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SPACE CHARGE LIMITED CONDUCTION IN GLASSY $Se_{100-x}Bi_x$ ALLOYS

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The present paper reports the measurements on space charge limited conduction (SCLC) in bulk glassy $Se_{100-x}Bi_x$ (x = 0.5, & 2.5,). Current –voltage (I-V) characteristics have been measured at various fixed temperatures. In all the samples, at low electric fields, ohmic behavior is observed. However, at high fields (E ~10^4 V/cm), non-ohmic behavior is observed. In all the samples studied, the experimental data fits well with the theory of space charge limited conduction (SCLC). From the fitting of the data to the theory of uniform distribution of traps, the density of defect states near the Fermi level is calculated.

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1. Introduction

Chalcogenide glasses belong to a special group of amorphous semiconductors, which contain one or more of the chalcogen elements S, Se, Te from the VI group of periodic table. In chalcogenide glasses, Se based glassy alloys have wide technical applications in electronics and optoelectronics. Amorphous Se is a very useful material from application point of view due to its current use as photoreceptors in TV vidicon pick-up tubes [1], conventional xerographic machines and digital X-ray imaging [2, 3]. However, the shortcomings of pure glassy Se for its practical application include its short life time, low sensitivity and thermal instability. To overcome these difficulties, certain additives are used and especially the use of Se-Te, Se - Ge, and Se-Sb, Se - In and Se - Bi binary alloys is of great interest owing to their various properties like grater hardness, higher sensitivity, higher conductivity and smaller ageing effects as compare to pure Se.

Recently, considerable attention has been focused on glasses of Se-Bi system [4-17] as these materials have found application for their electrical, optical, dielectric and thermal properties.

The density of defect states in the mobility gap controls many physical properties of amorphous semiconductors. One of the most direct methods for the determination of the density of localized states (g_0) in the mobility gap involves the measurement of SCLC which can easily be observed at high fields in chalcogenide materials. Due to their low conductivity, amorphous semiconductors are most suitable for high field conduction studies, as the joule hating is negligibly small in these materials at moderate temperatures. Some such studies have already been reported in literature [18-28] and the results have been interpreted in terms of space charge limited conduction or Poole-Frenkel conduction. Such a technique has already been applied to a- Si:H [29-32]. SCLC technique is not influenced by surface states; unlike field effect experiments where surface states may come in to play.

The present paper reports the SCLC measurements in an important glassy system Se-Bi, where properties have been found to be highly composition dependent. Using the theory of SCLC, for the case of uniform distribution of localized states, the density of localized states near the Fermi level is calculated for the present system.

2. Experimental

Glassy alloys of $Se_{100-x}Bi_x$ (x = 0.5, & 2.5,) were prepared by quenching technique. High purity (99.999%) materials were weighed according to their atomic percentages and were sealed in quartz ampoules (length ~ 5cm and internal diameter ~ 8mm) with a vacuum 10^{-5} Torr. The ampoules containing material were heated to 800 ^{0}C and were 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 ampoules were constantly rocked, by rotating a ceramic rod to which the ampoules were tucked away in the furnace. This was done to obtain homogeneous glassy alloys.

After rocking for about 12 hours, the obtained melt was cooled rapidly by removing the ampoules from the furnace and dropping them to ice-cooled water rapidly. The quenched samples were then taken out by breaking the quartz ampoules. The glassy nature of the alloys was ascertained by X-ray diffraction.

The glassy alloys thus prepared were ground to a very fine powder and pellets (diameter ~ 6 mm and thickness ~ 1 mm) were obtained by compressing the powder in a die at a load of 5 Tons. The pellets were mounted in between two steel electrodes of a metallic sample holder for d. c. conductivity measurements using a digital Picoammeter. The temperature measurement was facilitated by a copper-constantan thermocouple mounted very near to the sample. A vacuum of $\sim 10^{-2}$ Torr was maintained over the entire temperature range.

A d. c. voltage (0 to 400 V) was applied across the sample and the resultant current was measured by a digital Picoammeter. I - V characteristics were measured at various fixed temperatures. The temperature of the pellets was controlled by mounting a heater inside the sample holder and measured by a calibrated copper-constantan thermocouple mounted very near to the pallets.

3. Results and discussion

In the present work, I - V characteristics of glassy $Se_{100-x}Bi_x$ (x = 0.5 & 2.5,) are examined at various temperatures. At low fields (10^3 V/cm), an ohmic behavior is observed in all the samples. However, at higher fields (~ 10^4 V/cm), a super-ohmic behavior is observed at all the measuring temperatures.

