

ELECTRICAL CONDUCTIVITY OF Se-In CHALCOGENIDE GLASSES

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Over the last four decades, the researchers are involved in the study of electrical properties of chalcogenides glasses to explore the new dimensions for their end user applications with enhanced properties. Present work incorporates the study of I-V characteristics and electrical conductivity of bulk $\text{Se}_{100-x}\text{In}_x$ amorphous system, prepared by conventional rapid melt-quenching technique. It could be inferred out that the $\text{Se}_{90}\text{In}_{10}$ composition is most conducting as compared to its other counterparts in the proposed series. This could be explained on the basis of bonding between Se-Se, Se-In and In-In. On the other hand the decrease in electrical conductivity beyond 10 at. wt.% of In in $\text{Se}_{100-x}\text{In}_x$ system is explained on the basis of increment of the degree of disorder of the system.

Keywords: Chalcogenides glass, In-Se, DC Electrical conductivity, Band structure, Bulk amorphous.

1. Introduction

Recently, the efforts have been devoted to the development of chalcogenides materials suitable for optoelectronics. The phenomenon related with electronic conduction in amorphous chalcogenides semiconductors has attracted a great deal of scientific attention since the discovery of electrical switching in chalcogenides glasses in 1968 [1]. Selenium is selected because of its wide commercial applications. In pure state this Se has disadvantages because of its short lifetime and low sensitivity. To overcome these difficulties, certain additives are used e.g. Sb, In, Te, Ge etc. and binary and ternary alloys are formed [2]. Since, network connectivity, rigidity and nature of bonding do play important roles in electronic conduction process [3] and hence in order to understand the conduction phenomena, a great deal of experimental data is required. Many workers have carried out the investigations of electrical and optical properties of binary and ternary chalcogenides glasses [4-7]. The present work is devoted to the study of variation in electrical conductivity of $\text{Se}_{100-x}\text{In}_x$ ($x = 0, 5, 10, 15$ & 20) amorphous system with respect to In concentration.

2. Material preparation

The series of $\text{Se}_{100-x}\text{In}_x$ ($x = 0, 5, 10, 15$ & 20) samples has been prepared by melt-quenching technique. High purity material were weighed according to their at. wt.% for a particular composition. These materials were sealed in a quartz ampoules under a vacuum of 10^{-6} Torr and then heated in a furnace up to 900 °C for about 10 hrs. The ampoules were rocked to ensure the better homogeneity of the melt. These ampoules containing molten samples were then quenched in ice-cooled water and then the samples were crushed into fine powder. The amorphous nature of the sample was confirmed by X-ray diffraction measurements [8]. The pellets of these powders were prepared by a die using a pressure machine at a load of 5 tons. The pellets were about 1 mm thick and of 12 mm diameter in dimension.

3. Characterization of the samples

Typical I-V measurements of the pellet (≈ 1 mm thick) have been made at room temperature in the voltage range from 1 V to 20 V as shown in figure 1.

