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# Study of Electrical Conductivity of Chalcogenide Glasses of Ge-Te-Se System

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**Abstract**: *The Ge-Te-Se Samples were prepared on the basis of percentage weight composition. The ac conductivity chalcogenide glasses of Ge-Te-Se system have been studied at temperatures 300 to 450 K and over a wide range of frequencies 50 Hz to500 KHz. Experimental results shows that the ac conductivity depend on temperature, frequency and Se content. In the lower frequency region, the conductivity is constant and is taken as dc conductivity $\sigma_{dc}$. Theoretically this behavior is modeled by transport taking place through infinite random free-energy barriers. The conductivity is found to obey a power relation, $\sigma_{ac} \approx \omega^s$. It is observed that as temperature increases value of frequency exponent s decreases. Thus experimental results agree with the correlated barrier hopping model (CBH).*

**Keywords:** Ge-Te-Se glasses, ac conductivity, correlated barrier hopping (CBH)

## I. INTRODUCTION

Chalcogenide glasses have been recognized as a promising materials for many applications [1,2]. Chalcogenide glasses have recently attracted the researchers interest, since they exhibit several peculiar phenomenon useful for devices such as electrical threshold and memory switching [3,4] image storage and photoresistors. Measurement of AC conductivity of amorphous chalcogenide semiconductors has been extensively used to understand the conduction process in these materials [5]. Generally, the undoped chalcogenide lasses show low values of electrical conductivity, which could mean a serious limit to their technological applications and electrical measurements. Certain additives are used to improve these properties. Due to higher photoresistivity, higher crystallization temperature, great hardness and smaller aging effects, more importance has been given to Selenium-tellurium alloys as compared to pure amorphous Se [6]. When germanium is added to Ge-Se system then there exist structural changes in the material which in turn modify band structure, and hence the electrical properties of the material.

The aim of this study is to find out the effect of Selenium content on the electrical conductivity of the Ge-Te-Se system and characterize its dependence on temperature. Here we have studied three samples of $Ge_{21}Te_{79-x}Se_x$ composition: x = 12, 16,18 wt% and respective samples are denoted by $S_1$, $S_2$ and $S_3$.With Ge set at a fix content and Te part of the Ge-Te content is substituted by Se.

## II. EXPERIMENTAL PROCEDURE

$Ge_{21}Te_{79-x}Se_x$ samples with x = 12, 16, 18 wt% and respective samples are denoted by $S_1$, $S_2$ and $S_3$ were prepared on the basis of the weight percentage composition. High purity chemicals (99.99%) of the desired fractions were mixed together in a silica ampoule. The ampoule were heated in a muffle furnace of ability to heat to the maximum temperature of 1200 ± 20 $^0$C. To ensure good homogeneity, ampoules were heated for 6 hours at a temperature of 1200 $^0$C with continuous shaking. The ampoules kept horizontally, were then quenched in ice-water to ensure constant cooling rate. Samples in the form of small discs of thickness ≈ 0.05 cm were produced. Each disc has a thickness to about 0.05 cm and a diameter of about 1.0 cm. Both faces of the sample discs were painted with air-drying conducting silver paste to attain good electrical contacts.

The impedance, in terms of modulus |z| and phase angle ϕ, was measured using a TESLA BM 507 impedance meter, in the frequency range 50 Hz – 500 KHz and at various temperatures. The temperatures were chosen from the range 300-420 K. the resistance R and capacitance C were calculated by using relationship: $R = |z| \cos\phi$ and $C = \sin\phi / \omega |z|$, where, ω is the angular frequency. The AC conductivity has been calculated by the relation $\sigma_{ac} = 1/R.t/A$, where t and A are the thickness and cross-sectional area of the sample respectively.

## III. RESULTS AND DISCUSSIONS

The total measured conductivity as a function of frequency in the frequency range 50 Hz – 500 kHz at different temperatures in the range 300 – 420 K, for sample $S_2$, selected as an example of a typical Ge-Te-Se glass is as shown in figure 1.