According to theory of space charge limited conduction, in the case of a uniform distribution of localized states g (E) = g_0, the current (I) at a particular voltage (V) is given by the following relation [33]

$$I = (e\,A\,\mu\,n_0 V / d)\exp(S\,V), \tag{1}$$

Where d is electrode spacing, no 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 film and S is given by

$$S = 2\,\varepsilon_r\,\varepsilon_o / e\,g_o\,k\,T\,d^2 \tag{2}$$

As evident from equation (1) and (2), in the case of space charge limited conduction, a plot of ln I /V vs. V should be linear and slope of these lines should decrease inversely proportional to temperature.

In the present case, at higher fields, ln (I / V) vs. V curves are found to be straight lines with good correlation coefficient at all the measuring temperatures for all the glassy alloys studied here. To demonstrate this, the measurement data of ln (I / V) as a function of V for various temperatures is shown in Figs.1-2 in case of all the glassy alloys.

The slope of ln(I / V) vs. V for various temperatures is shown in Figs. 1-2 in case of glassy $Se_{100-x}Bi_x$. It is clear from these figures that the slope S decreases with the increase in temperature as expected from equation 2. This confirms the validity of SCLC theory in case of uniform distribution of localized states.

Using equation 2, the density of localized states is calculated from the slopes of the Figs 3-4. The value of relative dielectric constant ε_r is taken to be 10 which is the dielectric constant value of glassy Se. The results of these calculations are given in Table 1 as a function of Bi concentration. It is clear from this table that g_0 decreases with Bi concentration in glassy Se-Bi system.

Table.1 Composition dependence of density of localized states (g_0) in glassy $Se_{100-x}Bi_x$

Sample	Slope of S vs. 1 /T	g_o ($eV^{-1}.cm^{-3}$)
$Se_{99.5}Bi_{0.5}$	4.2192	1.0×10^{13}
$Se_{97.5}Bi_{2.5}$	5.8126	0.5×10^{13}

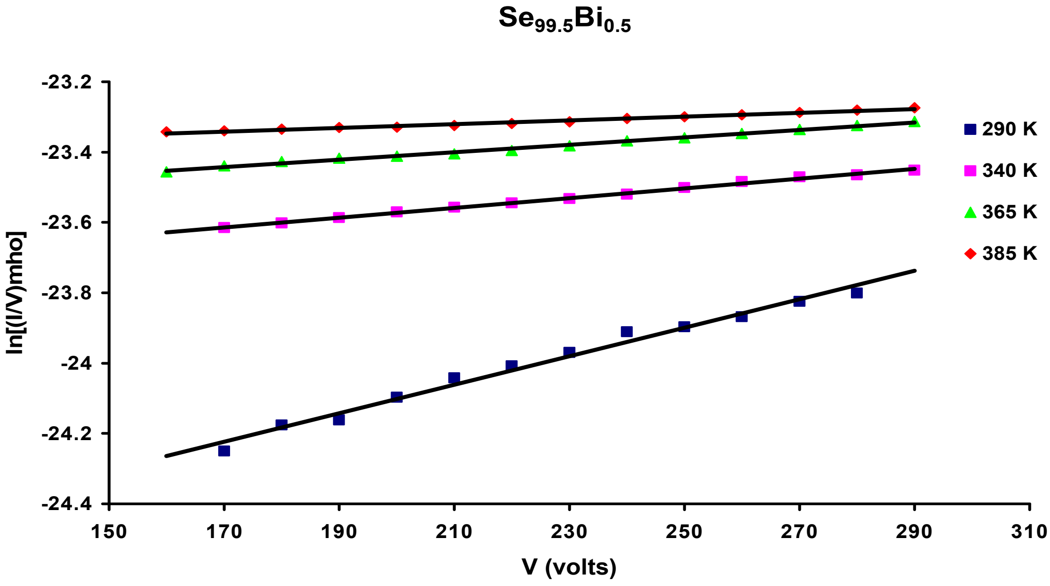

Fig.1. Plot of ln (I / V) vs. V for glassy $Se_{99.5}Bi_{0.5}$ at different temperatures.

