

Improvement Of Electrical Transport For PbTe Thin Films by Thermal Treatment

Najwa Jassim Jubier - University of Wassit - College of Science

تحسين الانتقالات الكهربائية لأغشية PbTe الرقيقة بواسطة المعالجة الحرارية

نجوى جاسم جبير - جامعة واسط / كلية العلوم / قسم الفيزياء

الخلاصة

تضمن البحث دراسة الخصائص الكهربائية لأغشية PbTe الرقيقة المحضرة بتقنية التبخير الحراري. لوحظ تحسن الخصائص الكهربائية لهذه الأغشية مع زيادة درجة حرارة التلدين. ولوحظت زيادة التوصيلية الكهربائية وحركية الحاملات مع درجة الحرارة لمدى محدود. وهذا يثبت تحسن الانتقالات الكهربائية لهذا المركب. وقد وجد أيضا "نقصان تركيز الحاملات مع ارتفاع درجة المعاملة الحرارية ووجد نقصان الحركية وازدياد تركيز الحاملات بعد ذلك.

كلمات مفتاحية : غشاء تولورايد الرصاص PbTe، الخصائص الكهربائية، حركية الحاملات

Synopsis

This research deals with electrical characteristics of the PbTe thin films that were prepared by thermal evaporation technique. It was noted that the electrical characteristics of these films improved with the increase in annealing temperature. It was also noted that the electrical conductivity and carrier's mobility increased with temperature to a limited extent. This proves the improvement of the electrical transport of this compound. It was also found that the concentration of carriers decreased when treated thermally with a high degrees and mobility decreased while the concentration of carriers increased after that.

Key words: PbTe Thin film, Electrical properties, Carrier mobility

Introduction

Among the II-IV compounds, the lead chalcogenides with narrow energy gap have been extensively studied due to their device applications in many fields like IR detectors, photoconductors, thin film transistor etc. [1-2]. The lead chalcogenides exhibit very interesting photoelectric, photoconducting, thermoelectric, optical and semiconducting properties. Many workers have been reported on the transport properties of these chalcogenides in the bulk state but very little is known about their properties in the thin film state. The electrical properties of these compounds have been studied by many workers [3, 4, 5]. The surfaces of polycrystalline films of PbTe condensed onto amorphous substrates have been studied by hot wall technique [6], RF magnetron sputtering [7], and thermal evaporation [3, 5, 8]. There has been some work on the thermoelectric power of impurity doped lead telluride films but, very little on pure undoped samples in the thin film form. Barisova has measured the thermoelectric power of bulk PbTe doped with Bi, Sb, Cr and Ag in amounts of 0.1 - 0.5 at %. He found that undoped PbTe was p-type whereas those doped with Bi, Sb and Cr was n-type. The room temperature value of thermoelectric power for undoped PbTe bulk was quoted [9] as around 30mV/K. The electrical properties of thallium and silver doped PbTe films were also reported [10, 11]. Thus it is seen that there has been very little study on transport properties of undoped PbTe films. The present work on the resistivity, carrier concentration, carrier mobility, thermoelectric power and structural information of PbTe films have been studied and an attempt is made to explain the charge transport on the basis of scattering mechanism.

Experimental procedure

In order to produce high quality of PbTe thin films by evaporation in vacuum, the glass substrates were carefully cleaned using distilled water and isopropyl alcohol sequentially. A molybdenum boat was charged with PbTe in granular form, of purity 99.99% were prepared from mixing two elements Pb and Te (in 1:1 atomic ratio) supplied from Koch-Light Laboratories Ltd (England). The vacuum chamber was pumped down to 10^{-5} Torr. The boat was gradually heated until the material started to evaporate. The vapor molecules leaving the source were deposited onto the substrate surface. The substrate temperature was held at room temperature during the deposition process. The film was electroded by Aluminum of distance separation 0.4cm. Electrical

