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Effect of annealing temperature on nano structured bi- layer thin films of Antimony and Tellurium

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Abstract— ***Antimony telluride (Sb_2Te_3) has high thermoelectric performance at room temperature. It has high electrical conductivity and high thermoelectric power with low thermal conductivity. In present work nano structured bi-layer thin films of Sb and Te of thickness 28 nm were fabricated on Si substrates using vapor deposition technique. These Bi-layer thin films were annealed at different temperatures of 100°C and 300°C and the variation in structural, morphological and Electrical properties were studied. It is reported that good quality bi-layer thin films of crystalline structured having optimum electrical properties have been formed.***

Keywords— Bi-layer, ADXRD, SEM, , structural, morphological, I-V properties

I. INTRODUCTION

Sb_2Te_3 is an inorganic compound with solid crystalline structure having 580°C melting point and 6.50 gm/cm^3 density. Its melting point, color and density depend upon crystalline form it adopts. Sb_2Te_3 can be transformed into both n-type and p-type semiconductor by doping with an appropriate dopant[1]. Classic semiconductors (Si, Ge) have high carrier concentration but with high thermal conductivity so highly covalent inter metallic compounds composed of heavy elements like Pb, Hg, Bi, Sb, S, Se, and Te best satisfy the compromise done for good thermoelectric materials [2]. Heavily doped Sb_2Te_3 and its alloys are the best performing thermoelectric materials at room temperature [3]. These interesting properties of Sb_2Te_3 grabbed the attention of researchers for its wide range application in the field of thermoelectric [4]. P type Sb_2Te_3 was reported with the figure of merit (ZT) 0.17, having high thermoelectric power, high electrical conductivity and low thermal conductivity compared to other pure semiconductors [5]. In this paper the bi-layer thin films have been synthesized which are annealed at different temperature of 100°C and 300°C. Typical measurements of structural, morphological and electrical properties are carried out using ADXRD, SEM and I-V methods. Results corresponding to all bi-layer thin films of Sb and Te as deposited and annealed at 100°C and 300°C are presented here.

II. EXPERIMENT

Tellurium powder (Aldrich, 99.8%, 200 mesh) and antimony powder (sigma- Aldrich, 99.5%, 100 mesh) were used. Si wafers were carefully washed using acetone. The deposition of bi-layer thin films on silicon substrate was carried out in a vacuum chamber using vapor deposition technique. In the vacuum chamber Sb was placed in a boat located downstream to Te boat and deposition done at the chamber pressure of 10^{-5} mbar. Thickness of Sb and Te Bi-layer was measured 28 nm by thickness monitor. Thin films were annealed at 100°C and 300°C.
The bi-layers thin films on Si substrates were directly used for ADXRD and SEM measurements. The Angle dispersive X-ray diffraction was obtained at beam line 12 at INDUS-2, RRCAT, Indore, India. This is a bending magnet based, high resolution XRD beam line having 2.5GeV, 300mA with a photon energy range of 5-25 KeV. The size and morphology of the particles in the thin films were characterized using Field emission gun- scanning electron microscopes (FEG- SEM) (JEOL JSM-7600F) at INUP, IIT bombay, India. The measurement of resistivity was carried out by one of the standard and most widely used four probe apparatus. The experimental set up consists of probe arrangement, sample, oven 0-200°C, constant current generator, oven power supply and digital panel meter (measuring voltage and current). Voltage and current readings were measured for bi-layer thin films annealed at different temperatures. [6]

III. RESULT & DISCUSSION

Structural properties

The ADXRD diffraction analysis (fig 1) shows the different diffraction patterns of bi-layer thin films of antimony and tellurium as deposited ‘ figure 1.1’ and annealed at 100°C and 300°C ‘figure 1.2’ respectively. From the figure 1.2 it reveals the crystalline structure of bi-layer thin films of Sb and Te annealed at 100°C and 300°C. The graph indicates that characteristics of XRD peaks corresponding to antimony and tellurium have been observed at specific 2θ angle corresponding to the orthorhombic face of thin films.