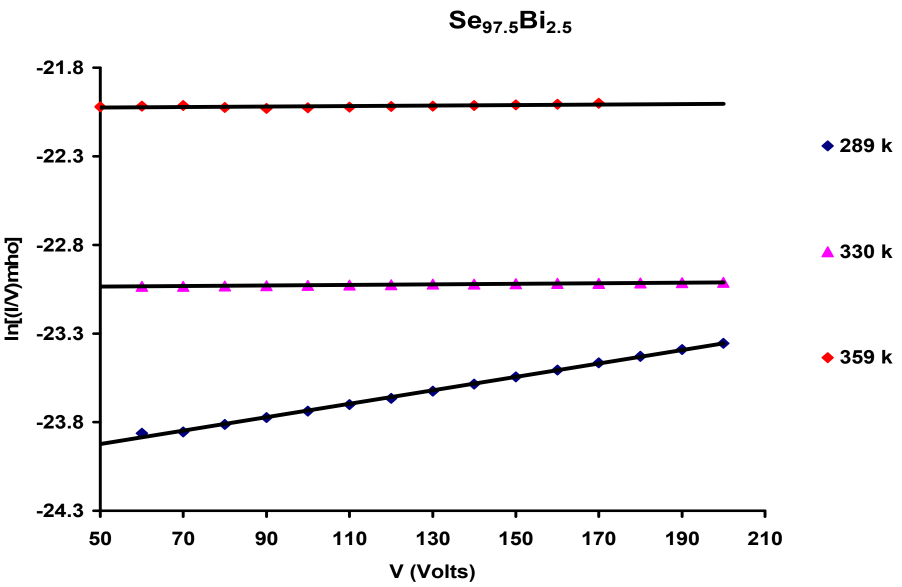

Fig.2. Plot of ln (I / V) vs. V for glassy $Se_{97.5}Bi_{2.5}$ at different temperatures.

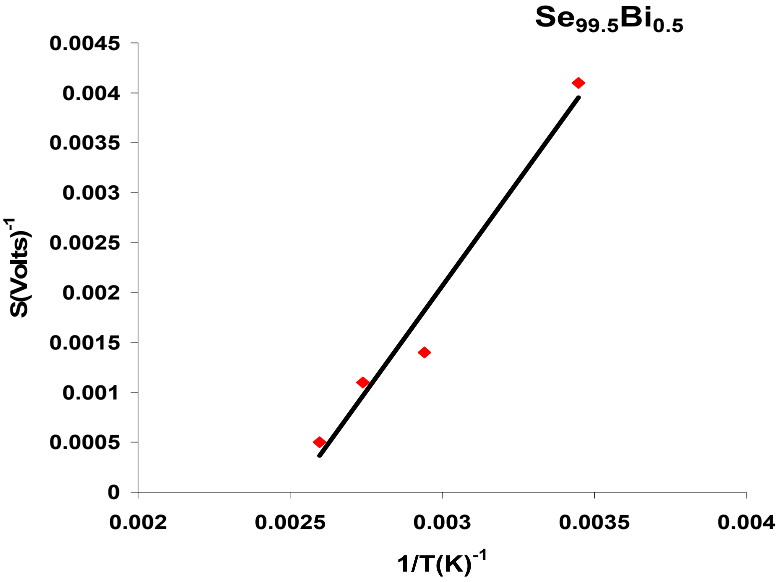

Fig.3. Plot of slope(S) vs. 1 / T for glassy $Se_{99.5}Bi_{0.5}$.

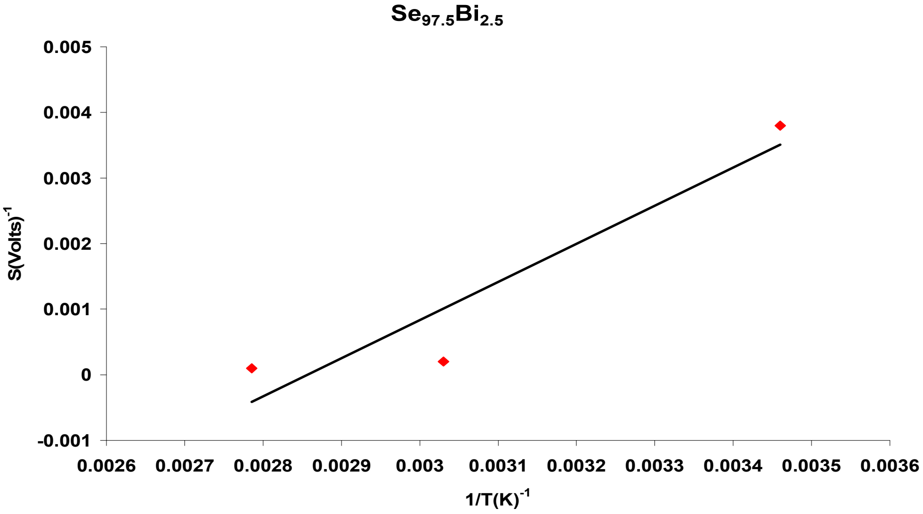

Fig.4. Plot of slope(S) vs. 1 / T for glassy $Se_{97.5}Bi_{2.5}$

4. Conclusions

I-V characteristics have been studied in glassy $Se_{100-x}Bi_x$ (x = 0.5 & 2.5). At low fields ($<10^3$V/cm), an ohmic behavior is observed. However, at high fields ($\sim 10^4$ V/cm), a super-ohmic behavior is observed. The space charge limited conduction is observed in these glasses. The density of localized states near Fermi level is calculated by fitting the data to the theory of SCLC in case of a uniform distribution of localized states.

