

ELECTRICAL PROPERTIES OF $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ CHALCOGENIDE GLASSES

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Electrical properties of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X= 0, 2, 4, 6$ and 10) chalcogenide glasses have been carried out at room temperature. I-V characteristic of the present glasses were recorded upto 200V. A drastic I-V characteristic change has been observed between 160 to 200V for 4, 6, 10 at % of indium glasses. The electrical conductivity, $\ln(I)$ vs $V^{1/2}$ characteristics and electrical conductivity vs average coordination number parameter of present glasses have been also determined, which extensively varied with indium concentration.

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1. Introduction

Chalcogenide glasses have been widely studied more than four decades in form of binary [1-6] ternary [7-12] and multicomponent [13-18]. Due to their broad range of commercial and technological applications, such as; switching memory, thermal imaging, chemical, Ultra-high-density phase-change storage and memory, Integrated fibre optics, infrared photodetectors and photovoltaics and bio sensors [19- 26]. It is well known that the binary chalcogenide glasses suffering from thermal stability, lower crystallization temperature and aging effects etc [7-12]. For resolving these problems of binary chalcogenide glasses several investigators have been reported improved work with ternary alloys [27-30]. Although ternary alloys have been exhibiting remarkably improved technological applications, but they are still suffering from won working limit performance. In process to achieved improved physical phenomena of chalcogenide alloys a few works have been done [13-18] on their multicomponent alloys.

Physical properties of chalcogenide glasses are broadly varied with its alloying elements concentration and purity of materials. The variations of concentration of alloying elements are creating chemical impurity within materials, and it produces structural defects in solids such as heterogeneous particles, microcrystalline phase separation, cracks and inhomogeneities etc. In recent years, the electrical properties of chalcogenide glasses have found greater consideration because of their solid state technical importance. The electrical properties of amorphous Se based chalcogenide glasses exhibit large Fermi level shift and large photo voltaic effects [31, 32]. I-V characteristics and consequents field effect study of several chalcogenide glasses have been reported by different investigators [33]. Characteristics of these glasses have explained by different existing models such as Pool-Frankel effect [34], Small polaron Conduction [35], Hopping Conduction [36], Tunneling Conduction [37] and Space Charge Limited [38].

In this research work we have explored the electrical properties of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X= 0, 2, 4, 6$ and 10) chalcogenide glasses. The present glasses have been showing enhanced values of I-V characteristic, electrical conductivity and Pool-Frenkel approximation for a certain Indium concentration, under voltage range 10 V to 200 V at normal room temperature.

2. Material preparation and characterization

Bulk multicomponent glassy materials were prepared by melt quenched technique. High purity elements (99.999% pure), Selenium, zinc, tellurium and indium were used. The desired amounts of atomic percentage of elements were weighed by electronic balance. The properly weighed materials were put into clean quartz ampoules, (length of ampoules 8 cm and diameter 14 mm). The material containing quartz ampoules were evacuated and sealed under vacuum of 10^{-5} Torr. The material sealing process needed evacuated clean quartz ampoules because; glasses are reactive at high temperature with oxygen. The bunch of sealed ampoules was heated in electric furnace upto 1173K at a rate of 5-6 K/min and samples kept at that temperature for 10-11 h. During the heating process ampoules were frequently rocked to ensure the homogeneity of molten materials. After achieving desired heating time, the molten materials ampoules rapidly quenched into ice cooled water. Then ingots of glassy materials were removed from the ampoules. The amorphous nature of materials was confirmed by PHELIPS XRD, as shown in Fig.1.

