COMPOSITION DEPENDENCE OF PHOTOCONDUCTIVITY IN AMORPHOUS $Se_{70}Te_{30-x}Zn_x$ THIN FILMS

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Temperature and intensity dependence of steady state photoconductivity is studied in amorphous thin films of $Se_{70}Te_{30-x}Zn_x$ (x = 0, 2 and 4). The results indicate that dark and photoconductivity both increase exponentially with temperature in all the glassy alloys studied here. The intensity (F) dependence of photoconductivity shows that photoconductivity increases as a power law, $\sigma_{ph} \alpha F^{\gamma}$ where γ is found to be 0.5 in all the three cases which shows that the recombination mechanism is bimolecular in these alloys. Photosensitivity (σ_{ph} / σ_d) calculations show that this quantity, at a particular intensity, decreases with the increase in temperature in all the three cases. At a particular temperature, σ_{ph} / σ_d is also found to decrease with Zn concentration, This indicates a higher density of defect states at higher concentration of Zn.

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1. Introduction

The presence of mono-energetic localized centers is a general characteristic of the crystalline semiconductors, while in disordered materials and primarily, in amorphous and glassy semiconductors, the individual groups of localized centers are energetically spread as it follows from theoretical studies [1]. The presence of these localized states may act as traps for the charge carriers and hence affect many properties of these materials. Presumably, the parameters of traps (their energy position, the character of energy distribution, trapping concentration and cross section for the charge carriers) are substantially different in various materials, and these parameters determine the specific features of kinetic processes in each case. This general conclusion has been confirmed by other experiments, primarily by studies on thermally stimulated conductivity and depolarization.

Since the photoconductivity kinetics of amorphous semiconductors are to a great extent determined by the process of trapping of non equilibrium charge carriers on localized centers of various depth [2], such studies are important to understand the energy distribution of the traps. From application point of view also photoconductive properties are important.

Photoconductivity measurements in chalcogenide glasses are found to have diversified results. A maxima in photoconductivity is observed near room temperature in most of glassy alloys [3-8]. However, this maxima is not seen in some of the alloys [9-11]. Similarly, the intensity dependence of photoconductivity is not same in all the glassy alloys. A linear dependence on light intensity is reported [3, 12] in some alloys near room temperature. On the other hand, some alloys [12, 14] show square root dependence in same temperature range.

The present paper reports the steady state photoconductivity measurements in amorphous thin films of $Se_{70}Te_{30-x}Zn_x$ (x = 0, 2 and 4) prepared by vacuum evaporation.

Temperature dependence of steady- state photoconductivity is studied at different light intensities. Intensity dependence of photoconductivity is studied at different temperatures.

Section 2 describes the experimental details. The results have been presented and discussed in section 3. The conclusions have been presented in the last section.

2. Experimental

Glassy alloys of $Se_{70}Te_{30-x}Zn_x$ (x = 0, 2 and 4) were prepared by quenching technique. The exact proportions of high purity (99.999%) Se, Te and Zn elements, in accordance with their atomic percentages, were weighed using an electronic balance (LIBROR, AEG-120) with the least count of 10^{-4} gm. The material was then sealed in evacuated (~10^{-5} Torr) quartz ampoule (length ~ 5 cm and internal diameter ~ 8 mm). The ampoule containing material was heated to 800 ^{0}C and was held at that temperature for 12 hours. The temperature of the furnace was raised slowly at a rate of 3 - 4 ^{0}C / minute. During heating, the ampoule was constantly rocked, by rotating a ceramic rod to which the ampoule was tucked away in the furnace. This was done to obtain homogeneous glassy alloy. After rocking for about 12 hours, the obtained melt was rapidly quenched in ice-cooled water. The quenched sample was then taken out by breaking the quartz ampoule.

Thin films of glassy alloys were prepared by vacuum evaporation technique keeping glass substrate at room temperature. Vacuum evaporated indium electrodes at bottom are used for electrical contacts. The thickness of the films was ~ 500 nm .The coplanar structures are used for the present measurements.

