

HIGH FIELD CONDUCTION STUDIES IN a- $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ THIN FILMS IN DARK AS WELL AS IN PRESENCE OF LIGHT

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Glassy alloys of $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0; 5$) were prepared by the quenching technique. Amorphous thin films of these alloys are prepared by the vacuum evaporation technique. Current – voltage (I-V) characteristics have been studied at various temperatures in dark as well as in presence of light. For this purpose, a dc voltage (0 – 300 V) is applied across the film. I-V characteristics show that, at low electric fields, an ohmic behaviour is observed. However, at high electric fields ($E \sim 10^4$ V/cm), the current becomes super ohmic. Analysis of the data shows the absence of space charge limited currents in a- $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ thin films as $\ln I/V$ vs V curves are not found to be straight lines with good correlation coefficient. Instead, $\ln I$ vs $V^{1/2}$ curves are found to be straight lines having good correlation coefficient. The slope of these curves decreases with the increase in temperature. A more detailed analysis shows that the dominated mechanism of the conduction is of Poole - Frenkel type in dark as well as in presence of light.

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1. Introduction

Due to their wide range of applications in various solid state devices e.g. switching and memory, image converters and optical mass memories etc, chalcogenide glasses have received a lot of attention from scientists and engineers. The common feature of these glasses is the presence of localized states in the mobility gap due to the absence of long range order as well as various inherent defects. The density of localised state in the mobility gap controls many physical properties of amorphous semiconductors.

Due to their low conductivity, amorphous semiconductors are most suitable for high field conduction studies as the joule heating is negligibly small in these materials at moderate temperatures. Some such studies have been reported [1-11] in chalcogenide glassy semiconductors and the results have been interpreted in terms of the space charge limited currents [2-8] or in terms of high field conduction due to the Poole-Frenkel effect of screened charged intrinsic defects and field induced lowering of energy barriers for the charge carrier hopping within localized states at the band edges [1,9,10,11].

The present paper reports the high field conduction in glassy $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0; 5$) thin films in dark and in presence of light.

2. Experimental

Glassy alloys of $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0; 5$) are prepared by quenching technique. High purity (99.999 %) materials are weighed according to their atomic percentages and are sealed in quartz ampoules (length ~ 5 cm and internal dia ~ 8 mm) with a vacuum $\sim 10^{-5}$ Torr. The ampoules

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containing the materials are heated to 800 °C and held at that temperature for 10 - 12 hours. The temperature of the furnace is raised slowly at a rate $\sim 3 - 4$ °C/min. During heating, all the ampoules are constantly rocked, by rotating a ceramic rod to which the ampoules are tucked away in the furnace. This is done to obtain homogenous glassy alloys.

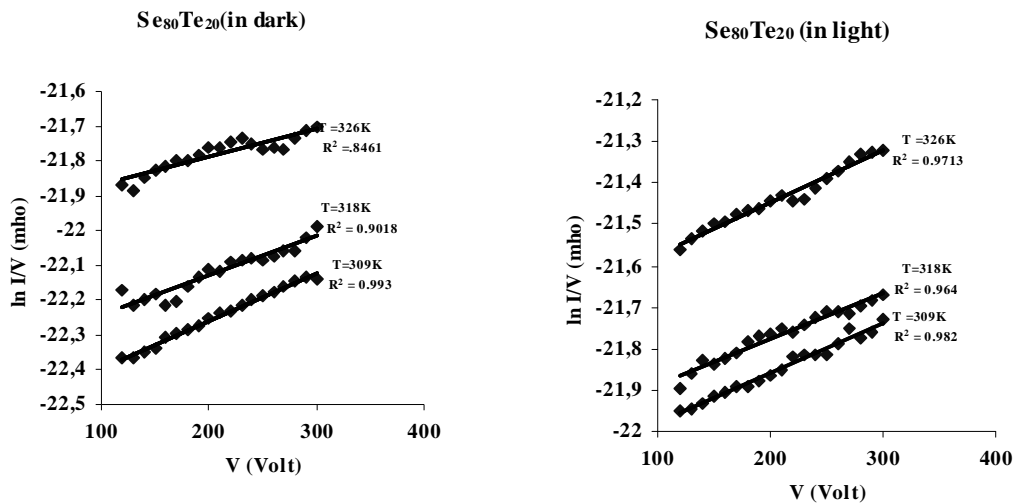


Fig. 1. Plots of $\ln I/V$ vs V for glassy $\text{Se}_{80}\text{Te}_{20}$ alloy at various temperatures in dark and in presence of light.