All peaks of Sb and Si are shown in XRD and no peak of Te is shown due its non crystalline behavior after heat treatment. Also some small peaks of Sb_2Te_3 also report due to merging of Te into Sb after annealing. As annealing increase these peaks become more visible. No additional peaks have been observed after annealing which shows that film exhibit a Sb rich composition and there is no any compositional variations occur after the annealing treatment of Sb and Te bi-layer thin films [7]. The intensity of Individual peaks has been observed increased after annealing which may be due to fact that after annealing the Sb Te thin films are arranged in more crystalline manner due to heat treatment [8].

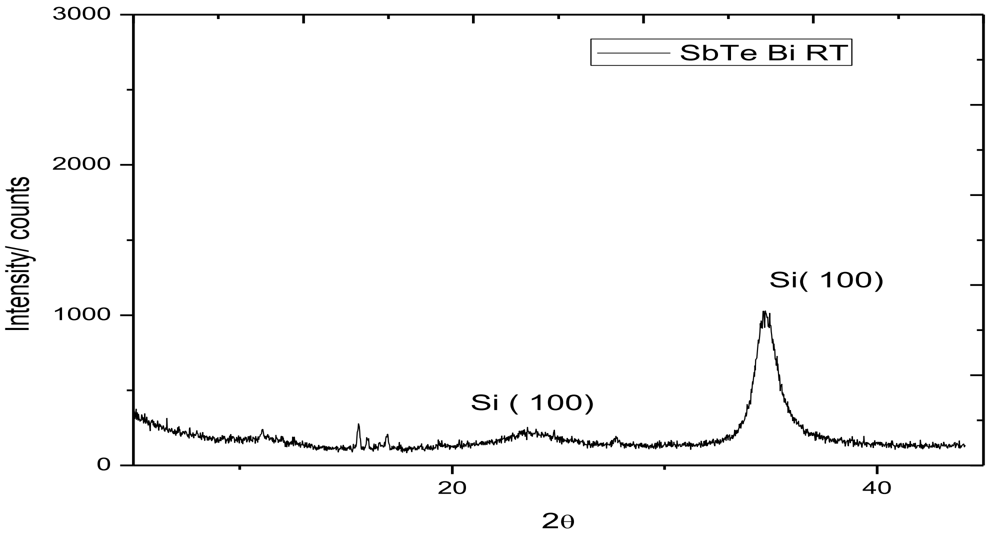


Fig. 1.1

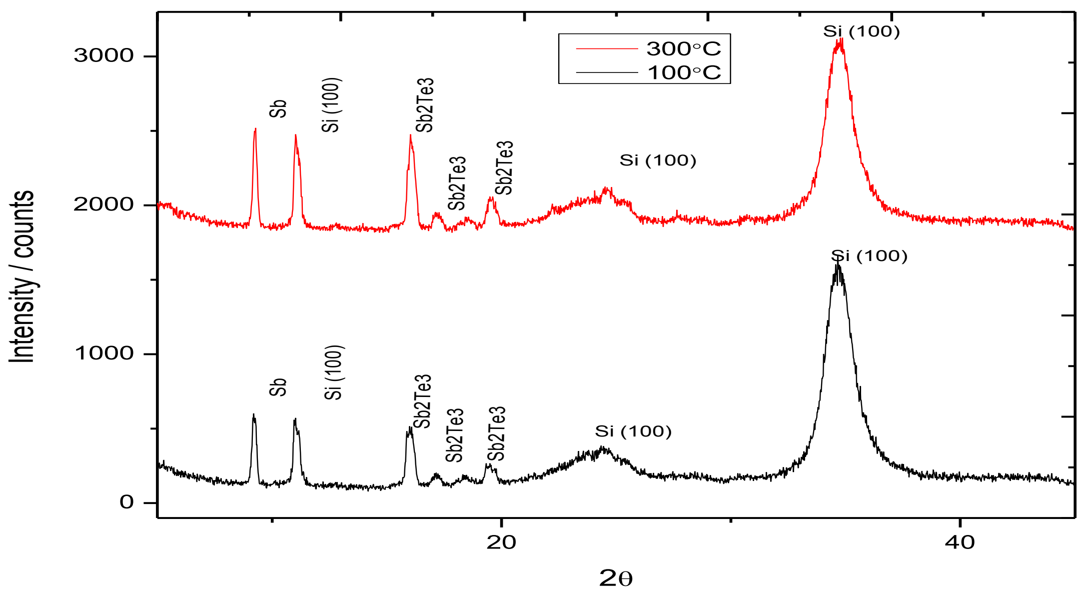


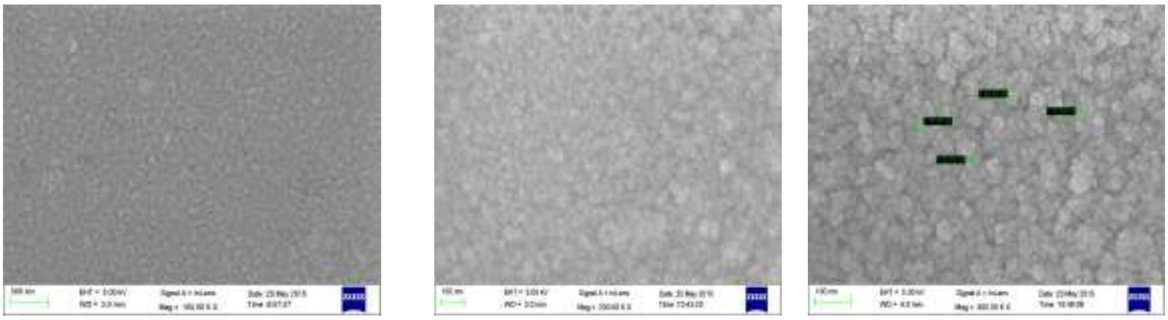
Fig. 1.2

Fig. 1.1 XRD patterns of Bi-layer thin films of Sb and Te as deposited

Fig.1.2 XRD patterns of Bi-layer thin films of Sb and Te annealed at 100°C and 300°C

SEM Analysis

The surface morphology of bi-layer thin films of Sb and Te by the SEM measurements is shown in fig 2. From the SEM measurements it can be seen that the grain size of bi-layer thin film annealed at 300°C is larger and crystalline than that of bi-layer thin film annealed at 100°C and as deposited thin film. It is observed form the SEM results that the grain size of annealed thin films is enhanced due to mixing of Te into Sb after heat treatment which satisfy the agreement with the ADXRD results



(a) (b) (c)

Fig. 2: SEM images: (a) As deposited (b) annealed at 100°C and (c) annealed at 300°C

Electrical Properties

V-I charactersitics are shown in figure 3 of Bi layer thin films of Sb and Te as deposited and annealed at 100°C and 300°C respectively.