For Photoconductivity measurements, thin films were mounted in a specially designed sample holder which has transparent window to shine light .A vacuum of 10^{-2} Torr is maintained throughout the measurements. The temperature of film is controlled by mounting heater inside the sample holder and measured by a calibrated copper – constantan thermocouple mounted very near to the film and the current is measured by Keithley electrometer model - 614. Before measurements, the films were annealed first at 370 K for one hour in a vacuum of 10^{-2} torr.

3. Results and discussion

3.1 Steady state photoconductivity

For the measurements of photoconductivity, thin film samples were mounted in a specially designed sample holder which has transparent window to shine light for these measurements in vacuum ~10^{-2} Torr.

The source of light was a 200 W tungsten lamp. The intensity of light was varied by changing the voltage across the lamp. The intensity was measured by a lux meter. A d.c. voltage of 10 volts is applied across the film and the resulting current is measured by digital Electrometer (Keithley, model 614).

Temperature dependence of dark and photoconductivity at different intensities, were studied in amorphous thin film of $Se_{70}Te_{30-x}Zn_x$ (x = 0, 2 and 4). The results of all the three samples were of the same nature. Therefore, the results of only two samples (a- $Se_{70}Te_{28}Zn_2$ and $Se_{70}Te_{26}Zn_4$) are given in this paper. Figs1 (a) and 1 (b) show the temperature dependence of dark conductivity and steady state photoconductivity at different intensities (F).

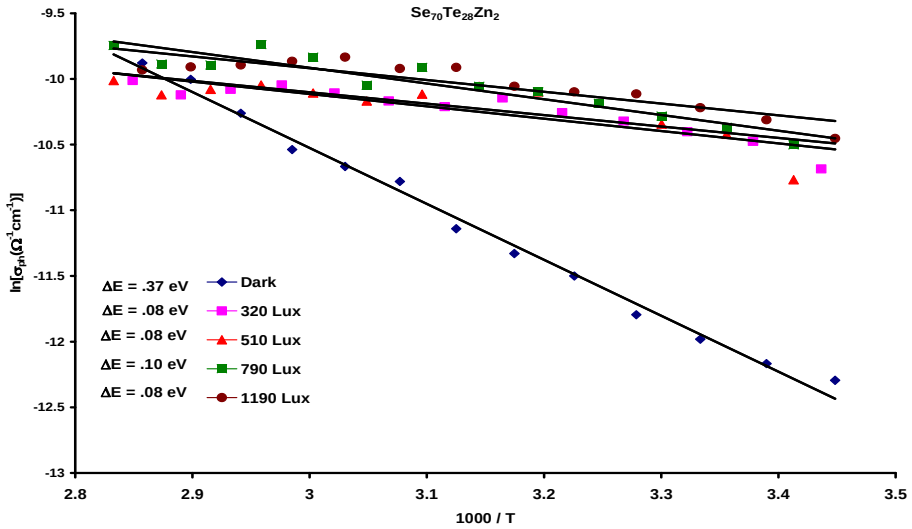

Fig.1 (a) Dark and steady state photoconductivity vs.1000/T at various levels of illumination in amorphous thin film $Se_{70}Te_{26}Zn_2$

It is clear from these figures that lnσ vs.1000/T curves in dark are straight lines having single slope indicating that the dark conductivity is due to an activated process having single activation energy in the present range of temperature. The dark conductivity can, therefore, be written as

