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The Impact of Annealing Temperature on Electrical Properties of Sb Thin Films

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Abstract

The impact of annealing temperature on the electrical properties of Sbthin films, theSb films were deposited on glass substrates at room temperature thermal evaporation technique with thickness (0.5 μm), all samples are annealed in a vacuum for one hour. The electrical properties of these films were studied with different annealing temperatures,the d.c conductivity for all deposited films decreases from 17.54×10^{-2} to 12.23×10^{-2} $(\Omega.cm)^{-1}$ with increase of annealing temperature form 373K to 473 K. The electrical activation energies E_{a1} and E_{a2}increase from 0.014 to 0.021eV and from 0.026 to 0.033eV with increasing of annealing temperature from 373K to 473K, respectively. Hall measurements showed that all the films are p-type.

Keywords: Electrical Properties ofSb,The d.c conductivity of Sb, Hall measurements of Sb.

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اعتماد الخواص الكهربائية على حرارة التلدين لأغشية الانتيمون

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الخلاصة

في هذا البحث تم دراسة تأثير حرارة التلدين على الخواص الكهربائيــة لأغشية Sb، حضرت أغشية Sb بسمك (0.5)µm بتقنية التبخير الحراري على أرضيات زجاجية بدرجة حرارة الغرفـة. لدنت هذه الأغشية بدرجات حرارة تلدين مختلفة لمدة ساعة. درست الخصائص الكهربائيــة للأغشية المحضرة بتغير درجة حرارة التلدين حيث قلّت التوصيلية الكهربائية المستمرة من $(17.54\times10^{-2}\_12.23\times10^{-2})(\Omega.cm)^{-1}$ بزيادة درجة حرارة التلدين من (373–473) K، ازدادت طاقات التنشيط الكهربائية (Ea_1), (Ea_2) من (0.014-0.021)eV ومن (0.026–0.033)eV بزيادة درجة حرارة التلدين، على التوالي. وقد بينت قياسات هول أن جميع الاغشية هي من النوع القابل.

1- Introduction

Antimony (Sb) is a semimetal. It has been employed in various semiconductor technologies including: infrared detectors, diodes and Hall-effect devices. Antimony has been known since ancient times. It is sometimes found free in nature, but usually obtained from the ores stibnite (Sb_2S_3)and valen-tinite(Sb_2O_3)[1].Despite the high quality film producing using many techniques [2], Thermal evaporation technique has been used in this study. The main reason behind adopting this method is fast and cheap method for producing Sb thin films. The electrical properties of thin films can be characterized by measuring the conductivity and Hall effect. In addition, activation energies obtained from those properties can be temperature dependent. The present work reports the study of electrical properties of Antimony thin films prepared by vacuum evaporation with annealing temperature ranging from room temperature to 473 K.

2- Experimental

Thin films of highly pure (99.999%)Antimony were deposited on glass substrates adopting vacuum evaporation method (Type Blazers Model [BL 510] using molybdenum boat with pressure 10-5 mbar. Electric current was passed through the boat gradually to prevent the boat breaking. The deposition process starts when the boat temperature achieved a desired temperature. All samples were prepared under fixed conditions including pressure substrate, temperature and rate of deposition. The main parameters controlling the nature of film properties are thickness (0.5) μm and annealing temperature (373, and 473) K. To study the electrical propertiesof deposited films,an Ohmic contact for the prepared films are produced by evaporating (Al) electrodes of 0.3 μm thickness. The film thicknesses measured with an

interference microscope. The electrical properties as the dc conductivity and Hall Effect, The electrical resistance has been measured as a function of temperature for Sbfilms in the range (30–160)^{0}C by using the electrical circuit consists digital electrometer of the type Keithley 616 and electrical oven type Herease.

The conductivity of the films was determinedfrom the relation:

$$\sigma_{d.c.} = \frac{1}{\rho} = \frac{L}{R\,A} \quad ....(1)$$

Where R is the sample resistance, A is the cross section area of the film, and L is the distance between the electrodes. The activation energies could be calculated from the plot of Lnσ versus 10^3/Taccording to equation (2):

$$\sigma = \sigma_o \exp(-E_a/k_B T) \ldots (2)$$

where σ_o is the minimum electrical conductivity at 0^oK, E_a is the activation energy, T is the temperature and k_B is the Boltzman's constant[3].

The Hall effect was measured by the electrical circuit which contains D.C. power supply and two digital electrometers (Keithley type 616) to measure the current and voltage with applying a magnetic field (B) (0.257 Tesla) perpendicular to the applied electrical field. Accordingly, the Hall coefficient is given by [4].

$$R_H = \frac{V_H}{I} \cdot \frac{t}{B} \ldots (3)$$

Where (V_H) Hall voltage,(t) is the sample thickness. Carrier's concentration can be determined by using the relation.

$$n_H = \frac{+1}{qR_H} \quad \text{for holes..(4)}$$

Hall mobility (μ_H) could be calculated according to equation [5][6].

$$\mu_H = \sigma\,|R_H| \ldots\ldots..(5)$$

3- Results and Discussion

The D.C. conductivity for Sb films has been studied as a function of 1000/T at RT and annealing temperatures (373 and 473) K and thickness (0.5) μm, as shown in Fig.(1).

The conductivity decreases with increase of annealing temperatures, this may be due to the rearrangement that may occur during annealing, 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.1 that there are two transport mechanisms, giving rise to two activation energies $E_{a1}$and E_{a2}This result is in conformity with Chittick[7]. At higher temperature range (373–433) K, the conduction mechanism is due to carrier excited into the extended states beyond the mobility edge and at lower temperature range (303–363) K; the conduction mechanism is due to carrier excited into localized states at the edge of the bands[8].

