Structural and Electrical Properties Dependence on Annealing Temperature of Bi Thin Films

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Abstract:

In this work the effect of annealing temperature on the structure and the electrical properties of Bi thin films was studied, the Bi films were deposited on glass substrates at room temperature by thermal evaporation technique with thickness (0.4 µm) and rate of deposition equal to 6.66Å/sec, all samples are annealed in a vacuum for one hour. The X-ray diffraction analysis shows that the prepared samples are polycrystalline and it exhibits hexagonal structure. The electrical properties of these films were studied with different annealing temperatures, the d.c conductivity for films decreases from 16.42×10^{-2} at 343K to 10.11×10^{-2} $(\Omega.\text{cm})^{-1}$ at 363K. The electrical activation energies E_{a1} and E_{a2} increase from 0.031 to 0.049eV and from 0.096 to 0. 162 eV with increasing of annealing temperature from 343K to 363K, respectively. Hall measurements showed that all the films are p-type.

Key words: Electrical Properties of Bi, , Structural and Electrical Properties of Bi.

Introduction:

Bismuth is a semimetal belonging into the fifth main group of the periodic system of chemical elements, it is rarely found in nature in its elemental form[1]. It has the lowest thermal conductivity of all metals, while its electrical conductivity is greater in the solid than in the liquid state. Main uses of bismuth in industry are in pharmaceuticals, low melting point alloys, fuses, sprinklers, glass, ceramics and as a catalyst in rubber production [2]. The study of Bi is interesting because has semi-metallic behavior, the low Fermi energy, small effect mass conduction electrons, high electron mobility highly an isotropic Fermi surface[3]. Thermal evaporation technique has been used to deposite the polycrystalline bismuth thin films, because this method is fast and cheap for bismuth study [4]. The electrical properties of thin films can be characterized by conductivity and Hall effect measurements. The present work reports the study of the structural and electrical properties measurements in thin films of bismuth prepared by vacuum evaporation with annealing temperature of (343 and 363) K.

Materials and Methods:

Thin films of highly pure (99.999%) bismuth were deposited on the glass substrates by the method of thermal vacuum evaporation (Blazers Model [BL 510] using molybdenum boat under vacuum pressur 10^{-5} mbar, an electric current was passed through the boat gradually to prevent breaking the boat, when the boat temperature reached the required temperature the deposition process starts. All the samples were prepared under constant conditions (pressure, substrate temperature and rate of deposition); the main parameters that control the nature of the film properties are thickness

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(0.4) μm and annealing temperature (343, and 363) K. To study the electrical properties for the films Ohmic contacts for the prepared films are produced by evaporating (Al) electrodes of 0.3 μm thickness, by means of thermal evaporation method, using Blazers Model with pressur 10^{-5} mbar. The film thicknesses measured with an interference microscope. Bi structure was studied by x-ray diffraction and comparative with standard value in ASTM, used a Philips x-ray diffractometer system which records the intensity as a function of Bragg's angle. The source of radiation was cu(k_{α}) with wavelength λ=1.5406A°, the current was 30mA and the voltage was 40 kv. The dc conductivity of the films could be calculated by using the electrical circuit which is consists of Oven type Herease and digital Keithley to measure the resistance as function to temperature.

The conductivity of the films was determined from the relation:

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

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 $10^3/T$ according to the following equation [5].

$$\sigma = \sigma_o \exp(-E_a/k_B T) \text{.......... (2)}$$

where σ_o is the minimum electrical conductivity at 0K, E_a is the activation energy, T is the temperature and k_B is the Boltzman's constant.

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. So that the Hall coefficient is given by [6].

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

where (V_H) Hall voltage,(t) is thickness of the sample and (I) is the passing current during the sample. Carriers concentration can be determined by using the relation.