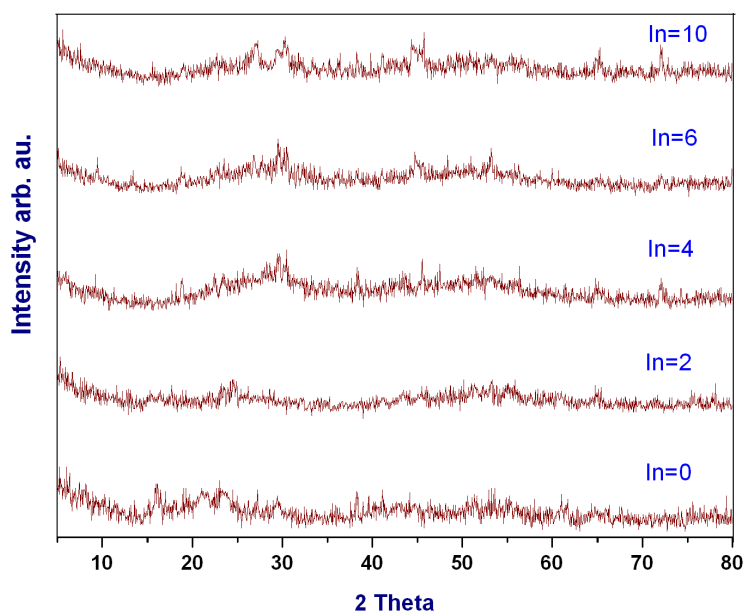


Fig. 1 XRD patterns of $Se_{93-X}Zn_2Te_5In_X$ ($X = 0, 2, 4, 6$ and 10) chalcogenide glasses.

The prepared glassy materials were cursed into fine powder then made its pellet (12 mm dia and ~ 2 mm thickness) under a 5 tons load. I-V measurements were performed across the plane surface of prepared pellet samples by Keithely 2400 source measure unit under fixed bias (V), in voltage range 10 to 200 V at normal room temperature. To ensure the continuity of experiments each sample I-V measurement 4-5 times performed. The schematic circuit diagram of I-V measurement is shown in Fig. 2.

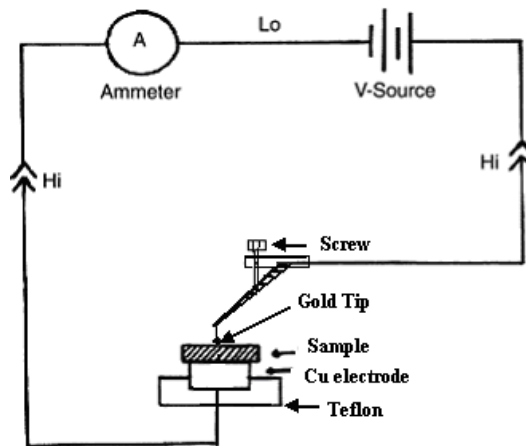


Fig. 2 Schematic circuit diagram of I-V measurement for Se-Zn-Te-In chalcogenide glasses.

3. Results and discussion

I-V characteristic of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X = 0, 2, 4, 6$ and 10) chalcogenide glasses are shown in Fig. 3, which recorded at room temperature in above said voltage range. It is clear from Figure (See Fig. 3) that the present glasses $X = 4, 6, 10$ shows nearly constant as well as abrupt growth of current with increasing voltage, however $X = 0, 2$ glasses exhibits nearly constant growth of current in studied voltage range. The constant and abrupt current growths of present glasses are indicating that electrical characteristics tend towards to non-ohmic behaviour. It is also evident from Fig. 3 that the resistance is lowest and current highest for $\text{Se}_{87}\text{Zn}_2\text{Te}_5\text{In}_6$ glass rather than other glasses of present series.

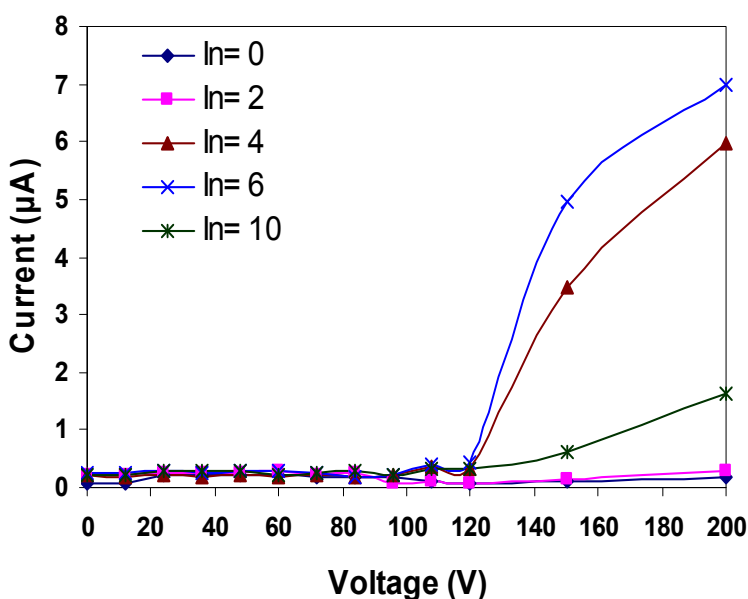


Fig. 3 I-V characteristics of Se-Zn-Te-In chalcogenide glasses.