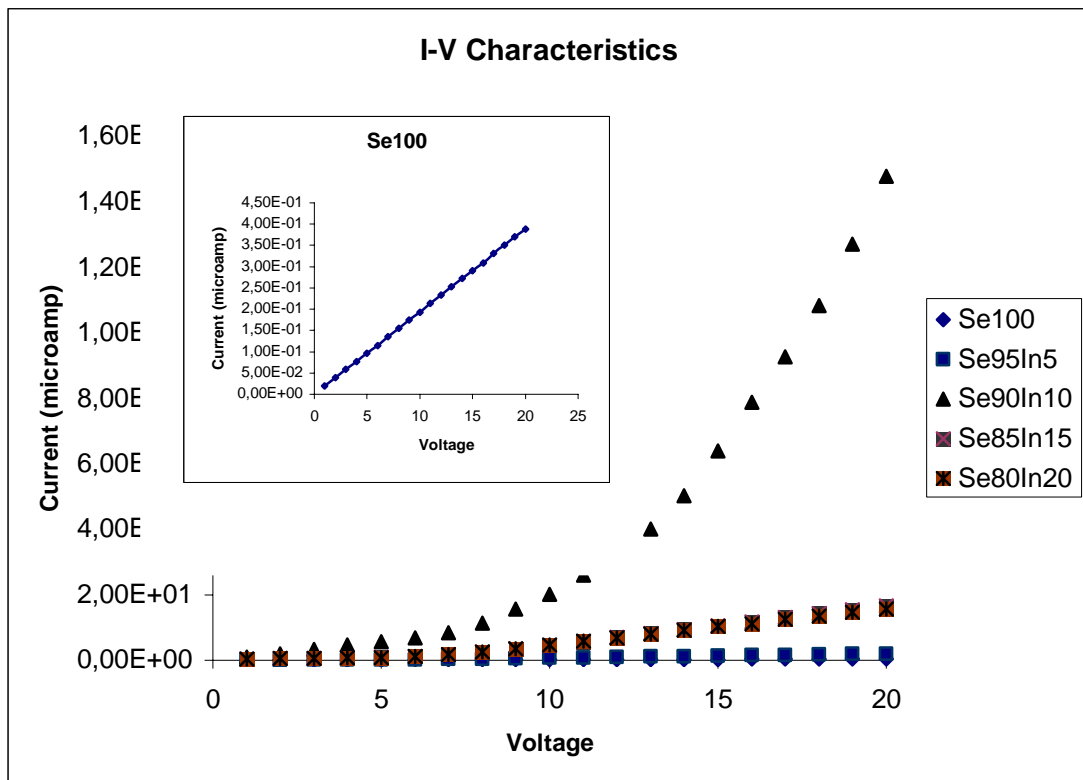


Fig. 1 I-V characteristics of samples of the system Se-In.

The slope of these curves is used to calculate the resistance of the pellets. This resistance is used to calculate the volume conductivity of the samples as follows

$$\sigma = (1/R)(l/A) \quad (1)$$

where, R is the resistance of the pellet, l is the length and A is the area.

These I-V curves were recorded using Keithley High Resistance meter/ Electrometer 6517A. The circuit diagram for such measurements has been discussed elsewhere [9]. Since this electrometer has an inbuilt voltage source of $\pm 1000V$ so, the same meter was used for applying voltage across the sample and to measure the current. The sample was sandwiched between two copper electrodes in a indigenously designed sample holder. A pressure contact arrangement was incorporated in the sample holder for better contacts between the electrodes and the sample.

4. Results and discussion

Figure 2 shows the variation of DC electrical conductivity vs In concentration in the sample. It is quite evident from this figure that $Se_{90}In_{10}$ sample is most conducting as compared to its other counterparts of the series.

