

SURFACE CONDUCTIVITY MEASUREMENT ON Se-Te-Sn GLASSES

Dr. Sudhir Kumar Mishra,

Principal,
S.S. College, Jehanabad,

Abstract: I-V characteristic curves of $\text{Se}_{75}\text{Te}_{25-x}\text{Sn}_x$ ($x=2, 4, 6 \& 8$) glassy system prepared by melt quenching technique have been studied at room temperature in thin film form. Experimental results indicate that the conduction mechanism in these systems is of Poole-Frenkel type. The change in dc surface conductivity is attributed to the Se-Sn bond concentration in the Se-Te-Sn system. Also the composition containing Sn_6 at. wt. % shows the maximum conductivity in thin film form. This maximum conductivity could be explained on the basis of maximum concentration of bonds having highest bond energy, which eventually results as most chemically dense material as compared to other counterparts of the series.

Keywords: Electrical conductivity, Se-Te-Sn glass, Chalcogenide, Surface conductivity

Introduction

The term *Chalcogenide glasses* was coined for the glasses containing any of chalcogenide elements S, Se and Te. These glasses are formed by the addition of other elements such as Ge, As, Sb, Ga etc¹. Chalcogenide glasses are very well known semi-conducting material owing to their high transmittance in the IR spectral region² and to variety of phenomena they show when exposed to light or other radiations^{3,4}. Recently, chalcogenide materials are widely studied for their potential applications in active as well as passive solid-state electronics and optical devices. The applications include photoreceptor in xerography⁵, optical recording and memory switching⁶, infrared optical fibers and waveguides⁷ and non-linear optics⁸. Due to high transmittance in the IR region of Chalcogenide glasses, these materials are being used as an active as well as passive component in IR optical devices. The chalcogenide materials containing S, Se and Te have high transmittance in the 0.8-7, 1-10, and 2-12 μm , respectively⁹. Investigations of the temperature dependence of conductivity, the effect of impurities on the activation energy, and the effect of high electric field on the conduction mechanism is a subject of great interest, because the result of such studies provide methods to control effectively the conductivity of amorphous semiconductors.

So, the present work incorporates the study of I-V characteristics and dc surface conductivity of $\text{Se}_{75}\text{Te}_{25-x}\text{Sn}_x$ ($x = 2, 4, 6 \& 8$) glasses in thin film form at room temperature.

Experimental details

For the glass preparation, first of all, the constituent materials (i.e. Se, Te & Sn) of high purity (99.999%) were taken in their elemental powder form in proper atomic weight percentage according to the proposed composition $\text{Se}_{75}\text{Te}_{25-x}\text{Sn}_x$ ($x = 2, 4, 6 \& 8$). Chalcogenide glasses belong to substances which have an incongruent melting point, exhibit a high partial vapour pressure during melting and are susceptible to oxidation and hydrolysis and therefore, the synthesis must be carried out in sealed evacuated quartz ampoule. The synthesis conditions are widely varied – they depend on the glass composition, glass-forming region, glass forming ability and the melting temperature of the constituents etc. The powders of Se, Te and Sn, in appropriate at. wt. % proportions were weighed and sealed in a quartz ampoule (10 mm inner dia. and 12 mm outer dia.) under a vacuum of 10^{-5} Torr to avoid oxidation at higher temperatures. Ampoules were slowly heated (rate 3-4 °C/minute) to 1000 °C and kept at that temperature for 14 hrs. at the maximum temperature, ampoules were frequently shaken to homogenize the melt. Quenching was done in the ice-cooled water to get glassy state. The ingots were taken out of ampoule and gently grinded to their powder form. The X-ray diffraction (XRD) patterns of powders were taken on Bruker DX8 Advance machine ($\lambda=1.5406\text{\AA}$), which confirmed the amorphous nature of materials (powders). Thin films of these powders were deposited using Vacuum Flash Evaporation technique. Figure 1 shows the XRD patterns of $\text{Se}_{75}\text{Te}_{25-x}\text{Sn}_x$ ($x=2, 4, 6 \& 8$) glasses. Measurements of I-V characteristics of $\text{Se}_{75}\text{Te}_{25-x}\text{Sn}_x$ ($x = 2, 4, 6 \& 8$) were performed on Keithley High Resistance Meter/ Electrometer 6517A at room temperature. Electrometer (6517A) was used to apply the voltage across the sample and to measure the current through the sample as it has an in-built capability of output independent voltage source of ± 1000 V. This electrometer 6517A was used in its Force voltage measure current (FVMI) mode. The basic circuit diagram used for this study is shown in Fig. 2.