After rocking for about 10 hours, the obtained melts are cooled rapidly by removing the ampoules from the furnace and dropping to ice-cooled water. The quenched samples are taken out by breaking the quartz ampoules.

Thin films of these glasses are prepared by vacuum evaporation technique keeping glass substrates at room temperature. Vacuum evaporated indium electrodes at bottom are used for the electrical contact. The thickness of the films is ~ 500 nm. The co-planar structure (length ~ 1.2 cm and electrode separation ~ 0.1 mm) are used for the present measurements.

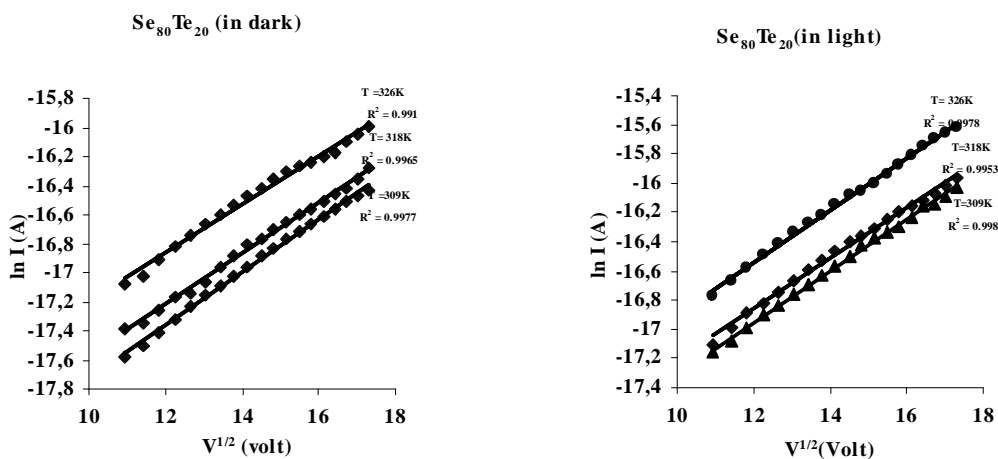


Fig. 2. Plots of $\ln I$ vs $V^{1/2}$ for glassy $\text{Se}_{80}\text{Te}_{20}$ alloy at various temperatures in dark and in presence of light.

For the measurements of high field conduction, thin film samples were mounted in a specially designed sample holder. A vacuum $\sim 10^{-2}$ Torr was maintained throughout the measurements. A d.c. voltage (0 to 300 V) was applied across the sample and the resultant current was measured by a digital electrometer (Keithely model: 614). $I - V$ characteristics were measured at various fixed temperatures (293-329K) in these films in dark as well as in presence of light. The temperature of the films was controlled by mounting a heater inside the sample holder and measured

by a calibrated copper- constantan thermocouple mounted very near to the films. Before measuring I – V characteristics, thin films were annealed in a vacuum $\sim 10^{-2}$ Torr near glass transition temperature for two hours in the same sample holder.

3. Results and discussion

A study of I-V characteristics is a matter of importance for properly analyzing the conduction mechanism in thin films. In the present work, I-V characteristics of thin films of $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0,5$) were examined at various temperatures (293-329K) in dark as well as in presence of light. At low fields ($<10^3$ V/cm), an ohmic behaviour is observed in both the samples. However, at higher fields ($\sim 10^4$ V/cm), non-ohmic behaviour is observed.