measurements were performed under normal atmosphere. For the current measurements, the d.c. bias voltage was provided by power supply and the current was recorded by digital KEITHLEY 610. For the measurements of resistivity of the PbTe thin film, the voltage across the sample was monitored by digital voltmeter. Sample temperature was monitored using the thermocouple of accuracy $\pm 1^\circ\text{C}$ attached to the films substrate. The thickness of deposited on films was determined using a quartz crystal monitor the thickness was 1500 \AA at various annealing temperature. The thicknesses of the films have been controlled using quartz crystal thickness monitor during film deposition and are crosschecked using. Film thicknesses found correct within $\pm 50 \text{ \AA}$. The resistivities of film samples have been measured as a function of temperature which can be determined from the relation

$$\rho = R \frac{w \cdot t}{l}$$

Where

(w) is the width of the contact .

(t) is the thickness of the film.

(l) is the space between the two contacts.

The two conductivity of the film can be estimated by the reciprocal of the resistivity with

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

$\ln \sigma$ was plotted as a function of $1000 / T$ to calculate the activation energy(E_a) by using the equation

$$\sigma = \sigma_0 \exp(-E_a / K_B T)$$

Where

(σ_0) is constant ,represent the metallic conductivity .

(K_B) is Boltzmann constant

Form the Hall coefficient (R_H) of the film and the resistivity at room temperature (σ_{d-c}) we can get the carrier concentrations (n) and carrier mobility (μ_H) by using these relation

$$R_H = \frac{1}{ne}$$

$$\mu_H = R_H \sigma_{d-c}$$

Results and discussion

Fig (1) represents natural logarithm of conductivity against $1000/T$. These graphs indicate that all the film samples have negative temperature coefficients of resistivity, which suggested their semiconducting nature. These graphs show linear variation in the temperature range (370-526) K and it has two regions which means the films has two conductivity mechanisms hopping from band to band and enter the bands .From these graphs the activation energy is calculated by taking the slope for linear regain [2].The thermal activation energy E_a has been evaluated and varied from (0.098 to 0.35) eV. This nearly agrees with other works [12]. These results are illustrated in Fig.(2).It was found that the conductivity decreases with increase of annealing temperature from $0.61 (\Omega.m)^{-1}$ at room temperature to $0.35 (\Omega.m)^{-1}$ at 373 K and decreases to $0.21 (\Omega.m)^{-1}$ at 423 K, but at 473 K increases again to $0.30 (\Omega.m)^{-1}$.This behavior may result from decrease of the defects in the stricture[12],but at 473 K it may result from effect of the non bonding Pb in crystal structure and decrease the barrier height between the grains. This agrees with the other results from Hall effects. The Hall Effect was measured for all the films at room temperature .The films were n- type converted to p-type after annealing due to reduction of the density of dangling bonds [7]. Fig (3) illustrates the carrier concentration and mobility. This figures shows increase in the carrier mobility and decrease in the concentration with increase of annealing temperature. The increase of the annealing temperature results in decrease of the electron concentration owing to the more fast decrease of the interstitial Pb atoms concentration than that of the charged lead vacancies and decrease of the defect and density of state near the conduction band, i.e. decrease of the electron collision then the mobility will increase, which decreases the scattering of the carriers [13]. But at 473 K we can see the inverse behavior, which result from effect of non bonding Pb on the surface [7].