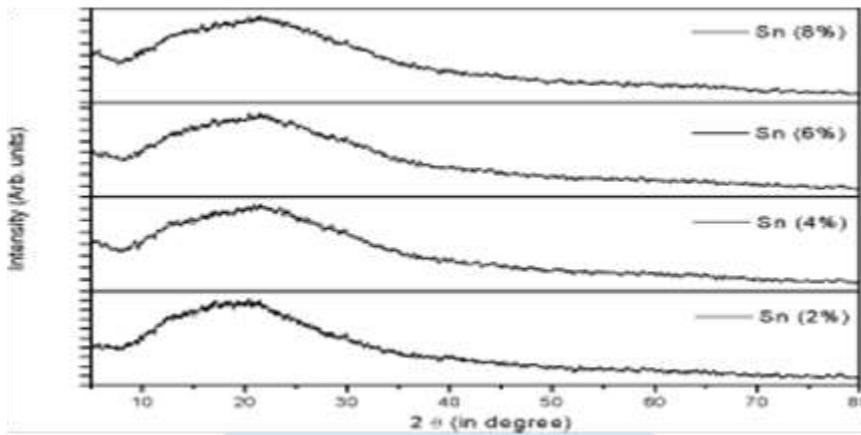


Fig. 1. XRD patterns of $Se_{75}Te_{25-x}Sn_x$ ($x=2, 4, 6$ & 8) glassy films.

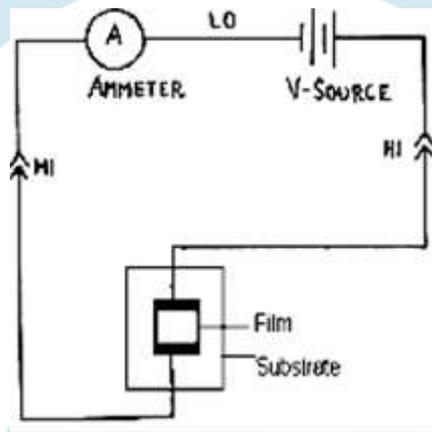


Fig 2. Schematic diagram of Electrical circuit used for I-V measurements.

Results and discussion

I-V characteristics of glassy thin films of $Se_{75}Te_{25-x}Sn_x$ ($x = 2, 4, 6$ & 8) were measured at room temperature. Fig. 3 shows the I-V characteristics of these film samples at room temperature.

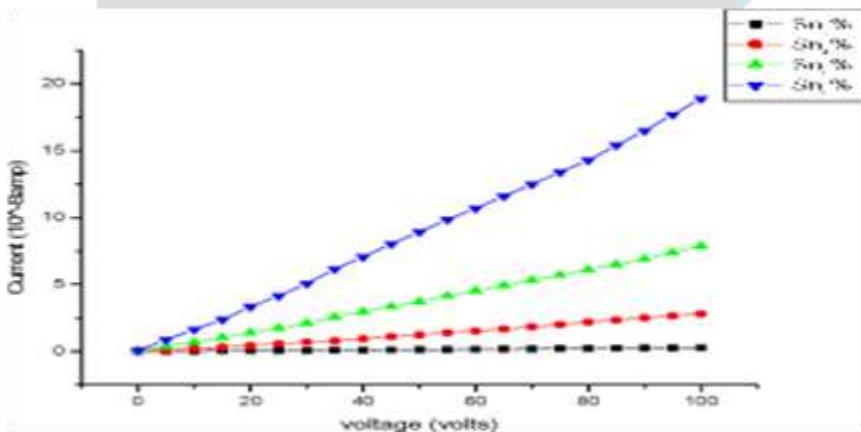


Fig 3. I-V characteristics $Se_{75}Te_{25-x}Sn_x$ ($x=2, 4, 6$ & 8) glassy thin film