The whole qualitative mechanism of present glasses could be related with composition dependence conductivity and ohmic to non-ohmic I-V characteristics as the electrical conductivity was calculated from the relation;

$$\sigma_{DC} = 1/\rho_{DC} = (1/R)(L/A) \quad (1)$$

Here R is the resistance of the samples which obtained from I-V measurements data, L is the thickness of the sample, A is the cross-sectional area of the sample and ρ_{DC} is the resistivity of the sample under test. The plot of electrical conductivity vs Indium concentration for entire studied voltage range is shown in Fig. 4. It is clear from the Fig.4 the overall electrical conductivity is maximum for X= 6 indium atomic concentration. As we described the I-V characteristics of (X= 4, 6 and 10) glasses are exhibits switching like growth in current between 120- 200V. Therefore, to explore abrupt drop in resistivity at threshold voltage, we have shown the variation of electrical conductivity vs indium atomic concentration at 200 V, in Fig. 5. The quick rise in electrical current and drop in resistivity in present glasses at particular voltage range may be arises due to existence of a few percolations in glassy structures.

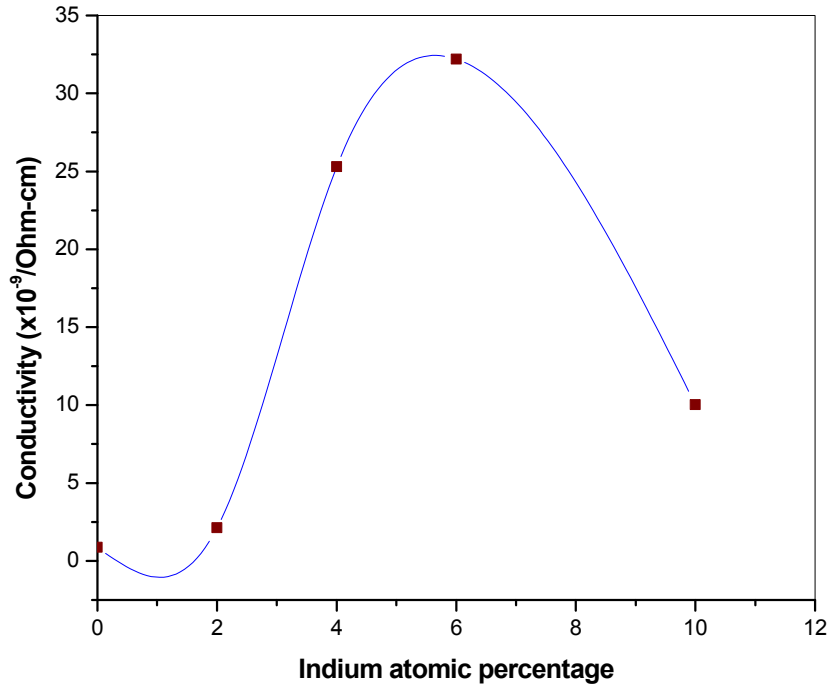


Fig. 4 Plot of average conductivity vs Indium atomic percentage of Se-Zn-Te-In glassy systems.

Moreover, in chalcogenide glasses the electrical conduction can take place by means two parallel processes namely band conduction and hopping conduction. The band conduction occurs when the carriers are excited beyond the mobility edges into non-localized states. The excitations of the carriers into localized states at band edge cause of hopping conduction [39]. Thus total electrical conductivity of system can be obtained as;

$$\sigma = \sigma_i + \sigma_h \quad (2)$$

Here σ_i is the intrinsic conductivity and σ_h is the hopping conductivity.

The thermal effects may introduce when applied voltage increases, as result decrease their resistance allowing more current flow through the sample. In these circumstances we can consider that I-V characteristics are changing their behaviour towards non-ohmic behaviour at higher voltages. The relationship between current and applied voltage Jonscher and Hill [40] defined as

$$I = I_{PF} \exp(\beta V^{1/2} / KT) \quad (3)$$

Here

$$\beta = (e^2 / 4\pi\epsilon\epsilon_0 d)$$

ϵ_0 is the permittivity of the space, ϵ is the relative permittivity of the sample, d is the spacing between filled and empty sites (jump distance) and I_{PF} is given as (at $V=0$)

$$I_{PF} = I_0 \exp(\phi / KT) \quad (4)$$

Here ϕ is the trap depth and

$$I_0 = A n e d v$$

A is the electrode area, n is the carrier concentration, e is the electronic charge and v is the phonon frequency [36], which was considered as constant ($10^{13}/s$).