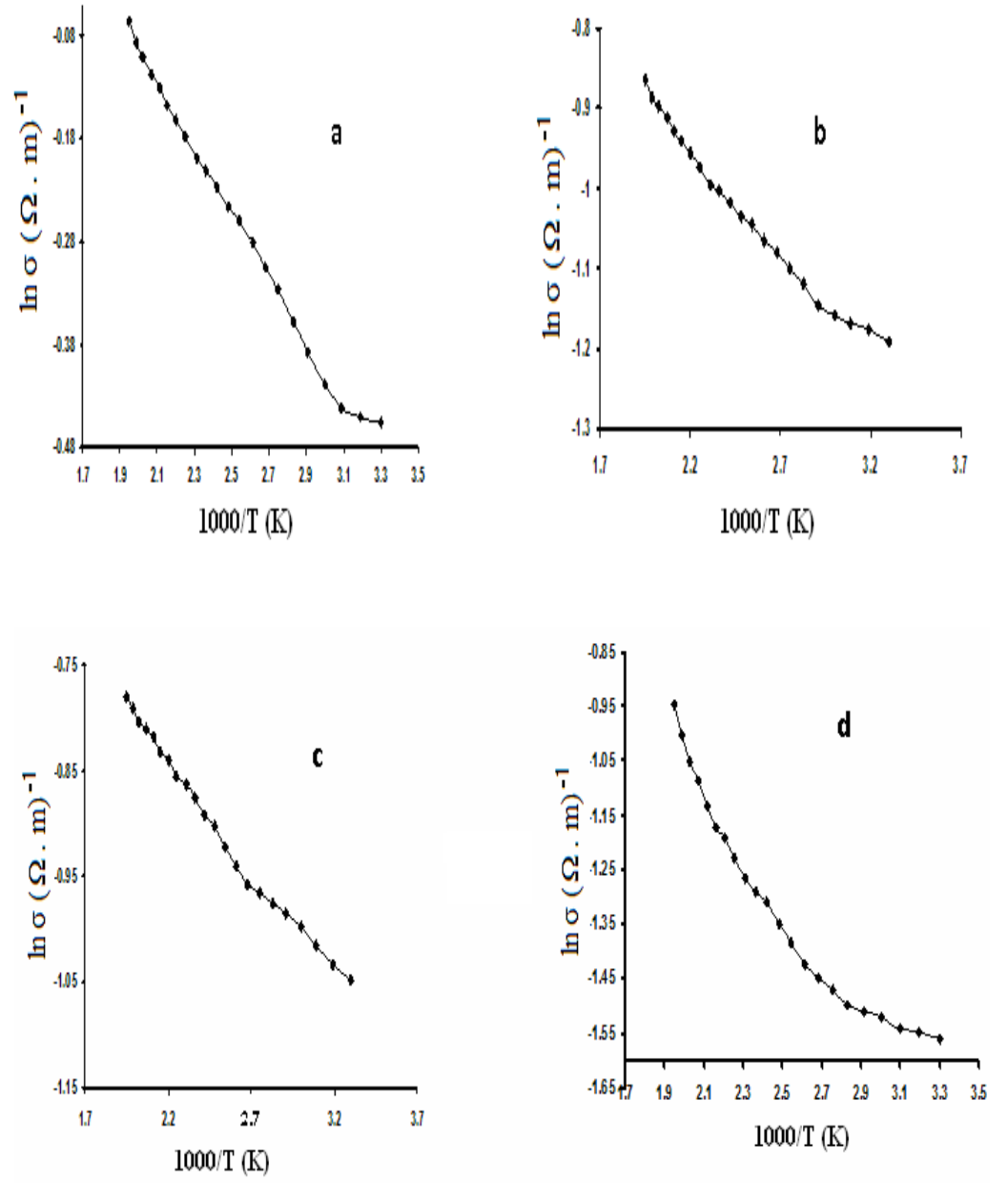


Fig (1) Variation \ln conductivity for PbTe at (a) 373 K, (b) 423 K, (c) 473K, and (d) 523 K with $1000/T$