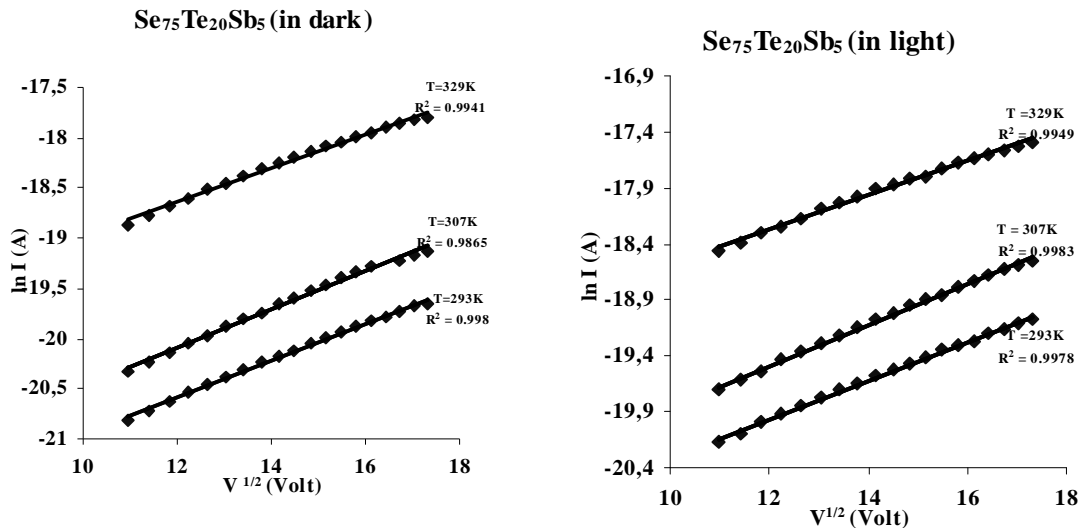


Fig. 3. Plots of $\ln I$ vs $V^{1/2}$ for glassy alloy $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ at various temperatures in dark and in presence of light.

According to the theory of space charge limited conduction, in the case of a uniform distribution of localised states $g(E) = g_0$, the current (I) at a particular voltage (V) is given by the following relation [12]

$$I = (eA\mu n_0 V/d) \exp(SV) \quad (1)$$

Where d is the electrode spacing, n_0 is the density of the thermally generated charge carriers, μ is the mobility, e is the electronic charge, A is the area of cross section of thin films and S is given by

$$S = 2\varepsilon_r \varepsilon_0 / e g_0 k T d^2 \quad (2)$$

As evident from eqs. (1) and (2), in case of space charge limited conduction, the $\ln I/V$ vs V curves should be a straight line and slope (S) of these curves should decrease linearly with the increase of temperature.

In the present case, at higher fields, $\ln(I/V)$ vs V curves are not found to be straight lines with good correlation coefficient at all the measuring temperatures in dark as well as in presence of light. The results for a- $\text{Se}_{80}\text{Te}_{20}$ in dark as well as in presence of light are plotted in Fig. 1. Similar results were obtained for $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ in dark as well as in presence of light (results are not shown here). The slope of $\ln(I/V)$ vs V curves also does not decrease linearly with the increase in temperature. These results indicate the absence of space charge limited conduction in present samples.

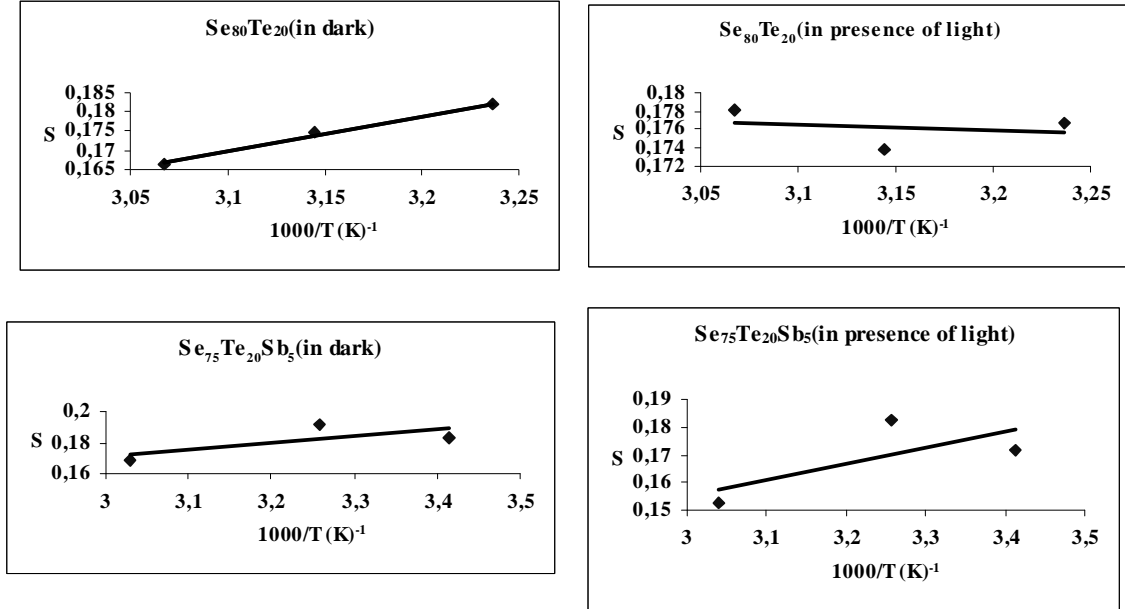


Fig. 4. Plots of S vs $1000/T$ for glassy $\text{Se}_{80}\text{Te}_{20}$ and $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ alloys in dark and in presence of light.

