STUDY THE EFFECT OF SN ON THE AMORPHOUS SE-TE THIN FILMS

Satendra Singh[1], Satish Kumar[2]

[1]Department of Physics, OPJS University, Churu, Rajasthan 331303 (India)

[2] Corresponding Auther, satish

ABSTRACT

Amorphous $Se_{40-x}Te_{60}Sn_x$ glassy alloys have been synthesized by thermal evaporation technique under high vacuum conditions (~ 10^{-5} torr). The optical spectra of amorphous $Se_{40-x}Te_{60}Sn_x$ (x = 0, 2, 4, 6, 8) thin films have been measured by a double beam UV-VIS-NIR computer controlled spectrophotometer over the range of 200-3000 nm. Swanepole technique has been used to calculate the optical constants [refractive index (n),extinction coefficient (k) and absorption coefficient (α)] and optical band gap of amorphous $Se_{40-x}Te_{60}Sn_x$ thin films. Absorption coefficient (α) increases with incident photon energy (hv) for all the samples. The optical band gap increases with increase of the tin (Sn) content. .

Keywords: Thin film, Optical constants, Optical band gap etc.

I. INTRODUCTION

Se-Te glassy alloy have gained much importance among chalcogenide glasses because of their high photosensitivity, greater hardness, high crystallization temperature and smaller ageing effect as compare to pure *a*-Se [1] and useful in practical application [2]. It was believed earlier that impurities have little effect on the properties of amorphous semiconductors as each impurity atom satisfies its requirement by adjusting its neighboring environment.

The role of various metals such as Ag, Sn etc. as "additives" in affecting the properties of chalcogenide glasses have been received much attention [3, 4]. It would be interesting to study the role of Ag, Sn metals in affecting the properties of the glasses of the Se-Te system. In this communication, we report the effect of Sn and Ag atom on the optical properties of Se-Te system. Sn is chosen as an additive material because it alloys with most of the metals and modify their physical properties. The knowledge of accurate values of wavelength dependent refractive index of thin films yields fundamental information on the optical energy gap (*Eg*), defect levels, phonon and plasma frequencies, etc. The optical behavior of material is utilized to determine its optical constant. Optical constants like refractive index (*n*) and extinction coefficient (*k*) are calculated by well known Swanepoel method [5],using transmission spectrum in the UV-VIS-NIR region. Analysis of absorption coefficient was also carried out to determine the *Eg* and the nature of transitions.

Sn-containing chalcogenide glasses have attracted much interest in glass science and technology for fundamental research of their structure, properties and preparation [6-10]. They have many current applications in optics, optoelectronics, chemistry and biology such as optical elements, gratings, photodoping, optical

memories, microlences, wave-guides, holography, bio and chemical sensors, solid electrolytes, batteries etc. [11-20].

The effect of an impurity in an amorphous semiconductor material may be widely different, depending on the conduction mechanism and the structure of material [21]. The study of the optical properties of chalcogenide glasses is important for the determination of the electronic band structure as well as other optical parameters, such as optical energy gap and refractive index. The aim of present paper is to study the effect of Sn incorporation on the optical properties of Se-Te alloys. The optical transmission spectra of the amorphous thin films of a-$Se_{40-x}Te_{60}Sn_x$ are measured by spectrophotometer.

II. EXPERIMENTAL PROCEDURE

Glassy alloys of a-$Se_{40-x}Te_{60}Sn_x$ (x = 0, 2, 4, 6, 8) were prepared by melt-quenching technique.The exact proportions of high purity 99.999% Se, Sn and Te granules were weighted according to the formula of a-$Se_{40-x}Te_{60}Sn_x$ (x = 0, 2, 4, 6, 8). The powder mixture was loaded into quartz ampoule and sealed under vacuum at 10^{-5} torr. The sealed quartz ampoules was loaded in a furnace and heated to 950^oC at a rate of 3-4 ^{0}C/minute for 18 hours to ensure the composition homogeneity and quenched in liquid nitrogen. The ingots were crushed, separated, grounded and characterized. The glassy nature of alloys was checked with the help of X-ray diffraction technique using Cu-Kα radiation.

The thin films of chalcogenide were synthesized by thermal evaporation technique under high vacuum conditions (~ 10^{-5} torr) using a small piece of bulk alloy as a source material and glass as a substrate. The films were kept inside the deposition chamber for 24 hours to achieve the metastable equilibrium. The optical transmission spectra of amorphous $Se_{40-x}Te_{60}Sn_x$ (x = 0, 2, 4, 6, 8) thin films have been measured by a double beam UV-VIS-NIR computer controlled spectrophotometer as a function of wavelength.

