

# Dielectric Study of $\text{Te}_{15}(\text{Se}_{100-x}\text{Sb}_x)_{85}$ ( $x=1, 2, 4$ at.%) Amorphous Semiconductors

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**ABSTRACT:** The dielectric properties viz. dielectric constant and dielectric loss were studied in the frequency range (2-20kHz) and temperature range (313-349K) for  $\text{Te}_{15}(\text{Se}_{100-x}\text{Sb}_x)_{85}$  ( $x=1, 2, 4$  at.%) amorphous semiconductors prepared by melt quenching technique. The dielectric constant and dielectric loss were found to increase with temperature and decrease with the increase in frequency. Dielectric loss data analysis shows that Guintini's theory of dielectric dispersion based on two electron hopping over a potential barrier is applicable in these samples.

**KEY WORDS:** dielectric constant; dispersion; dielectric loss

## I. INTRODUCTION

Chalcogenide glasses are amorphous semiconductors exhibiting many useful electrical properties including threshold and memory switching [1]. Se in pure form is useful in applications like switching, memory and xerography [2-3]. Pure Se has disadvantages due to its low photosensitivity, low crystalline temperature and short life time. Addition of Te to Se produces higher photo sensitivity, lesser aging effects, higher crystallization temperature and greater hardness [4-5]. Te addition initially resists crystallization but at higher contents the crystallization occurs. The properties of binary alloys can be varied by adding a third element from group 5 of the periodic table so that the new materials are tailor made for specific purposes. We have chosen Sb as it can change the dielectric properties appreciably. Recently there has been a great thrust on the study of dielectric properties of amorphous chalcogenide glasses as these can lead to the understanding of conduction mechanism. A study of temperature dependence of dielectric constant particularly in the range of frequencies where dielectric dispersion occurs can be of great importance for the understanding of the nature and the origin of losses occurring in these materials [6].

## II. EXPERIMENTAL

Bulk multicomponent glassy materials  $\text{Te}_{15}(\text{Se}_{100-x}\text{Sb}_x)_{85}$  ( $x=1, 2, 4$  at.%) have been prepared by the melt quenching technique. Selenium, Tellurium and Antimony of high purity were weighed according to their atomic percentages and were sealed in cleaned quartz ampoules at a vacuum of  $10^{-3}$  Pa. The ampoules were kept in a vertical furnace and heated to a temperature of 1073 K at a heating rate of 3-4 K/min. The ampoules were heated at this temperature for 12 hours. During heating the ampoules were frequently rocked to make the melt homogenous. The quenching was done in ice cold water. The ingots of glassy materials were obtained after breaking the ampoules. The ingots were grinded to get the powder of the materials. The amorphous nature was confirmed as no sharp peak was observed in their x-ray diffraction spectra. The pellets were made from the powder by applying a load of 5 tons. Impedance Analyzer (Wayne Kerr 6500B) was used for dielectric properties measurements. The dielectric properties of the pellets were measured in the frequency range 2 kHz to 20 kHz and temperature range (313-349) K.

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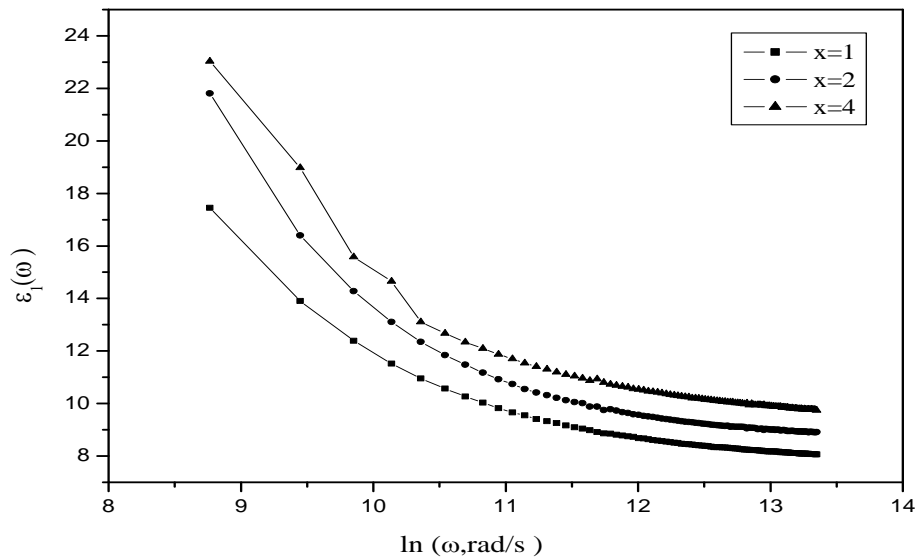
## III. RESULTS AND DISCUSSION

