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Dielectric relaxation in glassy $Se_{80-x}Te_{20}Ge_x$

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Dielectric relaxation studies have been made in glassy $Se_{80-x}Te_{20}Ge_x$ alloys where $0 \le x \le 20$. The measurements of dielectric constant (ϵ') and dielectric loss (ϵ'') are made in the audio frequency range (1 kHz to 10 kHz) at various temperatures from 30°C to 150°C. The results indicate that the dielectric dispersion occurs in the above frequency and temperature range. An analysis of the results shows that the dielectric losses are dipolar in nature and can be understood in terms of hopping of charge carriers over a potential barrier.

1. Introduction

Dielectric relaxation studies are important to understand the nature and the origin of dielectric losses which, in turn, may be useful in the determination of structure and defects in solids. Dielectric measurements on chalcogenide glasses have indicated that the dielectric dispersion does exist [1–6] in these glasses at low frequencies even though these materials are covalently bonded solids. The origin and the nature of dielectric losses in these materials have, therefore, been a matter of curiosity.

The present paper reports the dielectric relaxation studies in glassy $Se_{80-x}Te_{20}Ge_x$ where $0 \le x \le 20$. Temperature and frequency dependences of dielectric constant (ϵ') and dielectric loss (ϵ'') are studied in the frequency range 1 kHz to 10 kHz and temperature range 30°C to 150°C.

2. Experimental

Glassy alloys of $Se_{80-x}Te_{20}Ge_x$ ($0 \le x \le 20$) were prepared by a quenching technique. 5 N purity materials were weighed in accordance with their atomic percentages and then sealed in quartz ampoules (length ~5 cm, internal dia ~8 mm) in a vacuum $\sim 10^{-5}$ Torr. The sealed ampoules were kept inside a furnace where they were rocked frequently at 950°C for 10 hours. Quenching was done by dropping the ampoules in ice cooled water and the glassy nature was verified by X-ray diffraction.

The glassy alloys thus prepared were ground to a fine powder and pellets (dia ~6 mm and thickness ~1 mm) were obtained by compressing the powder in a die at a load of 3×10^4 N.

For the dielectric measurements, the pellets were mounted in between two steel electrodes of a metallic sample holder. The temperature was measured by mounting a thermo-couple very near to the sample. A vacuum $\sim 10^{-3}$ Torr was maintained over the entire range of temperature. ϵ' and ϵ'' were measured at three different frequencies (1 kHz, 5 kHz and 10 kHz) while maintaining a constant temperature inside the sample holder. Temperature was varied from 30°C to 150°C.

Parallel capacitance and conductance were measured simultaneously using a GR 1620 AP capacitance measuring assembly and the ϵ' and ϵ'' were calculated. Three terminal measurements were performed to avoid the effect of stray capacitances.

3. Results and discussions

The temperature dependence of ϵ' and ϵ'' is studied at three fixed frequencies (1, 5 and 10 kHz) for glassy $Se_{80-x}Te_{20}Ge_x$ (x = 0, 5, 10, 15 and 20). Figs 1 and 2 show the results for glassy $Se_{80}Te_{20}$ and $Se_{65}Te_{20}Ge_{15}$. The results for other glassy alloys were similar in nature. It is clear from Figs 1 and 2 that ϵ' and ϵ'' both increase with the increasing temperature; the increase being more at low frequencies. This indicates that dielectric dispersion exists in these glasses in the operating range of temperature.

An analysis of the frequency dependent dielectric loss shows that ϵ'' follows a power law with angular frequency (ω) in all the glassy alloys studied, i.e. $\epsilon'' = A\,\omega^m$. Figs 3 and 4 confirm this behaviour in case of glassy $Se_{80}Te_{20}$ and $Se_{65}Te_{20}Ge_{15}$ respectively where $\ln \epsilon''$ vs $\ln \omega$ curves are found to be straight lines at various temperatures. The results for other glassy alloys were similar in nature. The power m, calculated from the slopes of $\ln \epsilon''$ vs $\ln \omega$ curves, is found to be negative at all temperatures in all the glassy alloys studied here.