From Fig. 3, it is quite evident that I-V characteristics do not follow the power law i.e. $I = kV^m$; where k and m are constant. In case, where the power law is not obeyed for the I-V characteristics, different mechanisms have been proposed by the researchers to understand the conduction process in such materials e.g. Fowler-Nordheim, Recharadson, Schottky-Recharadson and Poole-Frenkel mechanisms etc. There are plenty of evidences in literature, that chalcogenide thin films obey Poole-Frenkel conduction mechanism. Using I-V characteristics, the surface conductivity was calculated with the help of very basic relation written below,

$$\sigma = \frac{1}{\rho} = (1/r) * (L/A) \tag{1}$$

where, symbols have their usual meanings.

The relation between the current and the square root of applied voltage as given by Jonschere and Hill [10],

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

Where,

$$\beta = (e^3 / (4\pi\epsilon\epsilon_0 d))^{1/2} \quad (3)$$

Eq. (2) has been used to plot the variation of $\ln(I)$ with square root of applied voltage.

Fig. 4 shows the plot between $\ln(I)$ and $V^{1/2}$ for $Se_{75}Te_{25-x}Sn_x$ ($x=2, 4, 6$ & 8). These plots are linear with positive slope and this linearity is suggestive of the fact that the conduction mechanism in these glassy samples is of Poole-Frenkel type [10]. This linearity between $\ln(I)$ and $V^{1/2}$ is due to the absence of space charge resulting in a uniformity of field distribution between electrodes¹¹. The current, in case of Poole-Frenkel effect, will practically remain unchanged when polarities of electrodes are reversed. This is due to the fact that current does not depend upon the potential barrier at the interface. In case of bulk samples Poole-Frenkel conduction mechanism also holds good. The Poole-Frenkel 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 flow of current because of a capture and emission process, thereby becoming the dominant current mechanism.

Fig. 5 shows the composition vs conductivity (mho/cm) plots at room temperature of thin films under test. When Sn is added to the Se-Te system, it makes the bonds with both Se and Te. The bond energy of Sn-Se bond is 402.8 kJ/mol and of Sn-Te bond is 320.5 kJ/mol¹². Since, Sn is added at the cost of Te in the proposed series, so, the incorporation of Sn at the cost of Te additionally increases the probability of formation of Sn-Se bonds i.e. higher bond energy bonds are formed more and more, as the content of Sn is increased in Se-Te-Sn system. The effect of increasing concentration of Sn-Se bonds, having higher bond energy than Sn-Te bonds, is reflected as the increase in conductivity of these glasses as we increase Sn content from 2 at. wt. % to 6 at. wt. % in Se-Te-Sn system. The composition $Se_{75}Te_{19}Sn_6$ can be considered as the most chemically ordered critical composition at which the system possesses the highest concentration of Sn-Se bonds. As we go beyond 6 at. wt. % of Sn in the system, there may be a possibility of small size Sn cluster formation in the system that can act as scattering centers for carriers resulting in the decrease in conductivity.