III RESULT AND DISCUSSION

3.1 Determination of Optical Constants

By Swanepole's method , the optical parameters are deduced from the fringe patterns in the transmittance spectrum. In the transmittance region where the absorption coefficient (α = 0), the refractive index n is given by

$$n = [N + (N^2 - s^2)^{1/2}]^{1/2} \qquad (i)$$

where $N = (2s / T_m) - (s^2 + 1) / 2$, s is the refractive index of the substrate and T_m is the envelope function of the transmittance minima.

Where (α ≠ 0), in the region of weak and medium absorption, the refractive index n is given by

$$n = [N + (N^2 - s^2)^{1/2}]^{1/2} \qquad (ii)$$

where $N = \{2s(T_M - T_m) / \}T_M T_m + (s^2 + 1) / 2$ and T_m is the envelope function of the transmittance maxima.

In the region of strong absorption, the transmittance decreases drastically and refractive index (n) can be estimated by extrapolating the values in the other regions.

If n_1 and n_2 are the refractive indices at two adjacent maxima and minima at λ_1 and λ_2 then the thickness of the film (d) is given by

$$d = \lambda_1\lambda_2 / 2[\lambda_1 n_2 - \lambda_2 n_1] \quad\quad\quad\quad (iii)$$

The extinction coefficient (k) can be calculated by relation

$$k = \alpha \lambda / (4\pi) \quad\quad\quad\quad (iv)$$

$$= (\lambda / 4\pi d) \ln (1/x)$$

where x is the absorbance and d is the film thickness.

In the region of weak and medium absorption, absorbance (x) can be calculated from the transmission minima T_m and given by the equation

$$x = [E_m - \{E_m - (n^2 - 1)^3 (n^2 - s^4)^{1/2}] / [(n - 1)^3 (n - s^2)] \quad\quad\quad\quad (v)$$

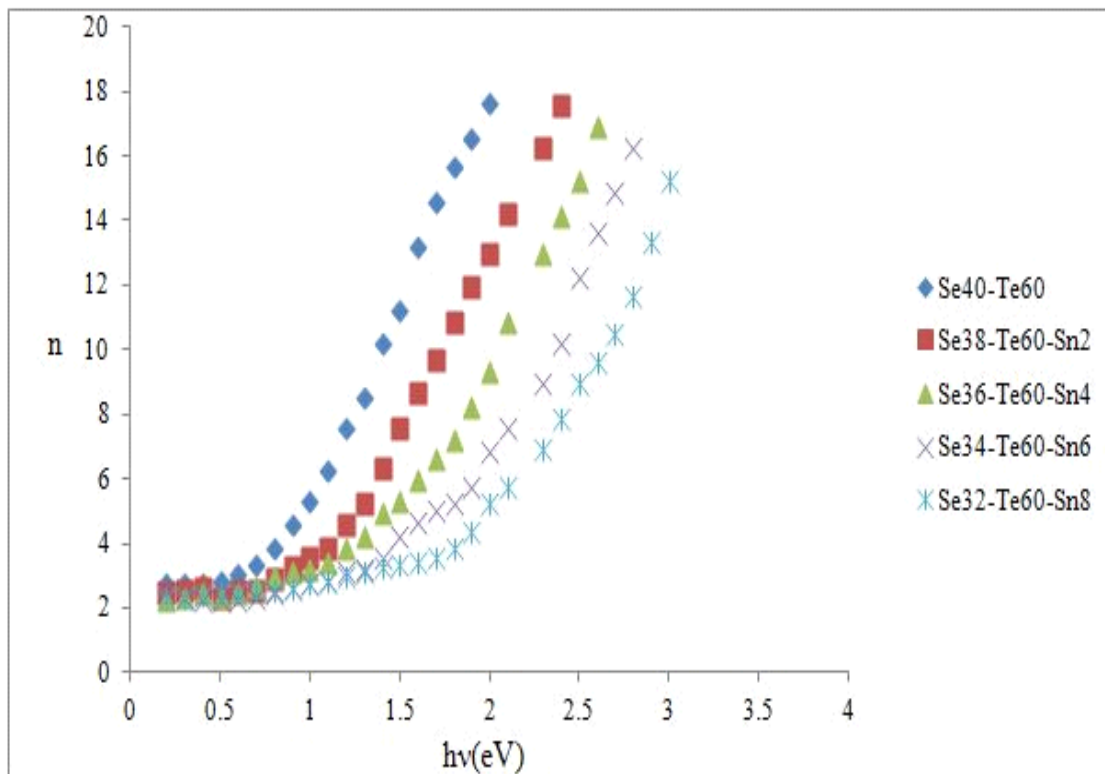where $\quad\quad\quad E_m = [(8n^2 s/T_m)-(n^2-1)(n^2-s^2)]$

Fig. 1. Variation of refractive index (n) with photon energy (hv) for amorphous $Se_{40-x}Te_{60}Sn_x$ thin films.