Guintini *et al.* [7] have recently proposed a model for dielectric relaxation in chalcogenide glasses. This model is based on Elliott's idea [8] of hopping of charge carriers over the potential barrier between charged defect states. Each pair of site is assumed to form a dipole which has a relaxation time depending on its activation energy [9, 10].

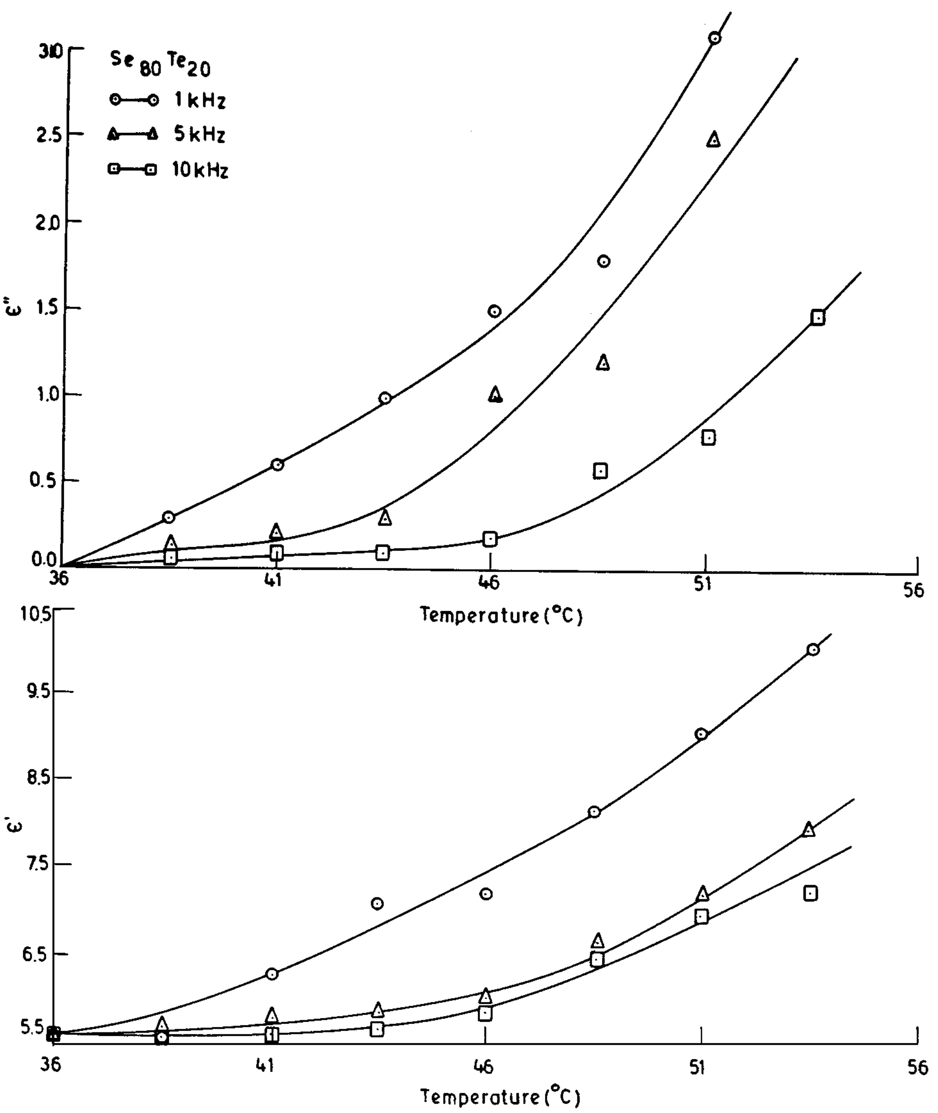

Figure 1 Temperature dependence of dielectric constant and dielectric loss in glassy $Se_{80}Te_{20}$.