Several amorphous dielectric and semiconducting thin films exhibit at high electric field E , current vs voltage characteristics of the form [13-17]

$$I = I_0 \exp(\beta E^{1/2} / k T) \quad (3)$$

where β is a constant given by

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

When $\lambda = 1$, eqn. (2) reduces to the Poole-Frenkel coefficient given by

$$\beta_{\text{PF}} = (e^3 / \pi \epsilon_0 \epsilon_r)^{1/2} \quad (5)$$

When $\lambda = 4$, eqn. (2) reduces to the Schottky coefficient given by

$$\beta_{\text{Sch}} = (e^3 / 4\pi \epsilon_0 \epsilon_r)^{1/2} \quad (6)$$

It is clear from the above that in Schottky as well as in case of Poole-Frenkel effect, $\ln I$ vs $V^{1/2}$ curves are expected to be straight lines following Eq (3). However, there are some differences [18] which distinguish between the Schottky effect and the Poole-Frenkel effect, e.g., in case of Schottky effect $\ln I/T^2$ vs $1/T$ curves for various fixed voltages would be linear. However, such curves will not show linearity in Poole-Frenkel effect. Moreover, the extrapolated portion of $\ln I$ vs $V^{1/2}$ curves should pass through a single point at zero applied voltage at different temperatures in case of Schottky effect. This does not happen in case of Poole-Frenkel effect. The value of the activation energy is expected to be greater than or equal to the 0.98 eV in case of Schottky effect while it is less than 0.98 eV in case of Poole-Frenkel effect.

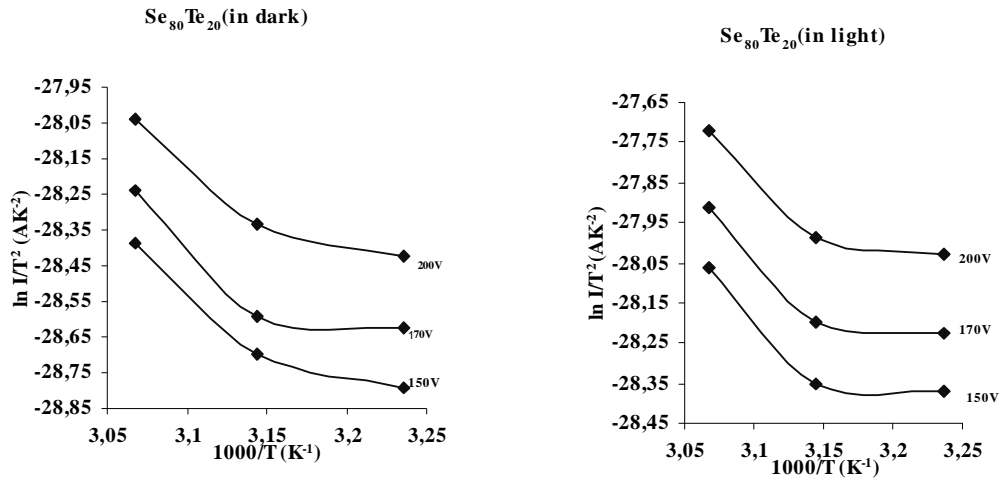


Fig. 5. Plots of $\ln(I/T^2)$ vs $1000/T$ for glassy $\text{Se}_{80}\text{Te}_{20}$ alloy at various voltages in dark and in presence of light.

In the present samples, $\ln I$ vs $V^{1/2}$ curves are found to be straight lines with good correlation coefficient at various temperatures in dark as well as in presence of light. To demonstrate this, we have plotted such curves for amorphous thin films of a- $\text{Se}_{80}\text{Te}_{20}$ and a- $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ in Figs. 2 and 3 in dark as well as in presence of light. The slope (S) of these curves decreases linearly with temperature for both the samples in dark as well as in presence of light (see Fig. 4). To distinguish between Schottky and Poole-Frenkel conduction, we have plotted $\ln I/T^2$ vs $1000/T$ curves for various fixed voltages in dark as well as in presence of light, which were found to be non-linear for both the alloys. Such curves for both glassy alloys are shown in Figs. 5 and 6. The extrapolated portion of $\ln I$ vs $V^{1/2}$ curves does not pass through a single point at zero applied voltage at different temperatures.