According to the measured frequency conductivity behavior can be divided. In the lower frequency region, the conductivity is constant and is taken as dc conductivity $\sigma_{dc}$. Theoretically this behavior is modeled by transport taking place through infinite random free-energy barriers. The conductivity is found to obey a power relation, $\sigma_{ac} \approx \omega^s$, where s is a function of temperature. This behavior is modeled as transport is dominated by conduction hopping through infinite clusters [7]. At higher frequencies, the conductivity tends to stability. The curve of log $\sigma_{tot}$ vs log *f* becomes nearly linear at higher temperature. This behavior suggests dc conduction. Other compositions also shows same trend. Hence the total conductivity is the sum of two components: dc conductivity $\sigma_{dc}$ which is independent of frequency; and frequency dependent conductivity $\sigma_{ac}$, i.e.

$$\sigma_{tot}(\omega) = \sigma_{dc} + \sigma_{ac} \qquad \text{.............................. (1)}$$

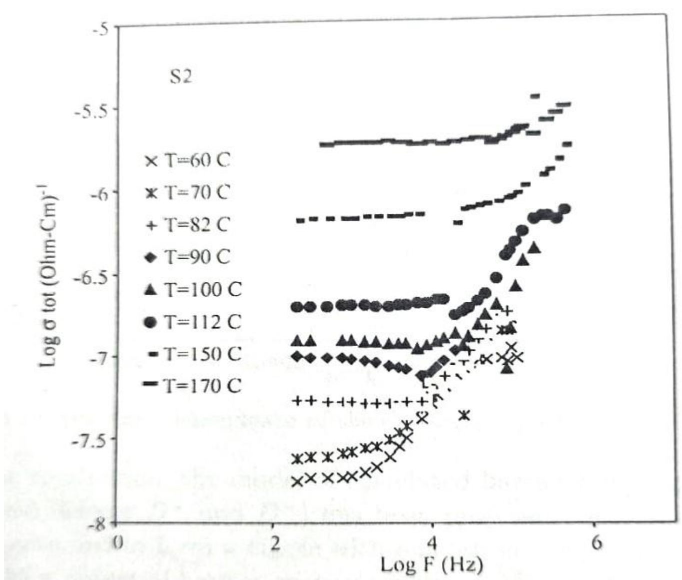


Figure 1. Total conductivity as a function of frequency at different temperatures

By extrapolating $\sigma_{tot}(\omega)$ to $\omega = 0$, the values of $\sigma_{dc}$ are obtained and plotted as a function of the reciprocal of temperature for each sample. The graph between log ($\sigma_{dc}$) vs 1/T for three samples $S_1$, $S_2$ and $S_3$ is as shown in figure 2. Here it is observed that sample $S_1$ exhibits a higher conductivity curve than other samples $S_2$ and $S_3$. The conductivity curves for each sample are temperature dependent. This causes change in the structure of the glass matrix, which in turn affects the electrical conductivity.

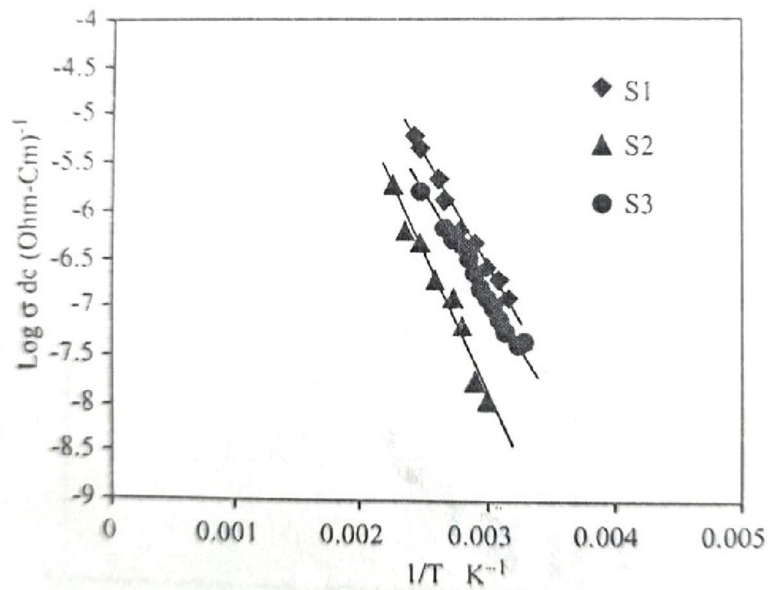


Figure 2. The dc conductivity as a function of reciprocal of temperature for different samples

Figure 3 shows the graph between values of frequency exponent s and temperature T for samples $S_1$, $S_2$ and $S_3$. It is observed that as temperature increases value of frequency exponent s decreases. It suggests that s is temperature dependent for each composition of the system. Thus experimental results agree with the correlated barrier hopping model (CBH), for a critical test of the CBH models comes from the temperature dependence of the ac conductivity and the frequency exponent s [8].

