoelectronic devices" Academic press.

[6]. Kavei, G and Karami, M.A. (2006) Bull. Mater. Sci., Vol. 29, No.7.

[7]. Jun Jiang, Lidong Chen, Qin Yao and Qun Wang**,** Materials Transactions, Vol. 46, No.5 (2005).959-962.

[8]. Junqiang Song, Qin Yao, Ting Wu, Xun Shi, and Lidong Chen, Laboratory of Materials for Energy Conversion, Shanghai Institute of Ceramics, Chinese Academy of Sciences, 1295 Dingxi Road, Shanghai 200050, P. R. China (2013).

[9]. Joy Kumar Das and M.A.I. Nahid (2014). Int. J. Thin. Fil. Sci. Tec. 4, No. 1, 13-16 (2015).