References

[1] E. Maruyama, jpn. J. Appl. phys. 21 (1982) 231.

[2] D. C. Hunt, S. S. Kirby, J. A. Rowlands, Med.Phys. 29 (2002) 2464.
[3] S. O. Kasap, Handbook of Imaging Materials, in: A. S. Diamond (Ed.), Marceal Dekker, New York, 1991, p.355.
[4] V. I. Mikla, Yu. Nagy, V. V. Mikla, A. V. Mateleshko, Mater. Sci. Eng., B, Solid-State Mater. Adv. Technol. 64 (1999) 1.
[6] D. Tonchev, B. Fogal, G. Belev, R. E. Johanson, S. O. Kasap, J. Non-Cryst.Solids 299 (2002) 998.
[7] K. V. Reddy, A. K. Bhatnagar, V. Srivsatava, J. Phys., Condens. Matter 4 (1992) 5273.
[8] S. S. Fouad, A. H. Ammar, M. Abo-Ghazala, Physica B 229 (1997) 249.
[9] M. Singh, D. R. Goyal, A.S. Maan, J. Phys. Chem. Solids 60 (1999) 877.
[10] M. A. Majeed Khan, M. Zulfequar, S. Kumar, M. Husain, J. Mod. Opt. 50 (2) (2003) 251.
[11] C. Kaito, T. Fujita, T. Kimura, K. Hanamoto, N. Suzuki, S. Kimura, Y. Saito, Thin Solid Films 312 (1998) 93.
[12] S. Jayakumar, C. Balasubramanian, Sa. K. Narayandas, D. Mangalaraj, C. P.Girrija Vallabhan, Thin Solid Films 266 (1995) 62.
[13] P. Arun, A.G. Vedeshwar, N.C. Mehra, J. Phys. D: Appl. Phys.32 (1999)183.
[14] V. I. Mikla, I. P.Mikhalko, Yu. Yu. Nagy, J. Phys., Condens. Matter 6 (1994) 8269.
[15] D. Dimitrov, M. A. Ollacarizqueta, C. N. Afanso, N. Starbov, Thin Solid Films 280 (1996) 278.
[16] D. Dimitrov, D. Tzocheva, D. Kovacheva, Thin Solid Films 323 (1998) 79.
[17] N. Choudhary, A. Kumar, Turk. J. Phys. 29(2005) 119.
[18] A. Abdel-All, A. Elshafie, M. M. Elhawary, Vacuum 59 (2000) 845.
[19] V. K. Saraswat, K. Singh, N. S. Saxena, V. Kishore, T. P. Sharma, P. K. Saraswat, Curr. Appl. Phys. 6 (2006) 14.
[20] J. E. Hall, J. Non-Cryst. Solids 2 (1970)125.
[21] M. A. Majeed Khan, M. Zulfequar, M. Husain, Physica B 366 (2005) 1.
[22] S. Kumar, R. Arora, A. Kumar, J. Mater. Sci. Lett. 10 (1991) 1280.
[23] B. T. Kolomiets, E. Lebedev, Fiz. Tekh. Polu. Prov. 1 (1967) 815.
[24] R. M. Mehra, H. Kumar, S. Koul, P. C. Mathur, Phys. Status Solidi, A Appl. Res. 83 (1984) 341.
[25] M. A. Majeed Khan, M. Zulfequar, M. Husain, Mater. Lett. 57 (2003) 2894.
[26] W. Den Boer, J. Phys. (Paris) 42 (C4) (1981) 451.
[27] P. S. Nikam, H. S. Aher, Ind. J. Pure Appl. Phys. 34 (1996) 393.
[28] S. P. Singh, S. Kumar, A. Kumar, J. Mater. Sci. 40 (2005) 481.
[29] M. Meaudre, R. Meaudre, Philos. Mag., B 55 (1987) 554.
[30] E. V. Grekov, O. G. Sukhorukov, Sov. Phys., Semicond. 22 1988 457.
[31] I. Soloman, R. Benferhat, H. Tran-Quoc, Phys. Rev., B 30 (1984) 3422.
[32] S. Okano, M. Suzuki, K. Imura, A. Fukada, J. Hiraki, Non-Cryst. Solids 59-60 (1983) 969.
[33] R. M. Hill, Phil. Mag.**20**, 59 (1970).