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

Hall mobility (μ_H) could be calculated according to equation [7].

$$\mu_H = \sigma\,|R_H| \text{..............(5)}$$

Results and Discussion:

X-ray diffraction pattern of Bi of thickness 0.4 μm for the as deposited film and annealed to 343 and 363 K are shown in Fig.1. The x-ray diffraction of the film represents poly-crystalline nature for as deposited and annealed films. For the as prepared Bi films, the XRD pattern displays strong reflections at (003), (006) and (009) direction as well as the low intensity peak at (110) these are hexagonal planes. The intensity of planes has increased with annealing. results agree with [8,9].

Table(1) shows the experimental data (2θ, d_{hkl}) at different annealing temperature compared with the standard value in ASTM **.**

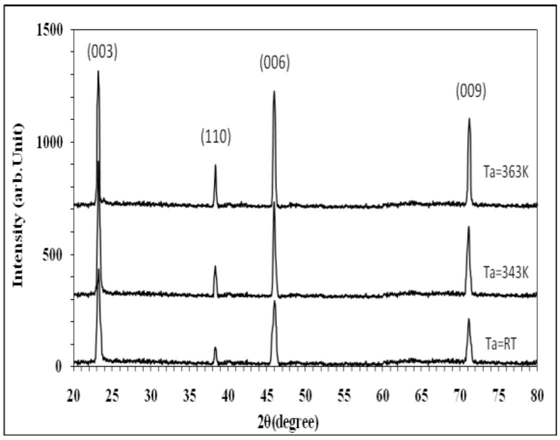


Fig.(1): XRD of Bi films with annealing temperatures.

Table(1): The structural parameters of Bi films.

T_a (K)	2θ Std.	2θ Exp.	d(Å)$_{Std.}$	d (Å)$_{Exp.}$	hkl
RT	23.24	23.32	3.954	3.952	(003)
	38.35	38.4	2.273	2.270	(110)
	45.95	45.92	1.976	1.977	(006)
	71.22	71.29	1.317	1.316	(009)
343	23.24	23.39	3.954	3.951	(003)
	38.35	38.41	2.273	2.272	(110)
	45.95	45.88	1.976	1.978	(006)
	71.22	71.09	1.317	1.326	(009)
363	23.24	23.29	3.954	3.951	(003)
	38.35	38.32	2.273	2.275	(110)
	45.95	45.93	1.976	1.978	(006)
	71.22	71.16	1.317	1.318	(009)

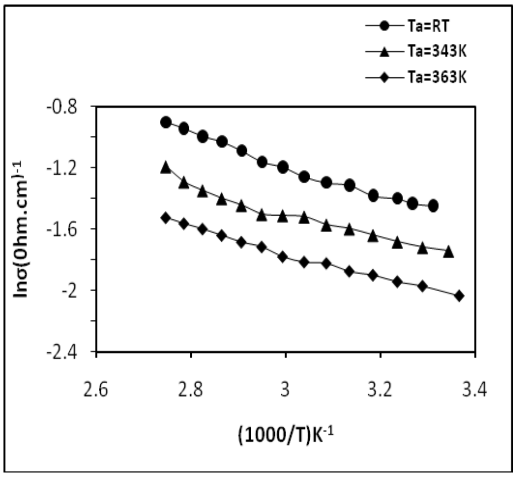


Fig. (2): Lnσ versus 1000/T for Bi films at different annealing temperatures

The d.c. conductivity for Bi films has been studied as a function of 1000/T as shown in Fig.(2).

The conductivity decreases with increase of annealing temperatures, this may be due to the rearrangement of atoms 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.2 that there are two transport mechanisms, giving rise to two activation energies $E_{a1}$and E_{a2}. At higher temperature range (334–364) K, the conduction mechanism is due to carrier excited into the extended states beyond the mobility edge and at lower temperature range (299 –329) K; the conduction mechanism is due to carrier excited into localized states at the edge of the bands. 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 crystalline during annealing.