### 1. Frequency Dependence of Dielectric Constant:

The complex dielectric constant of a material is represented by two terms

$$\varepsilon = \varepsilon_1 + \varepsilon_2 \quad (1)$$

where  $\varepsilon_1$  is real part (dielectric constant) and  $\varepsilon_2$  the imaginary part (dielectric loss). The dielectric constant ( $\varepsilon_1$ ) versus frequency  $\ln(\omega)$  graph for x=1, 2, 4 at.% composition is shown in fig.1. The dielectric constant decreases with frequency for all compositions because when the applied field frequency is increased the dipoles will no longer be able to rotate sufficiently rapidly, so that their oscillations begin to lag behind those of the applied



**Fig.1** Frequency dependence of dielectric constant for x=1, 2, 4 at. %.

field. Larger values of dielectric constant are observed for increased Sb content. This behavior can be explained on the basis of electrode polarization effects [7-9]. Further, with increase in Sb content the weak Sb-Se bonds increases where as the strong Se-Se bonds decreases. The weak bonds being more responsive to the electric field increases the dielectric constant with increase in Sb content.

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## 2. Temperature Dependence of Dielectric Constant:

The dielectric constant has been found to increase with temperature for all compositions, shown for x=4 at. % in fig .2.

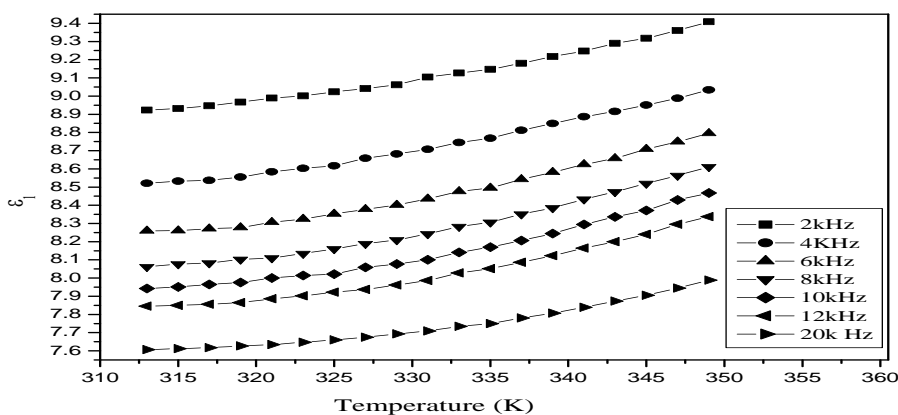


Fig.2 Temperature dependence of dielectric constant for x=4 at. %.

This increase is due to the fact that the dipoles in the polar material cannot orient themselves at low temperatures, however, when the temperature is increased the orientation of the dipoles is increased and hence increases the value of orientational polarizability and hence the dielectric constant [10].

## 3. Temperature Dependence of Dielectric Loss:

The dielectric loss increases with temperature for all compositions, shown for x=4 at. % in fig.3.

The loss is due to motion of ions over large distance. As the ions move they give their energy to lattice as heat which is proportional to ac conductivity. So, as temperature increases the ac conductivity increase and hence the dielectric loss. At low temperature the conduction, dipole and vibration losses have minimum value whereas at high temperature all these factors contribute to dielectric loss.