According to the above model [7], ϵ'' at a particular frequency in the temperature range where dielectric dispersion occurs, is given by

$$\epsilon''(\omega) = (\epsilon_0 - \epsilon_\infty)2\pi^2 N\left(\frac{ne}{\epsilon_0}\right)^2 kT\tau_0^m W_M^{-4}\omega^m \qquad (1)$$

where

$$m = -\frac{4kT}{W_M} \qquad (2)$$

Here, n is the number of electrons that hop, N is the concentration of localized sites, ϵ_0 and ϵ_∞ are the static and optical dielectric constants respectively. W_M is the energy required to move the electron from a site to the infinity.

According to Equation 1, ϵ'' should follow a power law with frequency and the values of m should be negative and linear with T as given by Equation 2.

In the present case also, ϵ'' follows a power law with frequency and the values of m are negative. The linear relation with temperature can, however, not be ascertained from the present results due to the narrow temperature range of measurements used.

The composition dependence of the dielectric parameters (ϵ' and ϵ'') is shown in Fig. 5. It is clear from this figure that ϵ' and ϵ'' both decrease with an increase of Ge concentration in glassy $Se_{80-x}Te_{20}Ge_x$. As the dielectric loss in these glasses depends upon the total number of localized sites, the decrease of ϵ'' with the increase of Ge concentration indicates the decrease in the density of defect states on addition of Ge to $Se_{80}Te_{20}$ binary system.

4. Conclusions

Temperature and frequency dependences of dielectric constant and loss are studied in glassy $Se_{80-x}Te_{20}Ge_{20}$ ($0 \le x \le 20$). Dielectric dispersion is found to occur in these alloys in the audio frequency range in the temperature range 30°C–150°C. A detailed analysis of the results showed that dielectric dispersion is dipolar in nature. A possible explanation is given in terms of the hopping of charge carriers over a potential barrier between charged defect states. The decrease of ϵ'' with Ge concentration indicated the decrease in the defect density on the addition of Ge to Se-Te system.

