I-V MESUERMENT OF Se-Sb-Bi THIN FILM

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Abstract— Amorphous Se90-xSb10Bix (x=0, 2, 4, 6, 8, 10) thin film are obtained by thermal evaporation technique of bulk material on to well cleaned glass substrates. Thin film was characterized by X-ray diffraction and the current – voltage characteristics were carried out in the temperature range (300K-340K). In all the samples, at low voltage, ohmic behavior is observed. However, at high voltage, non-ohmic behavior is observed. It has been also observed that the film containing 4 at wt% of Bi allow the resistance has been explained on the basis of bond formation between Se-Bi at different compositions. The linear relationship between In (I) between $V^{1/2}$ curves, confirm the conduction mechanism is Poole-Frankel mechanism.

Key words: Chalcogenide Glasses, Thin film, I-V characteristics, Poole-Frankel mechanism, XRD

I. INTRODUCTION

Chalcogenide glasses have the major advantage that these can be synthesized in any batch or compositions using the traditional melt quench technique. These glasses are finding more applications in infrared optical elements, infrared optical fibers, switching and memory devices, solar cells, phase change optical recording media waveguides, non-linear elements, etc. [1-12]. It has been found that Se based alloys are more useful as compared to pure Se, due to their grater hardness, high photosensitivity, higher crystallization temperature and smaller aging effect [13]. So this time, more attention has been focused on glasses of Se-Bi system [14-19].

The transport mechanism of charge carriers in amorphous semiconductors has been the subject of intensive theoretical and experimental investigations for the last few decades. These studies have been stimulated by the attractive possibilities of using the structure disorder in amorphous semiconductors for the development of better, cheaper and more reliable solid state devices [20]. The study of the electrical conduction of any medium gives us an insight in to the transport mechanism of the prevailing charge carriers. In low field conduction, the mobility and free carriers concentration are assumed to be constant with field. However, application of a high field to a free carrier system may influence both the mobility and the number of charge carriers. High field effects are most readily observed in materials with a small number of equilibrium carriers, since heating effects are kept reasonably small. For the same reason, the study of high field effects is particularly favored in low conductivity solids, e.g., amorphous semiconductors.[21-22]. However, more work is required in this direction.

II. EXPERIMENTAL TECHNIQUE

Glassy system of $Se_{90-x}Sb_{10}Bi_x$ (x = 0, 2, 4, 6, 8, 10) were prepared by quenching technique. The exact proportion of high purity (99.999%) elements, in accordance with their atomic percentages, were weighed using an electronic balance (LIBROR, AEG120) with the least count of 10-4gm. The materials were then sealed in evacuated (~10-5 Torr) quartz ampoules length ~ 6 cm and were internal diameter ~ 8 mm). The sealed ampoules containing were heated to 9500C and were held at that temperature for 10 hours inside a furnace. The temperature of the furnace was raised slowly at a rate of 3-40C / minute. During heating, all the ampoules were constantly rocked, by rotating a ceramic rod o which the ampoules were tucked away in the furnace. This was done to obtain homogeneous glassy alloys. After rocking for about10 hours, the obtained melts were cooled rapidly by removing the ampoules from the furnace and dropping to ice-cooled water rapidly. The quenched samples were then taken out by breaking the quartz ampoules. The glassy nature of the alloys was ascertained by X-ray diffraction patterns. Thin films of these glasses were prepared by vacuum evaporation technique keeping glass substrates at room temperature. Vacuum evaporated indium electrodes at bottom were used for the electrical contact. The thickness of the films was ~500 nm. The coplanar structure (length~1.2 cm and electrode separation~0.5 mm) was used for present measurements. Keithley's electrometer (model 6487) has been used to record the current-voltage measurements of thin film. An XRD plot For $Se_{90-x}Sb_{10}Bi_x$ where(x=0, 2, 4, 6, 8 & 10) alloy thin is shown in Fig. 1. The amorphous nature of thin film was confirmed by the absence of any sharp peaks in the X-ray diffraction patterns. I-V characteristics of $Se_{90-x}Sb_{10}Bi_x$ (x=0, 2, 4, 6, 8, 10) glassy system were carried out at room temperature.