$$\sigma_d = \sigma_0 \exp(-\Delta E / k T) \quad (1)$$

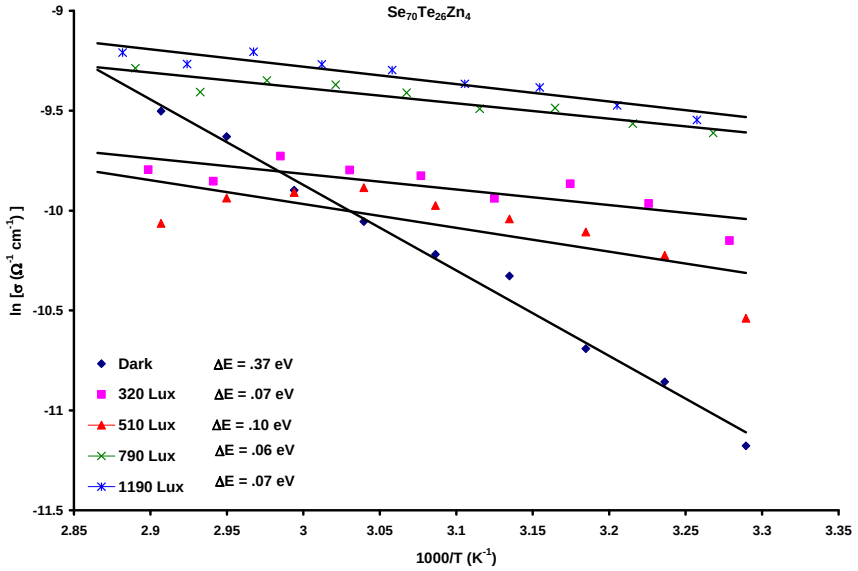

Fig.1 (b) Dark and steady state photoconductivity vs.1000/T at various levels of illumination in amorphous thin film $Se_{70}Te_{26}Zn_4$

Where, ΔE is the activation energy for conduction and k is Boltzman's constant.

The values of ΔE for dark conductivity are calculated using the slopes of Figs.1 (a) and 1 (b) and Eq.1.The results of these calculations are given in Tables 1(a) and 1 (b) for a- $Se_{70}Te_{28}Zn_2$ and a- $Se_{70}Te_{26}Zn_4$ respectively

The photoconductivity is also thermally activated at low temperatures with single activation energy. However, at higher temperatures, it decreases with the increase in temperature

showing a maximum at a particular temperature. This type of behavior is quite common in chalcogenide glasses.

The values of activation energy in the activated region is calculated at different intensities and the values are given in Tables 1(a) and 1(b) for a- $Se_{70}Te_{28}Zn_2$ and a- $Se_{70}Te_{26}Zn_4$ respectively.

Table-1(a) Dark and photoconductivity along with activation energy at various intensities in amorphous thin films of $Se_{70}Te_{26}Zn_2$

S.No.	Intensity (Lux)	σ ($Ohm^{-1}cm^{-1}$) at 293 K	σ_{ph} / σ_d	ΔE (eV)
1	Dark	4.57875 × 10-6	0.0	0.37
2	320	2.28938×10^{-5}	5.0	0.08
3	510	2.10623×10^{-5}	4.6	0.08
4	790	2.74725×10^{-5}	6.0	o.10
5	1190	2.88661×10^{-5}	6.3	0.08

Table-1(b) Dark and photoconductivity along with activation energy at various intensities in amorphous thin films of $Se_{70}Te_{26}Zn_4$

S.No.	Intensity (Lux)	σ ($Ohm^{-1}cm^{-1}$) at 293 K	σ_{ph} / σ_d	ΔE (eV)
1	Dark	8.01282 × 10-6	0.0	0.37
2	320	2.40385 × 10-5	3.0	0.07
3	510	2.64818 × 10-5	3.3	0.10
4	790	3.97655×10^{-5}	5.0	0.06
5	1190	4.32692×10^{-5}	5.4	0.07

The above tables indicate that the activation energy is almost same at different intensities of light and is much smaller than the activation energy in dark. This type of behavior is also quite common in chalcogenide glasses. Similar behavior was observed for other compositions (x = 0).