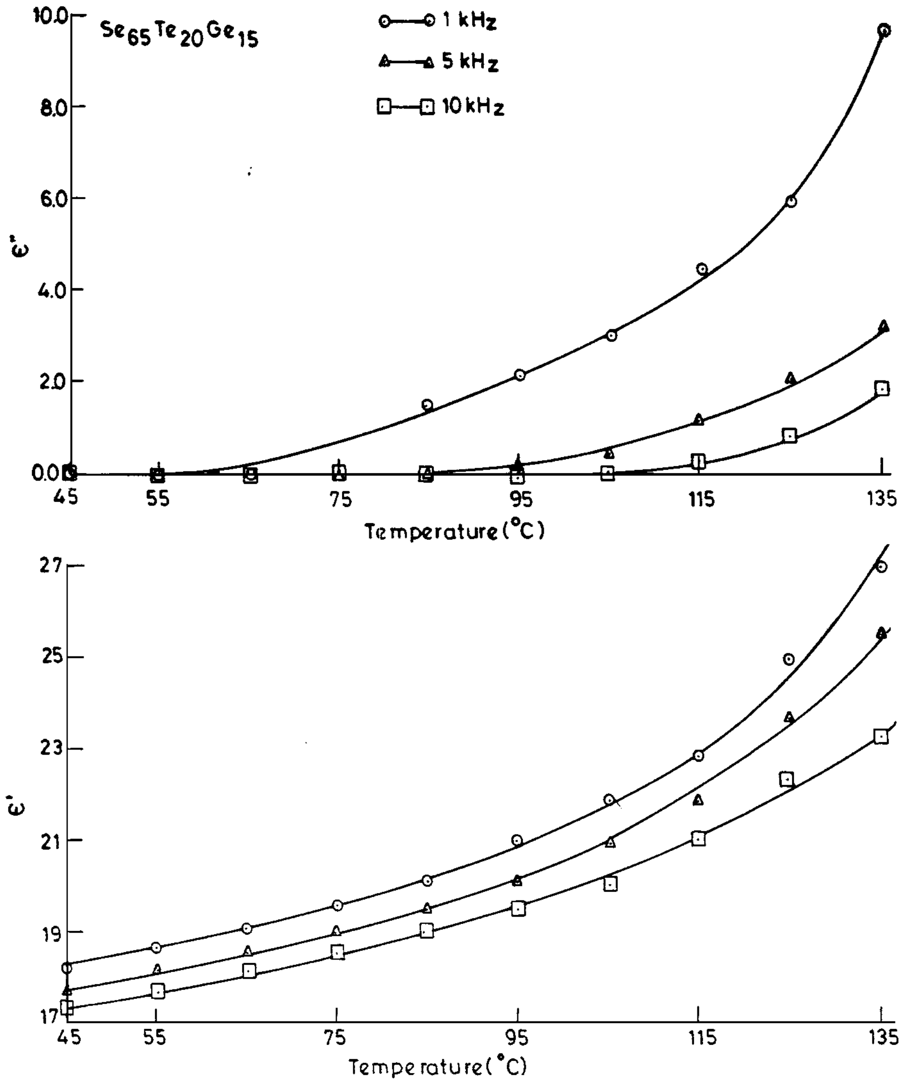

Figure 2 Temperature dependence of dielectric constant and dielectric loss in glassy $Se_{65}Te_{20}Ge_{15}$.

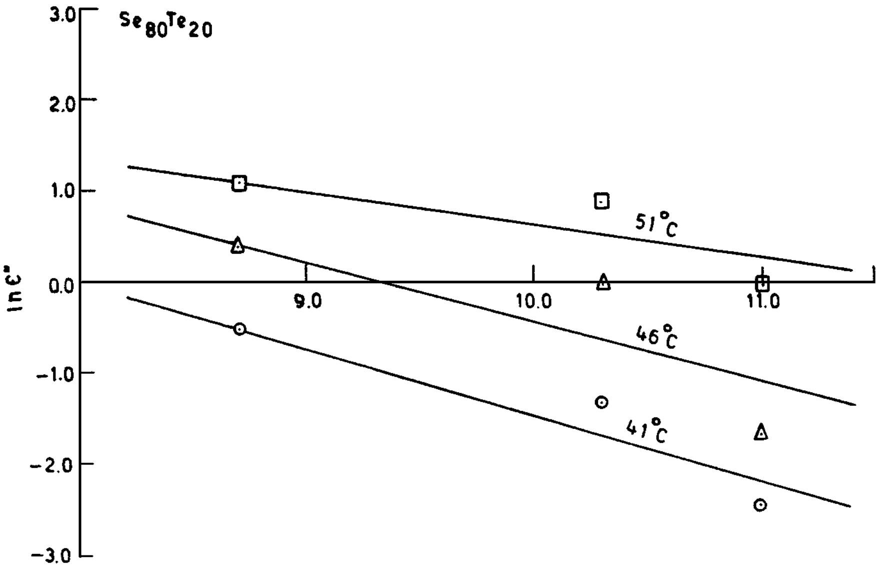

Figure 3 Frequency dependence of dielectric loss in glassy $Se_{80}Te_{20}$.