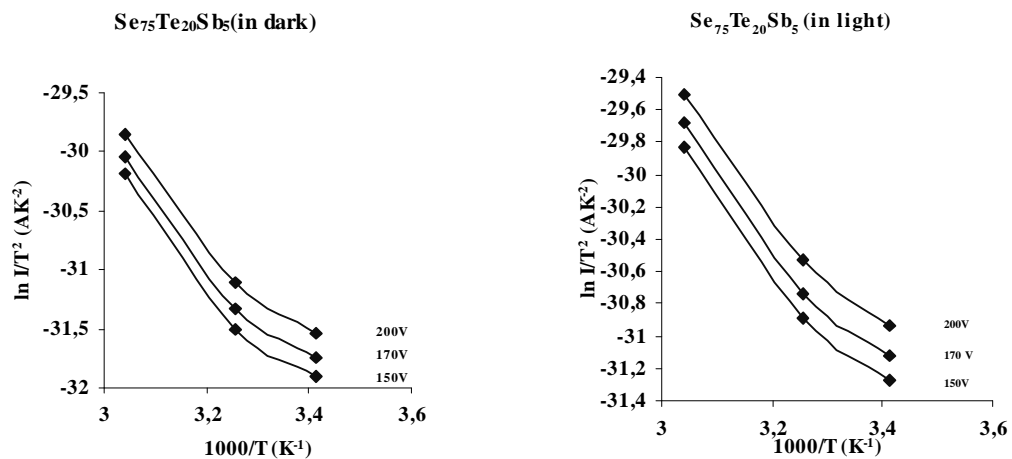


Fig. 6. Plots of $\ln(I/T^2)$ vs $1000/T$ for glassy $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ alloy at various voltages in dark and in presence of light.

As mentioned earlier, these results indicate that conduction is Poole-Frenkel type in the present samples. Figs. 7 and 8 plots $\ln I$ vs $1000/T$ curves at various fixed voltages in dark as well as in presence of light for amorphous thin films of a- $\text{Se}_{80}\text{Te}_{20}$ and $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$, which are found to be straight lines. This type of behaviour indicates that current is thermally activated following a relation

$$I = I_0 \exp(-\Delta E / kT) \quad (7)$$

Where ΔE is the activation energy which may correspond to energy of trap levels from the band edges and k is the Boltzmann's constant. From the slopes of $\ln I$ vs $1000/T$ curves, we have calculated ΔE at various voltages in dark as well as in presence of light. Such values are given in Table 1 for both the glassy alloys. The different values of ΔE at different voltages indicate that there is a energy distribution of trap levels instead of a single trap level. The decrease of ΔE in presence of light as compared to the results in dark further supports this view point as the position of Fermi level is shifted towards the band edges in this case. The values of activation energy in dark as well as in presence of light is less than 0.98 eV, which further confirms the presence of Poole-Frenkel conduction in present case.

Table 1. Activation energy in dark as well as in presence of light at different voltages in a- $\text{Se}_{80}\text{Te}_{20}$ and a- $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ alloys.

Sample	Voltage (in volts)	Activation energy (eV)	
		In dark	In presence of light
$\text{Se}_{80}\text{Te}_{20}$	150	0.257	0.209
	170	0.246	0.210
	200	0.247	0.209
$\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$	150	0.457	0.392
	170	0.454	0.391
	200	0.452	0.390

4. Conclusions

$I - V$ characteristics have been studied in amorphous thin films of $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0; 5$). At low fields ($<10^3 \text{ V/cm}$), an ohmic behaviour is observed. However, at high fields ($\sim 10^4 \text{ V/cm}$), a super ohmic behaviour is observed.