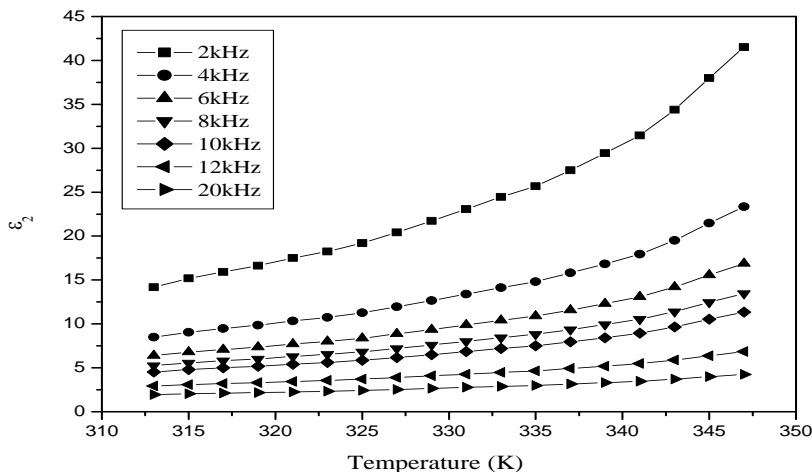


Fig.3 Temperature dependence of dielectric loss for x=4 at. %.

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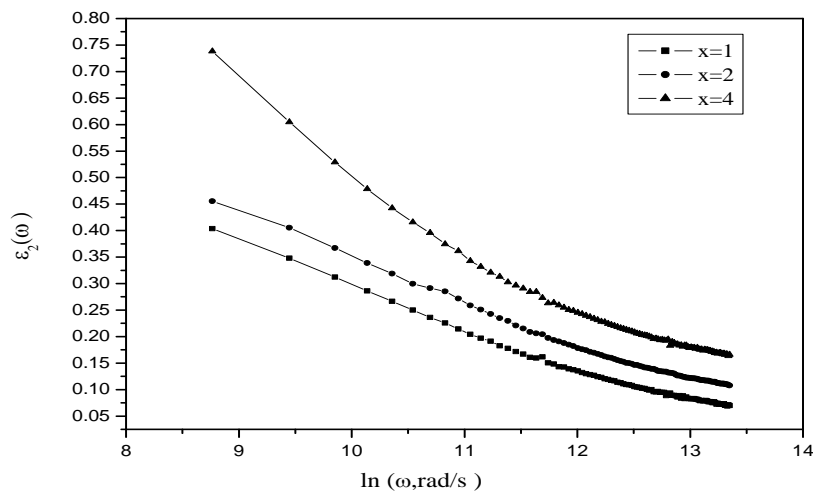
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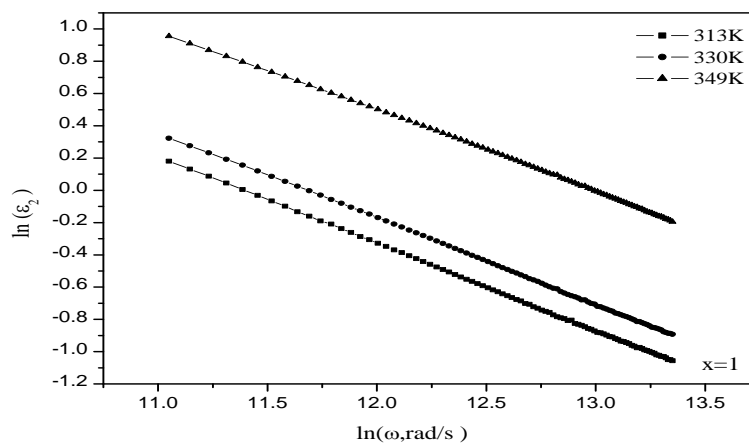
### 4. Frequency Dependence of Dielectric Loss:

Fig.4 shows that the dielectric loss ( $\epsilon_2$ ) decreases with frequency. The  $\epsilon_2$  obeys a power law with angular frequency ( $\omega$ ) for all compositions i.e.  $\epsilon_2 = B\omega^m$ . This behavior for x=1 sample is confirmed by the straight line graph, fig. 5, between  $\ln(\epsilon_2)$  and  $\ln(\omega)$ .



**Fig.4** Frequency dependence of dielectric loss for x=1, 2, 4 at. %.

Similar pattern is observed for other compositions. The power  $m$  calculated from the slope of this graph is negative for all compositions. Guintini [11] have proposed a model to dielectric relaxation in chalcogenide glasses based on Elliot's [12] idea of hopping of charge carrier over the potential barrier between the charged defect states.