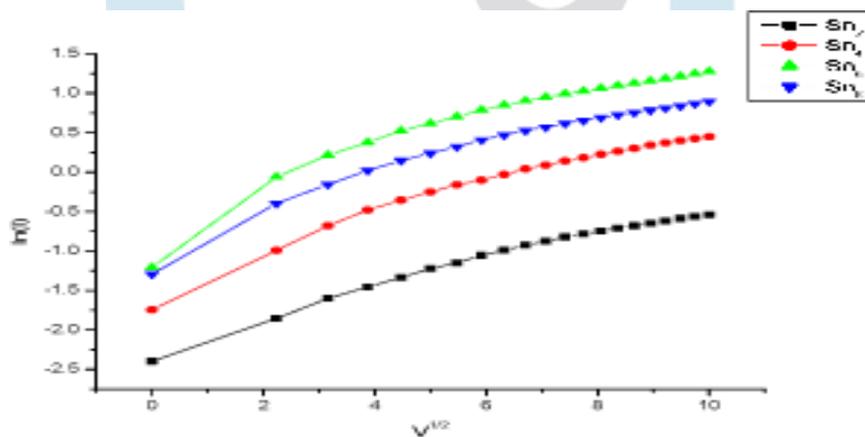


Fig. 4. Verification of Poole-Frenkel mechanism for $Se_{75}Te_{25-x}Sn_x$ ($x=2, 4, 6$ & 8) glassy thin films at room temperature

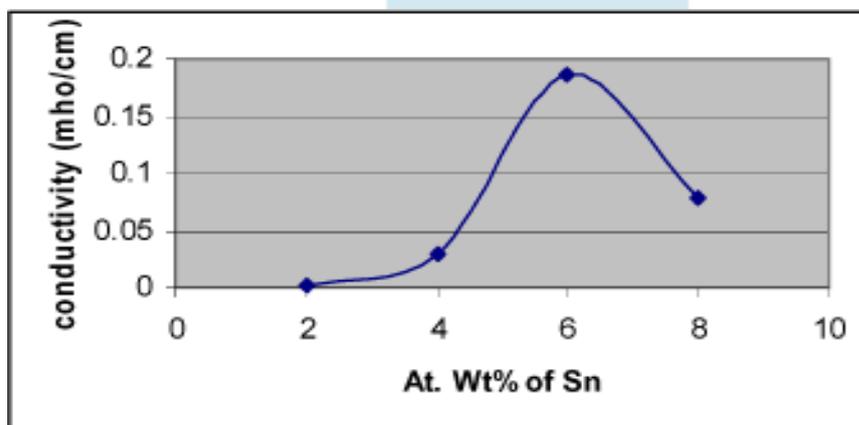


Fig. 5. Composition vs conductivity plots at room temperature

Conclusion

The following conclusions can be drawn from the present study:

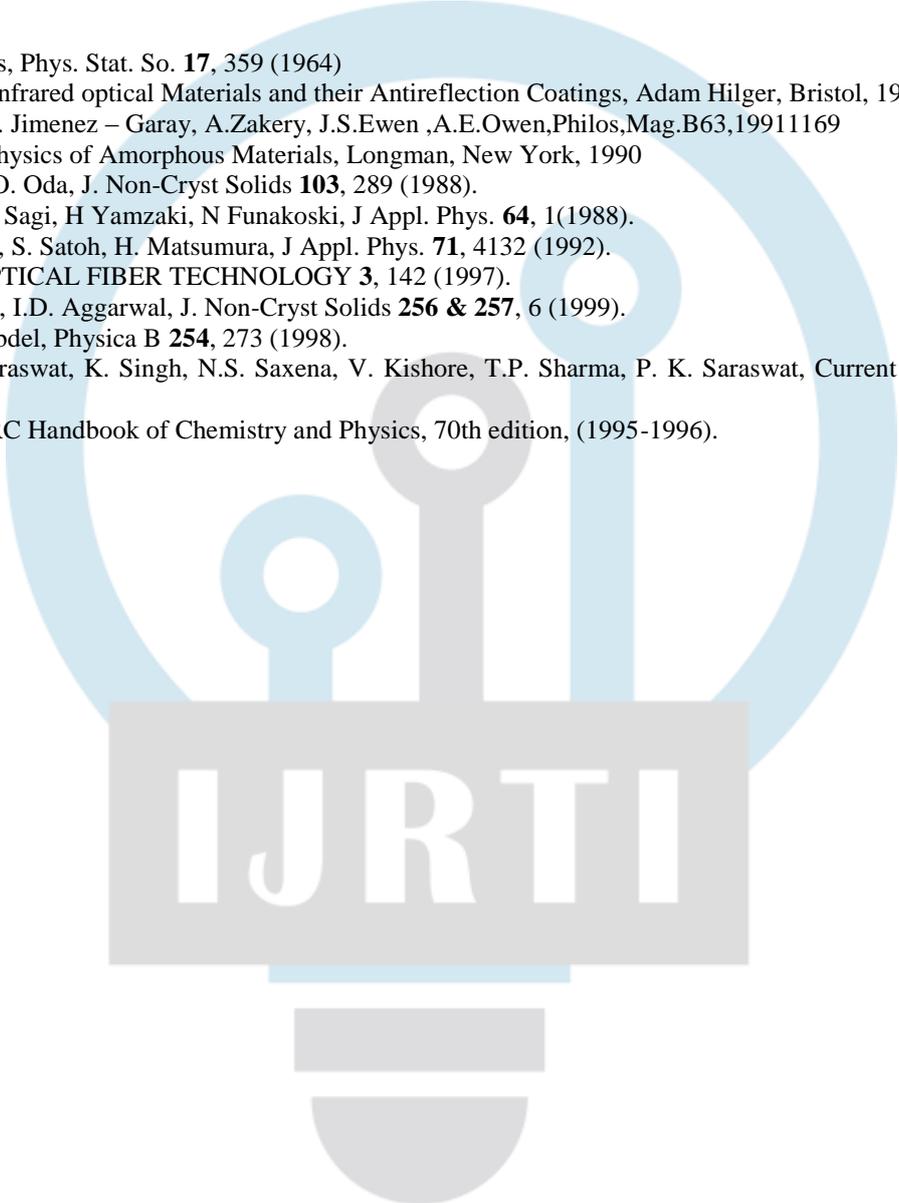
- -Films obtained are glassy in nature.
- The sample is semiconductor.
- $\text{Se}_{75}\text{Te}_{19}\text{Sn}_6$ is the most chemically ordered composition among the members of series under test.
- The conduction mechanism in glassy thin films is of Poole-Frenkel type.

Acknowledgement

The author extend his appreciation to the Dean Science J.P.U., Chapra, Prof. Udai Arvind, Prof. (Dr.) Rabindra Singh HOD, Deptt. Of Chemistry, J.P. University, Chapra, Rtd. Prof. & Former Head of Deptt. Of Chemistry, M.U., Bodh Gaya, Prof. (Dr.) R.P.S. Chauhan Saheb for their technical and administrative support.

References

1. B.T Kolomiets, Phys. Stat. So. **17**, 359 (1964)
2. J.A. Savage, Infrared optical Materials and their Antireflection Coatings, Adam Hilger, Bristol, 1985.
3. E.Marquez, R. Jimenez – Garay, A.Zakery, J.S.Ewen ,A.E.Owen,Philos,Mag.B63,19911169
4. S. R.Elliott, Physics of Amorphous Materials, Longman, New York, 1990
5. A. Onozuka, O. Oda, J. Non-Cryst Solids **103**, 289 (1988).
6. S Fugimori, S Sagi, H Yamzaki, N Funakoski, J Appl. Phys. **64**, 1(1988).
7. T. Katsuyama, S. Satoh, H. Matsumura, J Appl. Phys. **71**, 4132 (1992).
8. M. Asobe, OPTICAL FIBER TECHNOLOGY **3**, 142 (1997).
9. J. S. Sanghera, I.D. Aggarwal, J. Non-Cryst Solids **256 & 257**, 6 (1999).
10. R.M. Latif, Abdel, Physica B **254**, 273 (1998).
11. Vibhav K. Saraswat, K. Singh, N.S. Saxena, V. Kishore, T.P. Sharma, P. K. Saraswat, Current Applied Physics **6**, 14 (2006).
12. D.R. Lide, CRC Handbook of Chemistry and Physics, 70th edition, (1995-1996).



IJRTI