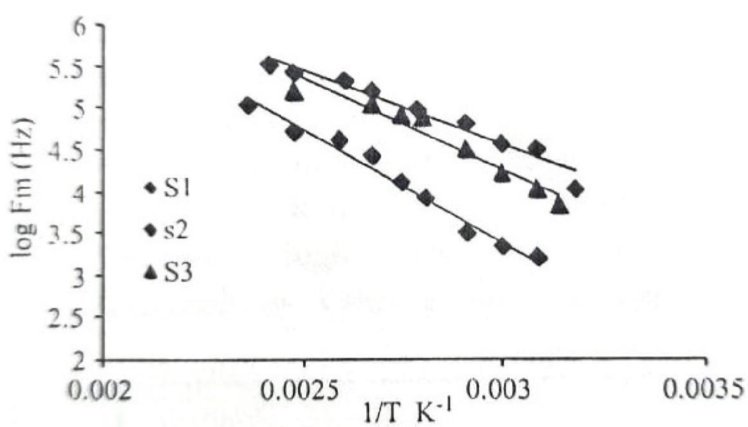


Figure 3. Temperature dependence of exponent s for different samples

### 3.2 Temperature dependence of the conductivity $\sigma_{tot}$

The variation of total measured conductivity $\sigma_{tot}(\omega) = \sigma_{dc} + \sigma_{ac}$ with the reciprocal temperature at different frequencies, for sample $S_2$ chosen as an example is as shown in figure 4. An Arrhenius plot of log σ vs 1/T is obtained with two different slopes at 1 KHz for each sample. Here, two different thermally activated relaxation processes identified with translational jump diffusion and a localized reorientation motion of the carriers within a given neighborhood [9]. In first process, at low temperature conductivity depends on frequency, while at high temperature is independent of frequency in second process. A typical Arrhenius type relationship gives the dependence of the electrical conductivity on temperature.

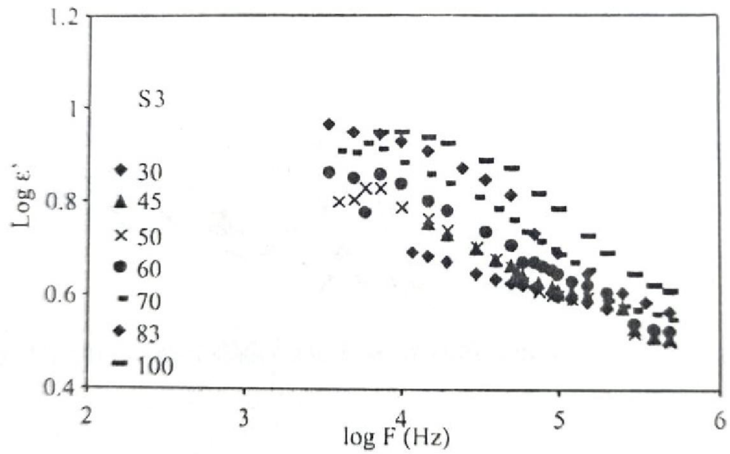


Figure 4. Temperature dependence of total conductivity at different frequencies for sample $S_2$.

$$\sigma_{tot}\, T = A \exp(-E_1 / kT) + B \exp(-E_2 / kT) \quad \ldots\ldots\ldots.. \quad (3)$$

where A and B are constants, $E_1$ and $E_2$ are the high and low temperature activation energies and k is Boltzmann constant. It is observed that the values of $E_1$ depend on the composition whereas the values of $E_2$ are nearly same for all compositions. The High temperature activation energy E1 values may be due to the existence of defects, which are essentially same in glasses.

## IV. CONCLUSION

The ac conductivity of Ge-Te-Se glasses have been studied at different temperatures and frequencies. Analysis of the result shows that the electronic conduction in Ge-Te-Se glasses takes place due to bipoloron hopping which is in accordance with correlated barrier hopping (CBH) model. Thermal agitation induces new types of defects which take part in the single poloran-hopping conduction process.

The Activation energy values for the temperature dependence of the total conductivity of the Ge-Te-Se glasses, which characterize the low temperature process, depend on the system structure, while the high temperature activation energy values seem to be independent of the composition. This familiar behavior results from space charge build up near electrodes.

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