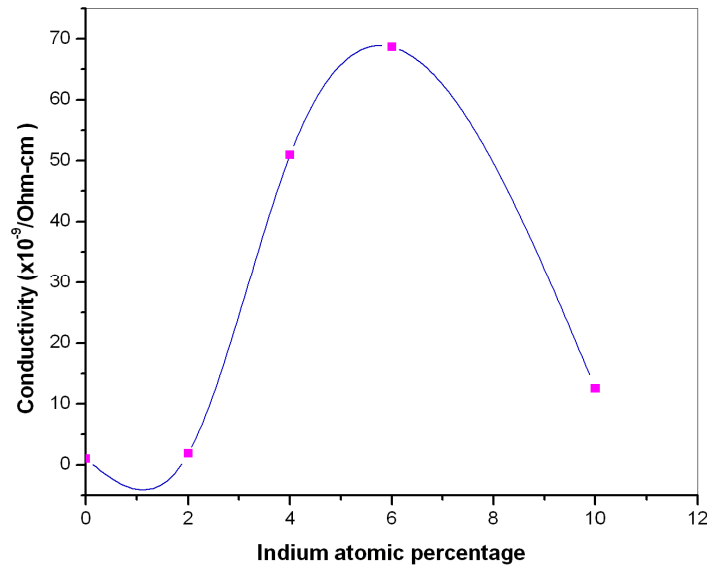


Fig. 5 Plot of conductivity vs Indium atomic percentage of Se-Zn-Te-In glasses at threshold (200V) voltage.

Here we have obtained the relationship between $\ln(I)$ and $V^{1/2}$ in studied voltage range with help of equation (3). The plot of $\ln(I)$ vs $V^{1/2}$ relationship is shown in Fig. 6. However past studies [41] of chalcogenide glasses have been reported that the such glasses generally exhibiting a linear relation between $\ln(I)$ vs $V^{1/2}$, while present system three glasses ($X = 4, 6$ and 10) are clearly exhibited a sharp increase between 120 to 200 V. On other hand two glasses ($X = 0$ and 2) of this system are exhibiting nearly constant current growth. The deviation from the linearity at certain voltage range may arise due to existence of micro phases in glassy structures. The existence of micro phases Se-Zn-In was also observed in its thermo-dynamical studies [42].

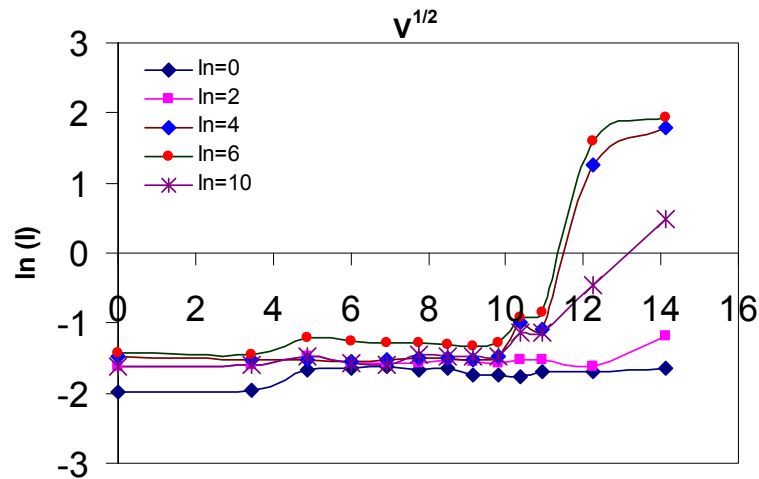


Fig. 6 Relationship between $\ln(I)$ and $V^{1/2}$ for verification of Poole-Frenkel conduction mechanism

Thus the non-linearity has been obtained for these glasses at higher voltage. Poole-Frenkel [43] established the conduction mechanism such materials. The conduction mechanism deals with the conduction in such materials where traps are involved and defects impurity generate electrons. The structural defects in the material cause additional energy close to the band edge called traps. These traps restrict the current flow because of a capture and emission process, their by becoming the dominant current mechanism.

It is broadly accepted for chalcogenide glasses that their physical properties are closely related to structural parameters such as average coordination number. In order to explore structural dependence of electrical properties of present glasses, we have determined the relation between electrical conductivity and average coordination number $\langle r \rangle$, as shown in Figure 7. It is evident from Figure 7, the electrical conductivity is maximum at $\langle r \rangle = 2.11$ which associated with X= 6 indium concentration.