Photosensitivity (σ_{ph} / σ_d), at a particular intensity, is an important parameter to use a material for photosensitive devices. We have, therefore, calculated σ_{ph} / σ_d at different intensities and the values of this parameter is given in Table -1(a) and 1 (b) in case of amorphous $Se_{70}Te_{28}Zn_2$ and $Se_{70}Te_{26}Zn_4$. These tables show that photosensitivity increases with the increase in light intensity. This parameter, however, is found to decrease with increase in temperature.

To compare the photosensitivity in various glassy samples, we have calculated the σ_{ph} / σ_d at a particular intensity 1190 lux, for all the three samples and the results are shown in Table 2. These results are plotted in Fig.2. It is clear from this figure that photosensitivity decreases with the increase in Zn concentration in glassy $Se_{70}Te_{30-x}Zn_x$ system.

Table-2 Composition dependence of photosensitivity at 1190 lux and at Room Temperature

Sample	σ_{ph} / σ_d
$Se_{70}Te_{30}$	8.6
$Se_{70}Te_{28}Zn_2$	6.3
$Se_{70}Te_{26}Zn_4$	5.4

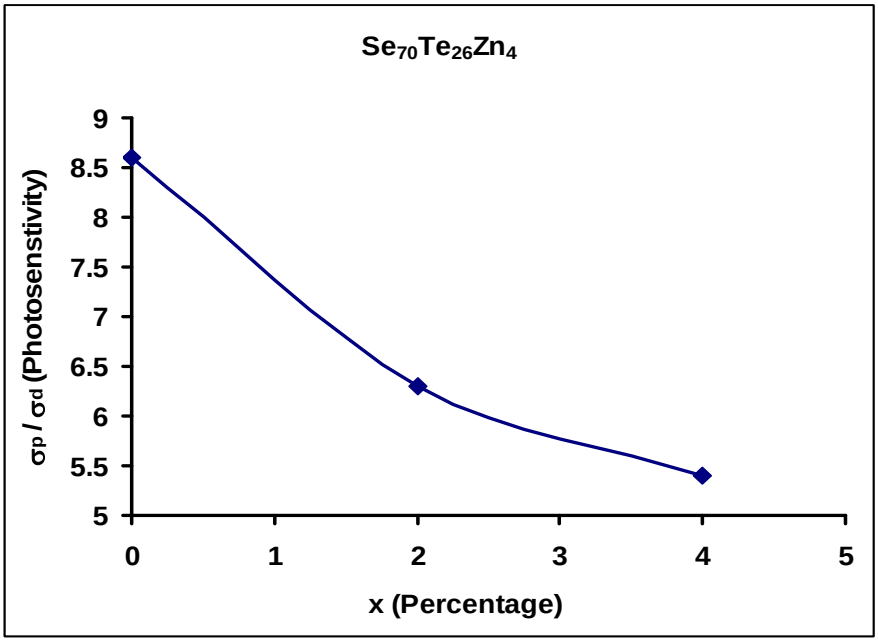

Fig. 2 Composition dependence of photosensitivity at light intensity 1190 lux

Photosensitivity depends upon the life time of the excess charge carriers which, in turn, depends upon the number of recombination centres. The lower photosensitivity in Zn containing samples indicates that the life time of the excess carrier is smaller in this case which further suggest in crease in the density of defect states on Zn incorporation in binary $Se_{70}Te_{30}$ system. This conclusion is supported by our earlier results on the density of defects in glassy $Se_{70}Te_{30-x}Zn_x$ system where density of defect states is found increase with Zn concentration [15].

3.2 Intensity dependence of photoconductivity

Intensity (F) dependence of photoconductivity is also studied at various fixed temperatures (290K to 351K). The results of these measurements are plotted in Figs. 3(a) and 3 (b) in case of amorphous $Se_{70}Te_{28}Zn_2$ and $Se_{70}Te_{26}Zn_4$. It is clear from these figures that, at all the temperatures, ln σ_{ph} vs. ln F curves are nearly straight lines which indicate that photoconductivity follows a power law with intensity ($\sigma_{ph} \alpha F^{\gamma}$). The power γ has been calculated from the slopes of lnσ_{ph} vs. ln F curves. The value of γ are nearly to 0.5 for both the samples. Similar behavior was observed for other compositions (x = 0).