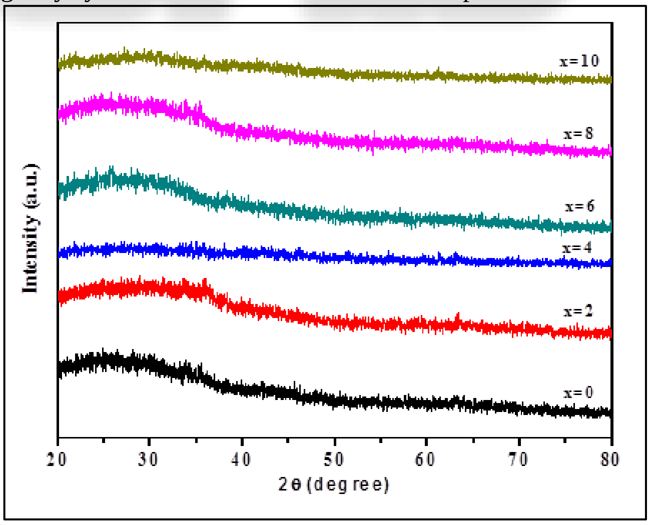

Fig. 1: XRD pattern of Se90-xSb10Bix (Where x=0, 2, 4, 6, 8, 10) chalcogenides glasses at room temperature

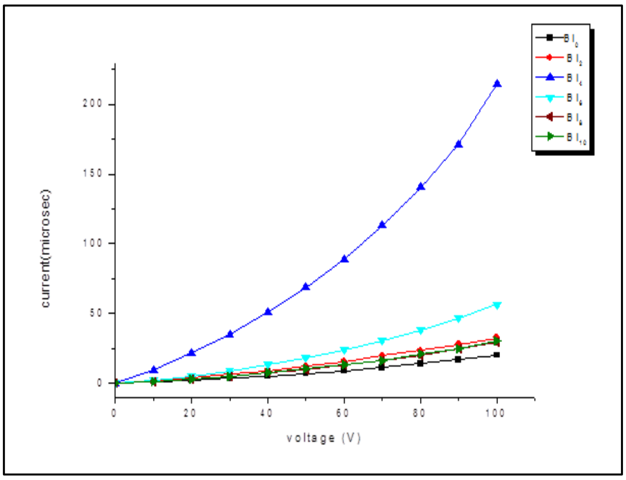

Fig. 2: I-V characteristics of Se90-xSb10Bix (Where x=0, 2, 4, 6, 8, 10) chalcogenides glasses at room temperature.

III. RESULT AND DISCUSSION

I-V characteristic of different thin film were recorded at room temperature of composition dependence. Figure 2 shows I-V characteristic of Se-Sb-Bi glassy system at room temprature. At low voltage range (0-45V), the curve shows the ohmic behavior and up to 45V, the curves deviate from linearity i.e the curves shows the non-ohmic behavior. It is also evident from figure 2, that lowest resistance for the sample $Se_{86}Sb_{10}Bi_4$ gives maximum current among these compositions. At higher voltage, the I-V characteristic deviate from ohmic behavior and resistance decreases slowly. The slope of these curves gives the value of resistance at particular voltage range.

To understand the behaviour of material the whole mechanisum could be divided in two parts. First one is related the composition dependence of I-V characteristics of the sanples. Second is related with ohmic towards non-ohmic behavior of I-V characteristic.