Table (2) D.C. conductivity parameters for Bi films at different annealing temperature

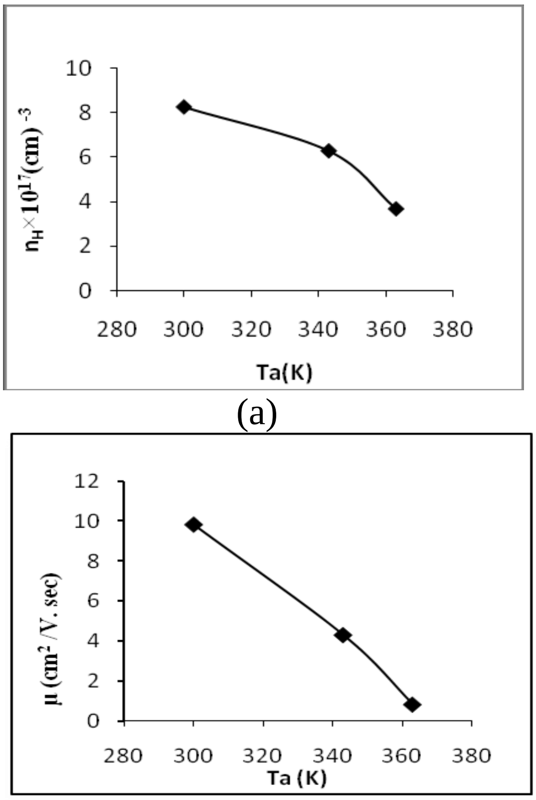
Thickness (μm)	T_a (K)	(299-329)K	(334-364)K	$\sigma_{R.T} \times 10^{-3}$ $(\Omega.cm)^{-1}$
		E_{a1} (eV)	E_{a2} (eV)	
0.4	R.T	0.031	0.096	164.26
	343	0.038	0.109	122.52
	363	0.049	0.162	101.16

The type of charge carriers, carrier concentration (n_H), Hall mobility (μ_H) has been estimated from Hall measurements. Hall measurements show that all the films are a positive Hall coefficient (p-type charge carries).

Table (3) and Figure (3) show the variation of carrier's concentration and Hall mobility with annealing temperatures of Bi films. It can be observed from this table and Figure the carrier's concentration and mobility decreases with the increase of annealing temperatures. This result is in agreement with Göksel Durkaya [10].

Table: (3): Hall parameters for Bi films at different annealing temperatures.

Thickness (μm)	T_a (K)	$n_H \times 10^{17}$ (cm^{-3})	$\mu_H \times 10$ $(\frac{cm^2}{V.sec})$
0.4	**R.T**	**8.27**	**9.8**
	343	**6.3**	**4.3**
	363	**3.7**	**0.84**



(a)

(b)

Fig. (3): (a) Variation of Hall concentration with annealing temperature for Bi films (b)Variation of Hall mobility with annealing temperatures for Bi films

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اعتماد الخواص التركيبية والكهربائية على حرارة التلدين لأغشية البزموث

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الخلاصة :

في هذا البحث تم دراسة تاثير التلدين على الخصائص التركيبية والكهربائيـــة لأغشية Bi ، المحضرت بتقنية التبخير الحراري على أرضيات زجاجية بدرجة حرارة الغرفـة مع سمك (0.4µ m) و معدل ترسيب 6.66Å/sec. لدنت هذه الأغشية بدرجات حرارة K(343 , 363) لمدة ساعة. أظهرت نتائج XRD أن جميع الأغشية متعددة التبلور ولها تركيب سداسي. درست الخصائص الكهربائيـــة للأغشية المحضرة بتغير درجة حرارة التلدين اذ وجد ان التوصيلية الكهربائية المستمرة تقل من 16.42×10^{-2} $(\Omega.cm)^{-1}$ عند درجة حرارة (343 K) الى 10.11×10^{-2} $(\Omega.cm)^{-1}$ عند درجة حرارة (363 K)، أزدادت طاقات التنشيط الكهربائية (Ea_1), (Ea_2) من (0.031 eV) الى (0.049 eV) و من (0.096 eV) الى (0.162 eV) بزيادة درجة حرارة التلدين من 343K الى 363K، على التتالي . بينت قياسات هول أن جميع الاغشية هي من النوع القابل.