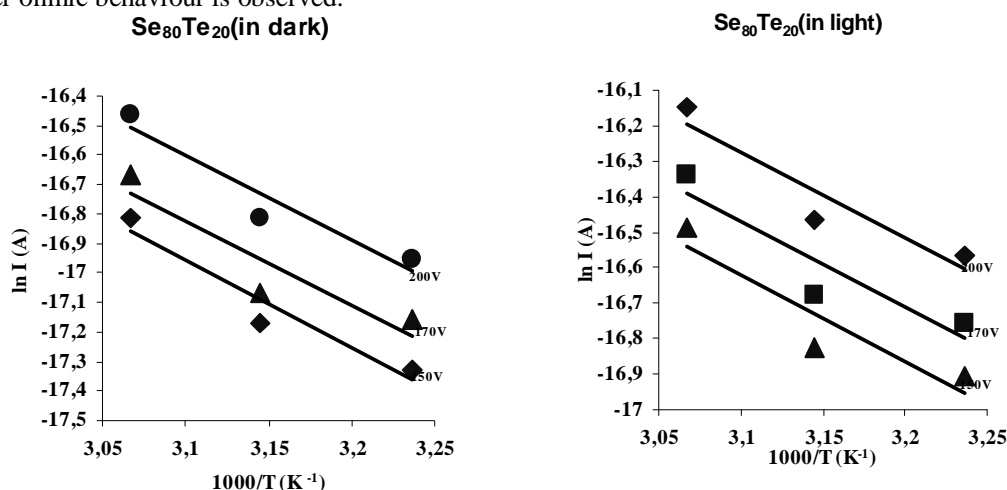


Fig. 7. Plots of $\ln I$ vs $1000/T$ for glassy $\text{Se}_{80}\text{Te}_{20}$ alloy at various voltages in dark and in presence of light.

Analysis of the observed data shows the absence of space charge limited conduction in a- $\text{Se}_{80-x}\text{Te}_{20}\text{Sb}_x$ ($x = 0; 5$) alloys in which $\ln I/V$ vs V curves are not found to be straight lines with good correlation coefficient and the slope of these curves do not decrease linearly with temperature.

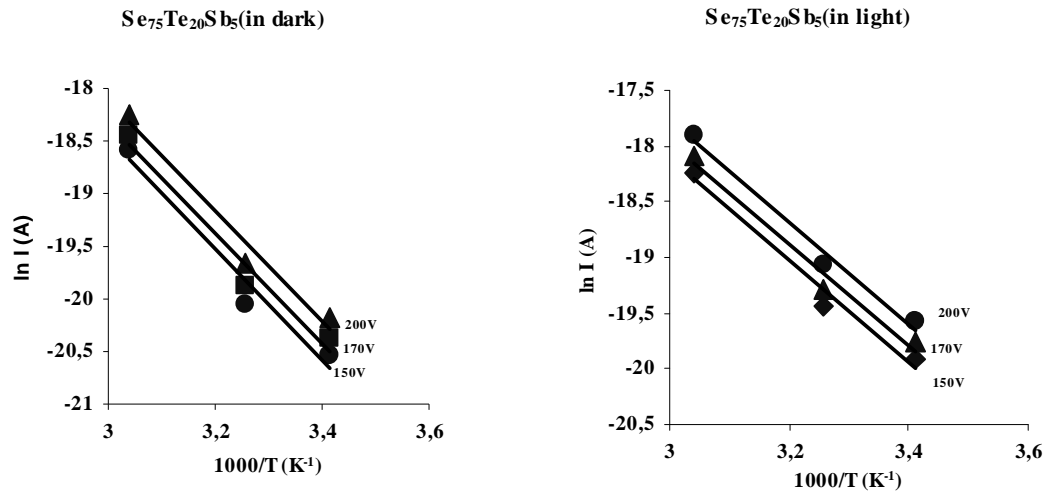


Fig. 8. Plots of $\ln I$ vs $1000/T$ for glassy $\text{Se}_{75}\text{Te}_{20}\text{Sb}_5$ alloy at various voltages in dark and in presence of light.

Instead, $\ln I$ vs $V^{1/2}$ curves are found to be straight lines with good correlation coefficient. The slope of these curves decrease linearly with increase in temperature. To distinguish between Schottky and Poole-Frenkel effect, $\ln I/T^2$ vs $1000/T$ curves are plotted, which are non linear. A detailed analysis shows that conduction is Poole-Frenkel type in the present alloys in dark as well as in presence of light. The values of activation energy calculated at different voltages indicate that there is a energy distribution of traps in these alloys. The decrease of ΔE in presence of light as compared to the results in dark further supports this view point as the position of Fermi level is shifted towards the band edges in this case.

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