The electrical conduction mechanism can take place by means of two parallel processes *viz* band conduction and hopping conduction. The band conduction occurs when the carriers are excited beyond the mobility edges into non-localized states at high temperatures. The excitation of the carriers into localized states at band edges causes the hopping conduction [23], It is known that unsaturated bonds are produced as a result of insufficient number of atoms in the amorphous material [24]. Those bonds are responsible for the formation of some defects in the material. Such defects produce localized states in the band gap of amorphous solid.Some researchers have established that in Se-glass containing, there is a tendency to form polymerized network glasses and the homo-polar bond is qualitatively suppressed [25].The strature of Se-Sb glassy system prepared by melts quenching by a mixture of Se_8-rings. A strong covelent bond exists between the atom in the rings and Se-Sb chains dominate vander waal's force [26]. The addiation of Bi ((4 at. wt.%) to the Se-Sb system leads to the crosslink chains and increasing the stability in the glass. This stability of this glassy system, increase up to 4 at. wt. % of Bi. Further addiation of Bi stability is reduces. At lower percentage of Bi the system contains $BiSe_{4/2}$ tetrahedral units dissolved in a matrix composed of Se chains. With the increases of Bi content, the glassy matrix becomes heavily cross-linked and the steric hindrance increases. The Se-Se bonds (bond energy 205.8 KJ/mol) will be replaced by Bi-Se bonds, which have higher bond energy (214.2 KJ/mol). It is found that electrical conductivity is maximum at 4 at % of bismuth (Bi) This composition can be considered as a critical composition at which the system becomes a chemically ordered alloy containing high-energy Bi-Se hetropolar bonds. Further addition of Bi favours the formation of Bi-Bi bonds (bond energy 176.4 KJ/mol) thus reducing the Sb-Se bond concentration.One can say that the current-voltage characteristics are changing their behaivour as non-ohmic at higher voltage and one can infer that these curves do not follow the power law.

The relation between the current and the square root of the applied voltage is given by Jonschere and Hill [27] is given by

$$I=I_{PF}\exp(\beta V^{1/2}/kT) \qquad \ldots\ldots\ldots. (1)$$

where $\beta=(e^3/4\pi\varepsilon\varepsilon_0 d)^{½}$, ε_0 is the permittivity of the space, ε is the relative permittivity of the sample, d is the inter-spacing between the filled and empty sites (jump distance) and I_{PF} (at V=0) is given by

$$I_{PF}= I_0 \exp(-\Phi/kT) \qquad \ldots\ldots\ldots (2)$$

Where Φ is the trap depth and I_0 = (Anedν)

Since A, n, e and ν are the electrode area, carrier concentration, electronic charge and phonon frequency, respectively. The constant υ is taken as 10^{13} s^{-1} [28].

According to Eq. (1) the linear relation between In(I) and $V^{1/2}$ has been obtained at different voltage. Linearity of ln (I) vs $V^{1/2}$ curves suggests that the conduction in such material obey the Poole-Frankel conduction mechanism. The Poole-Frankel conduction mechanism deals with the conduction in such materials where defect/ impurity generated electron, traps are involved. The structural defects in the material cause additional energy states close to the band edge called 'traps'. These traps restrict the current flow because of the capture and emission process, thereby becoming the dominant current mechanism.

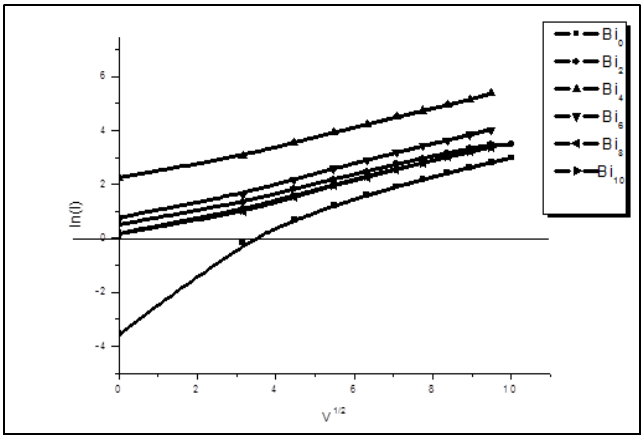

Fig. 3: Verification of Poole Frankel conduction mechanism

IV. CONCLUSION

The I-V characteristic of $Se_{90-x}Sb_{10}Bi_x$ (where x = 0, 2, 4, 6, 8, 10) glassy alloy have been explained in term of their parent structure of Se-Sb-Bi system. The conduction is explained qualitatively in terms of Poole Frankel conduction. The excess of Bi in Se-Sb-Bi system induces changes in resistance and found that 4 at. wt. % of Bi has the maximum conduction. Most stable composition is

$Se_{86}Sb_{10}Bi_4$, favoring thermal and electrical conductivity. Also the linear relation between In (I) and $V^{1/2}$ confirm the Poole Frankel conduction mechanism.

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