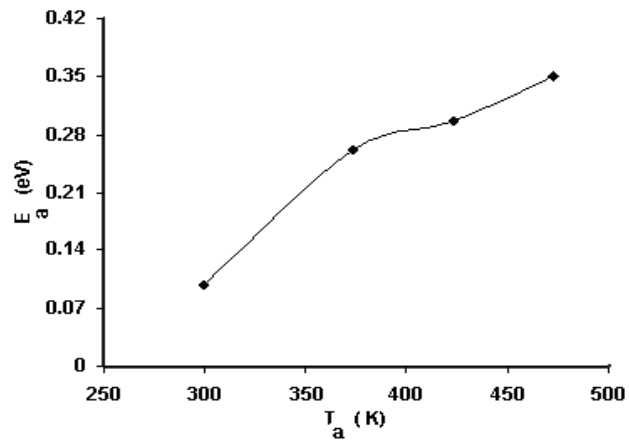


Fig. (2) Variation the activation energy E_a with annealing temperature T_a

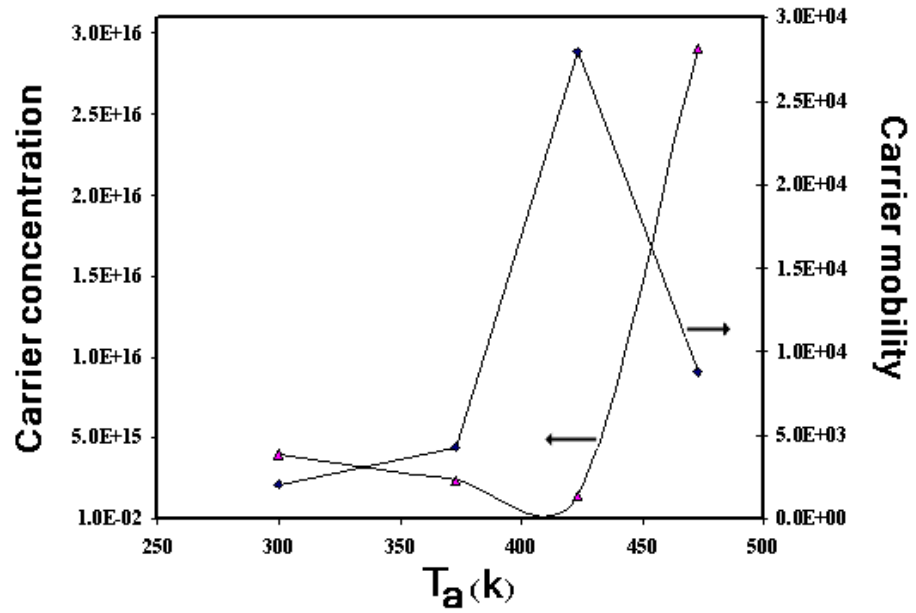


Fig (3) variations the carrier concentration and mobility with annealing temperature

References

- 1- R. W. Vass, and R. M. Andersen, (1974). J. Appl. Phys. 45: pp 3463-3466.
- 2- A.G. Fischer, (1976). Thin Solid Films 36, 2: pp469-474.
- 3- F. S. Terra, G. M. Mahmoud, (1997). J. of Materials Science Letters 8, 43: pp 617-618.
- 4-J.F. Butler, (1964). J Electrochem. Soc. 111: pp 1150 -1154.
- 5-V. Das Damodara and K. Bhat Seetharama, (1983). J. App. Phys. 54: pp 6641-6645
- 6-H. Kinoshita, T. Sakashita, and H. Fujiyasu, (1981). J. Appl. Phys. 52: pp 2869-2871.
- 7-M.I. Abd El-Ati(1997). Physics Department, Faculty of Science, Tanta University, Egypt, 1, 39:pp79-82
- 8-S. J. Boichot, (1978). J. Phy. D: Appl. Phy. 11: pp 2553 -2558.
- 9-L. D. Barisova, (1979). phys. stat. soli A 53: pp K19-K22.
- 10-B. F. Grukinov, I. A. Drabkin Eliseeva, Yu. Ya., (1979). Sov. Phys. Semicond. 13: pp767-772
- 11-A. L. Dawar, S. K. Paradkar, P. Kumar, O. P. Taneja, and P.C. Mathur, (1981). phys. stat. sol. A 68: pp 227-232.
- 12-U. P. Khairnar, P. H. Pawar, G. P. Bhavsar, (2002), Cryst. Res. Technol. 37, 12:pp1293-1302.
- 13-D.M. Freik, V.V. Prokopiv, A.V.Nych , (1997). Materials Science Engineering, B48: pp. 226-228.

Recived (11/5/2008)
Accepted (3/9 /2008)