In case of a semiconductor with only one type of recombination centre, the excess electron density (Δn can be related to the generation rate (g) as follows [16]

$$g = C_n (\Delta n^2 + 2\, n_0 \Delta n) \tag{2}$$

Where, C_n is the capture coefficient (the product of capture cross section and the thermal velocity of the carrier). n_0 is the density of thermal carriers. In the case of monomolecular recombination where $n_0 > > \Delta n$, equation (2) reduces to

$$\Delta n = g / 2C_n\, n_0 \tag{3}$$

As the generation rate is proportional to the light intensity (F), the photoconductivity will vary linearly with light intensity in the above case. In case of bimolecular recombination where $\Delta n > > n_0$, equation (2) reduce to

$$\Delta n = (g / C_n)^{1/2} \tag{4}$$

Equation (4) shows that the photoconductivity will be proportional to square root of the light intensity in case of bi molecular recombination.

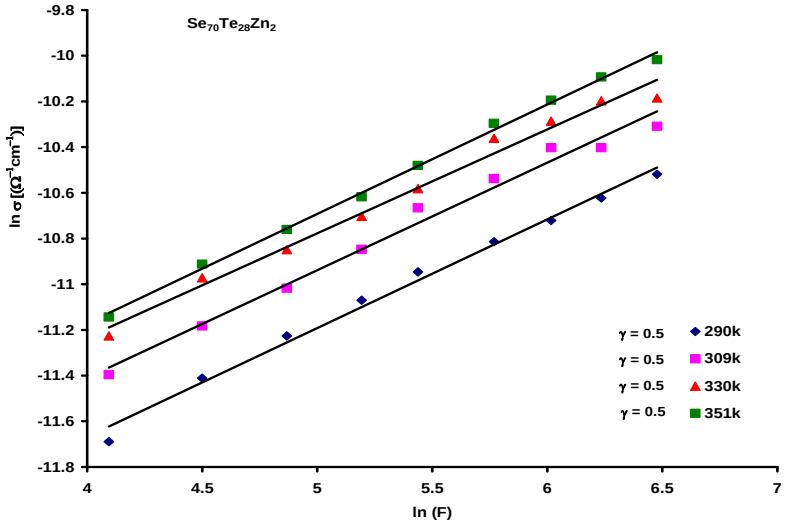

Fig.3 (a) Intensity dependence of photoconductivity at various temperatures in amorphous thin film $Se_{70}Te_{26}Zn_2$

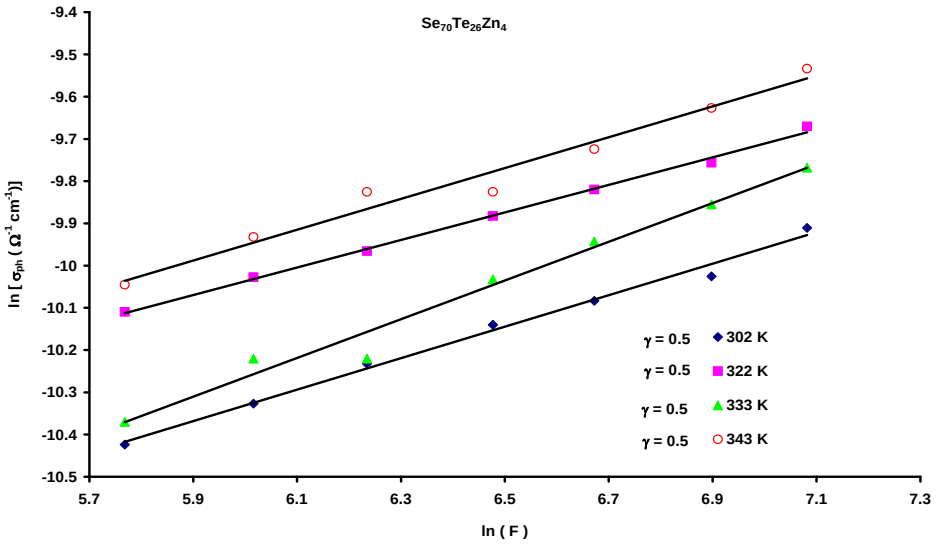

Fig.3 (b) Intensity dependence of photoconductivity at various temperatures in amorphous thin film $Se_{70}Te_{26}Zn_2$