Fig(2) shows the effect of annealingtemperature on both activation energies $E_{a1}$and E_{a2} for Sb films, The values of E_{a1} andE_{a2} increase with increasing of annealing temperatures due to the elimination of some defects from the films and the improvement in crystalline during annealing.These result are in agreement with Beyer and Stuke [9], Abd-El Mongy[10].

Table (1) illustrates the values of conductivity and activation energies $E_{a1}$and $E_{a2}$for Sb films at different annealing temperatures.

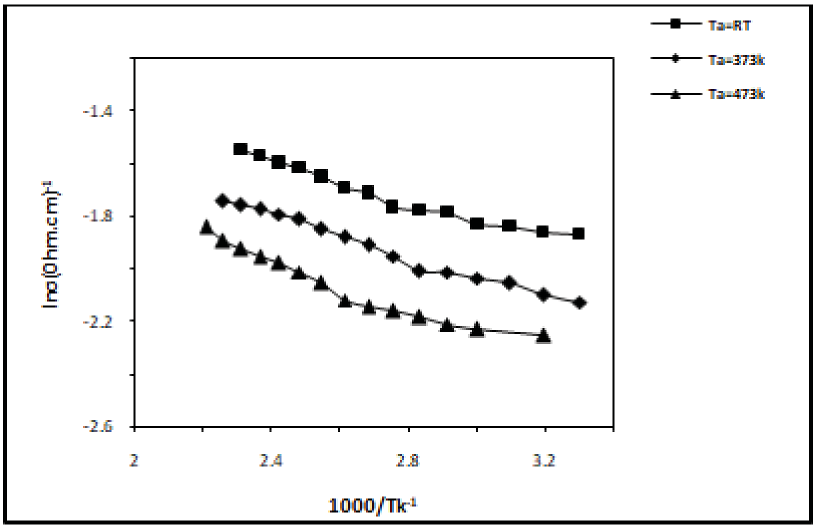

Figure (1): shows Lnσ versus 1000/T for Sb films at different annealing temperatures

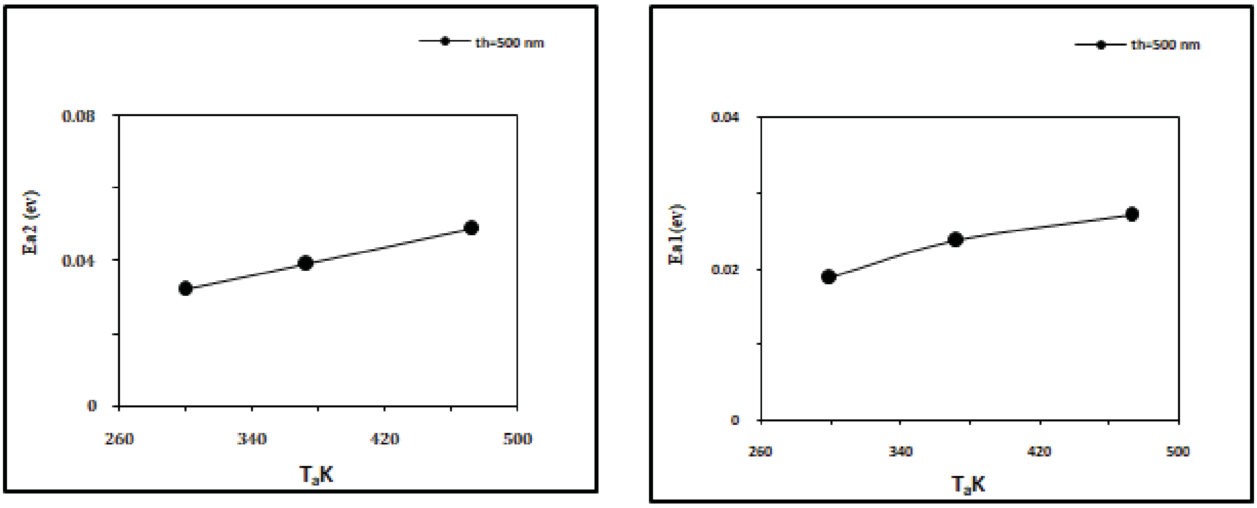

Figure (2): shows E_{a1} and E_{a2} as a function of T_a for Sb films.

Table (1) D.C. conductivity parameters for Sbfilms at different annealing temperature.

Thickness (μm)	**T_a (K)**	**(303-363)K**	**(373-433)K**	**$\sigma_{R.T} \times 10^{-3}$ (Ω.cm)$^{-1}$**
		E_{a1} (eV)	**E_{a2} (eV)**	
0.5	R.T	0.014	0.026	175.4
	373	0.017	0.028	151.5
	473	0.021	0.033	122.3

The types of charge carriers, carrier concentration (n_{*}) and Hall mobility (μ_H) have been estimated from Hall measurements.Hall measurements show that all the films are positive Hall coefficient (p-type charge carries).

Table (2) shows the variation of carrier's concentration and Hall mobility withannealing temperatures of Sb films. It can be observed that the carrier's concentration and mobility decreases with increasing annealing temperatures. This may be due to the higher grain boundary.

Table: (2): Hall parameters for Sb films at different annealing temperatures.

Thickness (μm)	**T_a (K)**	**$n_H \times 10^{19}$ (cm^{-3})**	**$\mu_H \times 10^{-3}$ ($\frac{cm^2}{V.sec}$)**
0.5	**R.T**	**15.01**	**36.1**
	373	**11.56**	**20.9**
	473	**6.07**	**4.05**

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