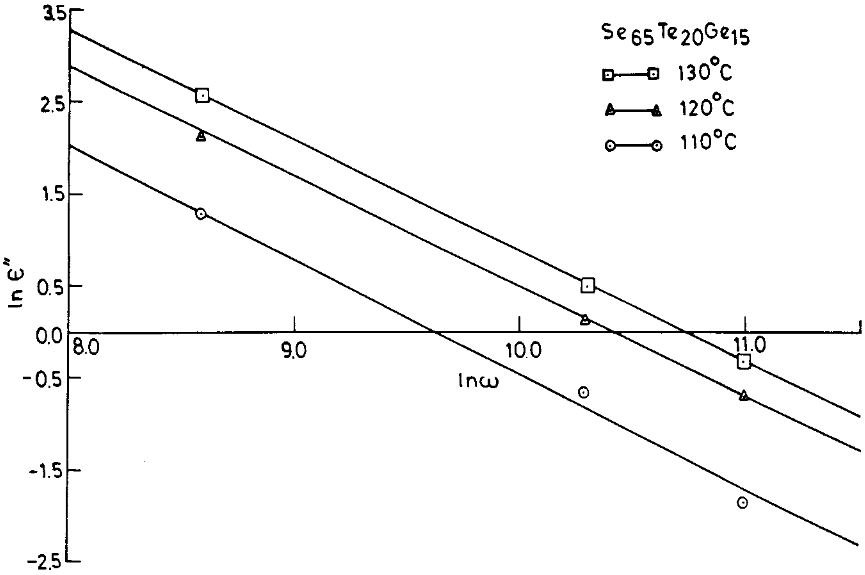

Figure 4 Frequency dependence of dielectric loss in glassy $Se_{65}Te_{20}Ge_{15}$.

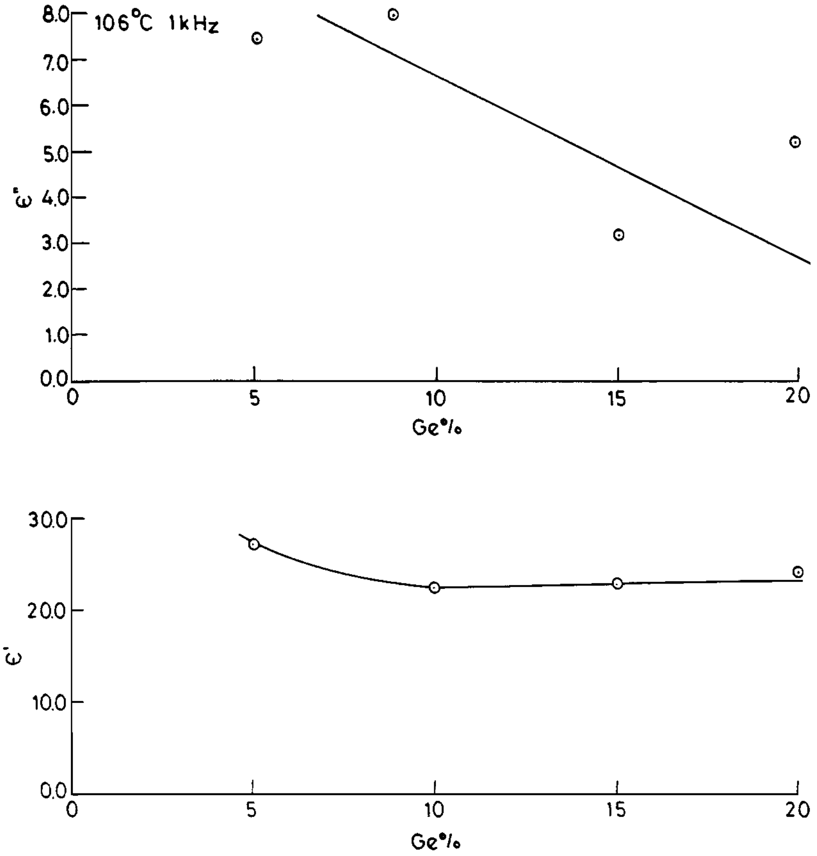

Figure 5 Composition dependence of dielectric constant and dielectric loss in glassy $Se_{80-x}Te_{20}Ge_x$.

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