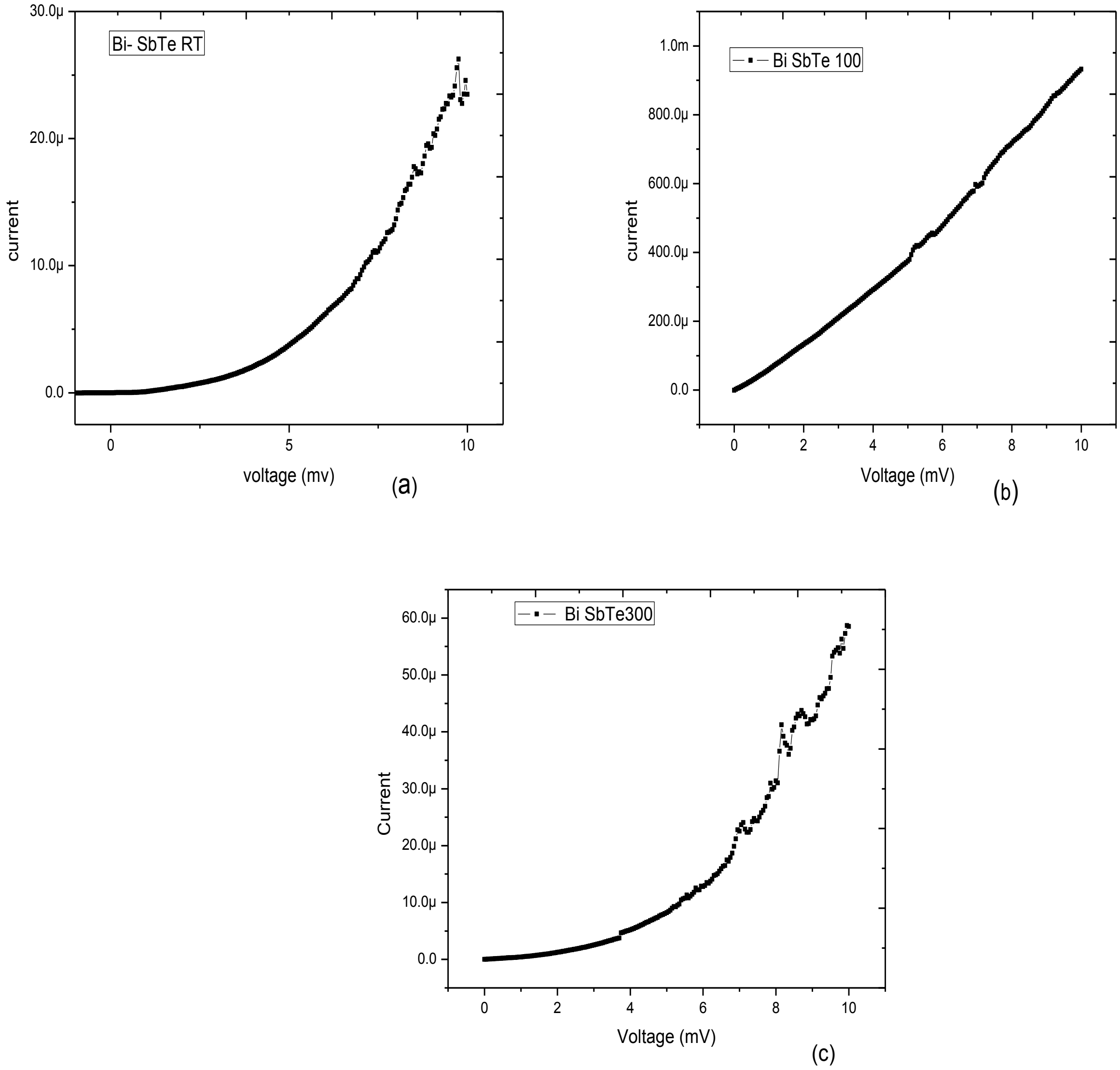


Fig.: 3 Dependence of voltage on current for Bi layer thin films as deposited (a) and annealed at 100°C (b) and 300°C (c).

(I-V) characteristics were taken for samples of bi-layer thin film of Sb and Te as deposited, annealed at 100°C and 300°C. The plot 'a' is for bi layer thin film as deposited whereas plot 'b' is for bi-layer thin film grown at 100°C and 'c' is for this same thin film annealed at 300°C. Figure 3 shows the variations in current in as deposited thin film and annealed bi layer thin films at different temperatures The I-V curves (Figure b) indicate ohmic conduction throughout the voltage (from lower voltages to higher voltage region) i.e. the current changes linearly with voltage for bi-layer thin films of Sb and Te annealed at 100°C. Whereas the slope of bi-layer thin film annealed at 300°C is increased in figure (c); this confirms the presence of injected space charge due to high temperature which shows the non-linear curves due to granular uniformity of the surface of thin film. Thin film indicates that after heat treatment the thin films attained the semiconductor nature and hence conductivity is decreased.

IV. CONCLUSION

The bi-layer thin films of Sb and Te fabricated on Si substrate and annealed at 100°C and 300°C. It is observed in V-I characteristics that bi-layer thin film of Sb and Te annealed at 100°C, has linear behaviour compare to bi-layer thin film annealed at 300°C. ADXRD, SEM results show the crystalline and homogenous structure of bi-layer thin film of Sb and Te annealed at 300°C. Thin films indicates that after annealing at 300°C the grain size enhanced and tiny gapes appeared between granules. Which confirms the mixing of Te into Sb after annealing at 300°C and its semiconductor nature and non-linear behavior as shown in V-I curves.

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