From the above discussion, it is clear that in both types of recombinations discussed above, photoconductivity follows a power law with light intensity, i.e., $\sigma_{ph} \alpha F^{\gamma}$ where $\gamma = 1$ for monomolecular recombination and $\gamma = 0.5$ for bimolecular recombination [17].

In the present case, γ is 0.5 at various temperatures, which indicate that bimolecular recombination is predominant in glassy $Se_{70}Te_{30-x}Zn_x$ system.

4. Conclusion

Temperature dependence of dark and steady state photoconductivity is studied in amorphous thin films of $Se_{70}Te_{30-x}Zn_x$ prepared by vacuum evaporation technique at various temperatures. Temperature dependence of photoconductivity measurements at different intensities

indicates that photoconductivity is also thermally activated in the low temperature range. The photosensitivity increases with the increase of intensity. However, it decreases with the increase in temperature in each glassy alloy. At a particular temperature and intensity, photosensitivity is found to decrease with the increase in Zn concentration in glassy $Se_{70}Te_{30-x}Zn_x$ system. This is explained in terms of the increase in the density of defect states on Zn incorporation in binary $Se_{70}Te_{30}$ glassy system which is consistent with our earlier results on the density of defect states in the same glassy system.

References

[1] N. F. Mott, E. A Davis, Electronic Processes in Non - crystalline Materials, 2nd ed. Oxford,Clarendon Press: (1976).
[2] P. G. Lecomber, J. Mort, Electronic and Structural Properties of Amorphous Semiconductors. London, New York: Academic Press, P. 527. (1973).
[3] E. A. Fagen and, H. Fritzsche, Non- Cryst. Solids **4,** 480 (1970).
[4] T. C. Arnoldussen, R.H. Bube, E.A. Dazen, and S. J. Holmberg, Appl. Phys. **43**, 1798 (1972).
[5] J. M. Marshal, C. Main and E. E. Owen, J. Non- Cryst. Solids **8-10**, 760. (1972)
[6] R .H. Bube, H. E. Mahan, R. T. S. Shiah and Vanderplas, Appl. Phys.Lett. **25**, 419, (1974).
[7] G. W. Taylor and J. G. Simmons, J. Phys. **C 7**, 3067, (1974).
[8] T. D. Moustaksa and K. Weiser, Phys. Rev. **B 12**, 2448, (1975).
[9] R. T. S. Shiah and R. H. Bube J. Appl. Phys, **47**, 2005, (1976).
[10] M. Igalson and R.Trykozko, Solid State Commun, **40**, 99, (1981).
[11] Sangeeta Singh, R. S. Sharma, R. K. Shukla and A.Kumar,Vacuum **1-9,** 72 (2004).
[12] K. Shimakawa, A. Yoshida and T. J. Arizumi Non. Cryst. Solids **16**, 258, (1974).
[14] T. C. Arnoldussen, R. H. Bube, E. A. Fagen and S. Holmberg, Non-Cryst.Solids **8-10**, 933, (1972).
[15] Krishna ji, R. K. Shukla, A. K. Agnihotri, A. Kumar J. Ovonic Research, 4 (2008). 123 – 127.
[16] P. Nagels in Amorphous Semiconductors, edited by M.H.Brodsky (Springer-Verlag, Berlin, Heidelberg) (1979).
[17] R. H.Bube, Photoconductivity of Solids (John Wiley and Sons, Inc., New York) (1960).