**Fig.5**  $\ln(\epsilon_2)$  vs  $\ln(\omega)$  plot for x=1 at. %.

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According to this model the  $\varepsilon_2$  at a particular frequency and the temperature range in which the dielectric dispersion occurs is given by

$$\varepsilon_2(\omega) = (\varepsilon_0 - \varepsilon_\infty) 2\pi^2 N \left( \frac{ne^2}{\varepsilon_0} \right)^3 k_B T \tau_0^m W_M^{-4} \omega^m \quad (2)$$

where

$$m = -\frac{4k_B T}{W_M} \quad (3)$$

here,  $n$  is the number of electrons that hop,  $N$  is the concentration of localized sites,  $\varepsilon_0$  and  $\varepsilon_\infty$  are the static and optical dielectric constant respectively.  $W_M$  is the energy required to move the electron from a site to infinity. Thus a increase in frequency decreases the dielectric loss. Further, the decrease in dielectric loss with frequency may be due to migration of ions at low frequencies.

### IV. CONCLUSION

The dielectric constant and dielectric loss are found to increase with temperature and decrease with frequency for all compositions. Further, these dielectric properties increase with increase in Sb content in Se-Te glassy alloys.

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### REFERENCES

- [1] N. Suri, K.S. Bindra, and R. Thangraj, "Electrical conduction and photoconduction in  $\text{Se}_{80-x}\text{Te}_{20}\text{Bi}_x$  thin films", *J. phys. condens. Mater* 18 9129 2006.
- [2] J.M. Marshall, "Carrier diffusion in amorphous semiconductors", *Rep. Prog. Phys.*, 46 1235 1983.
- [3] S. Gautam, Anup Thakur, S.K. Tripathi and Navdeep Goyal, "Effect of silver doping on electrical properties of  $\alpha\text{-Sb}_2\text{Se}_3$ ", *J. Non-Cryst. Solids*, 353 1315 2007.
- [4] M.K. El-Mansy and I.L. Nuovo, "Effect of temperature and pressure on nonlinear conduction in Ge-Te-Se chalcogen glasses", *Cimento (D)*, 20 701 1998.
- [5] Y.L.A. El-Kady, "The glassy state of semiconducting system  $\text{Ge}_{10}\text{Sb}_x\text{Se}_{90-x}$ ", *Phys. Stat. Solidi (a)*, 175 577 1999.
- [6] A. Dwivedi, R. Arora, N. Choudhary and A. Kumar, "Dielectric relaxation in  $\text{Se}_{80}\text{Ge}_{20}$  and  $\text{Se}_{75}\text{Ge}_{20}\text{Ag}_5$  chalcogen glasses", *Semiconductor Physics, Quantum Electronics and Optoelect.* 8 45 2005.
- [7] A.R. Long, J. Macmillan, N. Balkan and S. Summerfield, "Electrical transport properties of amorphous  $\text{Se}_{78-x}\text{Te}_{22}\text{Bi}_x$  thin films", *Phil. Mag. B*, 58 153 1988.
- [8] J.R. Macdonald, "Analysis of dispersed, conducting system frequency response data", *J. Non-Cryst. Solids*, 197 83 1996.
- [9] M. Cutroni, A. Mandanici, A. Piccolis and C. Tomasi, "Dielectric response of some solid electrolytes at low and high frequencies", *Phil. Mag. B*, 71 843 1995.
- [10] N. Mehta, D. Sharma and A. Kumar, "Effect of Ag additive on the photoelectric and dielectric properties of Se-Te alloys", *Physica B Condens. Mater.*, 391 108 2007.
- [11] J.C. Guintini, J.V. Zanchetta, D. Julien, R. Eholie, P. Houenou, "Temperature dependence of dielectric losses in chalcogen glasses", *J. Non-Cryst. Solids* 45 57 1981.
- [12] S.R. Elliot, "The mechanism for a.c. conduction in chalcogenide semiconductors: Electronic or atomic", *Phil. Mag. B*, 40 507 (1979).