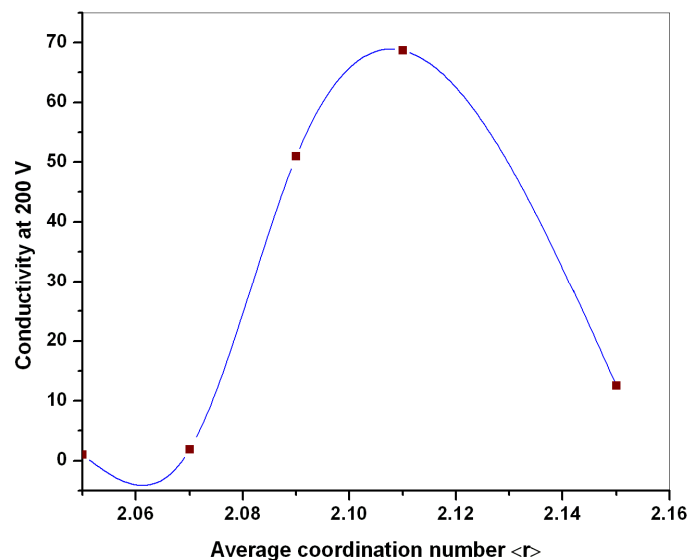


Fig. 7 Conductivity vs average coordination at 200 V for Se-Zn-Te-In glasses.

The present electrical phenomena of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X= 0, 2, 4, 6$ and 10) chalcogenide glasses could be explained with help of chemical bond theory of solids. It is expected that Zn and Te are dissolved in Se chains which causes the formation of Zn-Zn, Te-Te, Se-Se homonuclear bonds and Se-Zn, Se-Te, Se-Zn-Te heteronuclear bonds. Initially, ternary Se-Zn-Te glass forms cross-linked heteronuclear metastable state structure and produce more defects in density of localized state due to existence of dangling bonds of combined stoichiometrics [43, 44].

Incorporation of Indium in ternary glassy matrix system transforms it into quaternary Se-Zn-Te-In system. The quaternary Se-Zn-Te-In system of present glasses form Se-In heteronuclear bonds with other possible bonds Zn-In, Te-In of more metallic character due to In concentration dissolved in matrix. Here Se-In bonds are mainly responsible for changes of physical parameters of present glasses because fixed concentration of Zn and Te. Due to addition of Indium concentration in quaternary glassy matrix, the structures are heavily cross-linked and steric hindrance increases. Therefore, the expansion of Se chains and replacement of weak Se-Se bonds by Se-In bonds results the increase and decrease in their associative electrical properties. The chemical threshold has been occurred at critical composition 6 at % of In. On this concentration, glass structure becomes more chemically ordered and contains only strong Se-In bonds. Due to this, the maximum cross-linking has been occurred which results larger number of defects in density of localized states. It might be reason to generate larger number of free electrons in density of localized states due to that we have obtained maximum (sudden) rise in current at threshold concentration. Incorporation of In concentration beyond the threshold atomic percentage probably reduces the Se-In bonds increases In-In bond strength in glassy structure, therefore decreases the defects bonds in density of localized state, resulting decrease in corresponding electrical properties of $\text{Se}_{83}\text{Zn}_2\text{Te}_5\text{In}_{10}$ glass.

4. Conclusions

From above study of electrical property of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X= 0, 2, 4, 6$ and 10) chalcogenide glasses we have drawn the following conclusions;

1. I-V characteristics of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ chalcogenide glasses have exhibited both ohmic and non-ohmic behaviour in studied voltage range. The enhanced values of I-V characteristics, electrical conductivity, Pool-Frenkel approximating and average coordination number are obtained for $\text{Se}_{87}\text{Zn}_2\text{Te}_5\text{In}_6$ chalcogenide glass.
2. The present glasses $X= 4, 6$ and 10 have shown a considerable switching like electrical behaviour at higher voltage. This property of present three glasses makes strong possibility for its practical application.
3. Thus on the basis of electrical characterization of $\text{Se}_{93-x}\text{Zn}_2\text{Te}_5\text{In}_x$ ($X= 0, 2, 4, 6$ and 10) we can conclude $\text{Se}_{87}\text{Zn}_2\text{Te}_5\text{In}_6$ is a critical glass composition for this series.

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