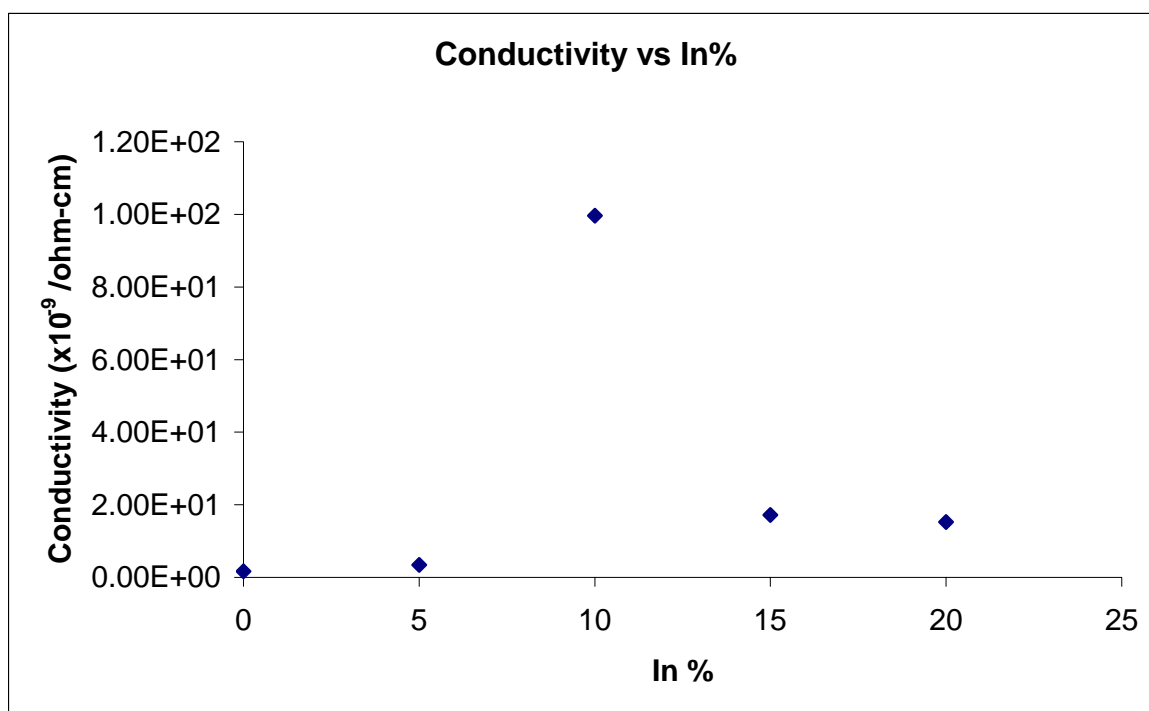


Fig. 2 Variation of DC electrical conductivity with indium concentration

The variation of the electrical conductivity is explained on the basis of the formation of Se-Se, Se-In and In-In bonds. It is a well-established fact that in a-Se about 40 at. wt.% of the atoms enter into ring structure and the remaining are bonded in polymeric chains [10]. If the concentration of In is increased in Se, a slight increase in the number of polymeric chains is observed and this increment is found responsible for enhanced effective thermal conductivity and effective thermal diffusivity up to a given composition [11].

As we start adding In at the cost of Se, some of original Se-Se structural units are replaced by Se-In structural units and the chain length increases leading to a slight increment in conductivity. For further increment in indium concentration, at 10 at. wt.%, the system possesses the maximum chain length and heavily cross linked with ring concentration which is responsible for the maximum conductivity as shown in Fig. 2. Since bond strength of Se-Se (79.5 kcal/mole) and Se-In (54.0 kcal/mole) does not differ by a large value, the change in conductivity could only be expected by the increase of the In content in the system. When one passes beyond 10 at. wt.% of In, the concentration of In-In exceeds the Se-In bond concentration and this leads to the decrement in conductivity. This decrement in electrical conductivity of Se-In beyond 10 at. wt.% of In is also explained on the basis of order - disorder transformation occurring in the system. Since In-In bond length (325 pm) is larger than that of Se-Se (232 pm), therefore, for higher concentration of In in Se-In system the concentration of In-In bonds increases in the system. This brings an effective decrease in molecular weight of the glasses and hence in the density of localized states as well [12]. A decrease in the density of localized states increases the porosity resulting into a more disordered system [13]. This disorder is responsible for the decrement in conductivity. As the In concentration is further increased, the disorder of the system increases and hence the conductivity decreases. Reported results [8, 11, 14] on band gap, activation energy and thermal stability of $\text{Se}_{100-x}\text{In}_x$ ($x = 0, 5, 10, 15 \text{ \& } 20$) with the concentration of In in at. wt.% strongly support our results on electrical conductivity.

5. Conclusions

A critical study on the DC electrical conductivity of $\text{Se}_{100-x}\text{In}_x$ bulk system indicates that the system under study is most conducting for indium concentration equal to 10 at.wt.%. The observed variation is due to the relative bond strength and bond length of Se-Se, Se-In and In-In bonds present in the material at different concentration of indium.

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