The obtained values of refractive index and extinction coefficient are given in Table 1. The variation of refractive index with photon energy (hv) is shown in Fig. 1 and the variation of extinction coefficient with photon energy is shown in Fig. 2. It is observed that the value of refractive index and extinction coefficient show an overall increasing trend with the increase in photonic energy. From Table 1, it is observed that the values of refractive index (n) and extinction coefficient (k) increases with the increase of Sn content for a-$Se_{40-x}Te_{60}Sn_x$ thin films. This spectral and dopant dependence of optical constants with the photonic energy will be helpful in deciding on the suitability of this system for application in optical data storage devices.
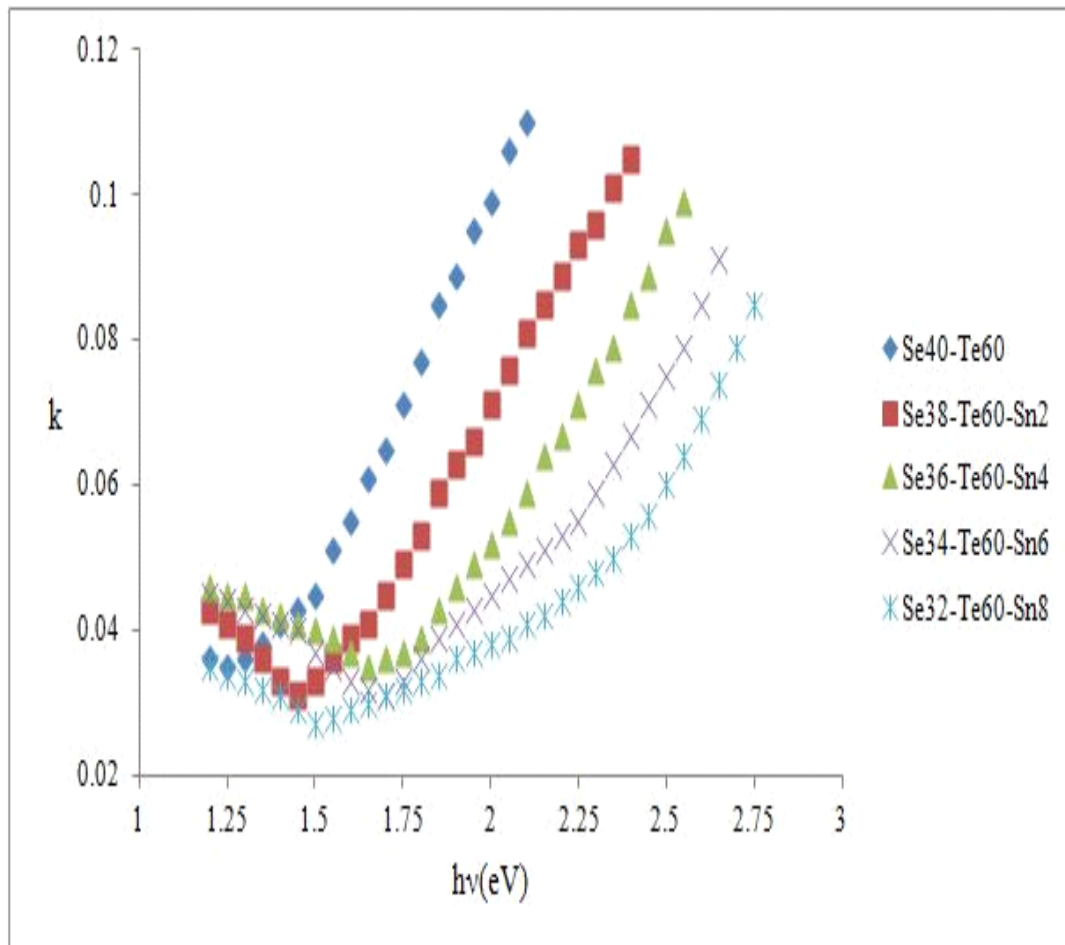
International Journal of Advance Research in Science and Engineering

Vol. No.6, Issue No. 05, May 2017

www.ijarse.com

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Fig.2. Variation of extinction coefficient (k) with photon energy (hν) for amorphous $Se_{40-x}Te_{60}Sn_x$ thin films.

Table 1: Optical constants for amorphous $Se_{40-x}Te_{60}Sn_x$ thin films at 1600 nm.
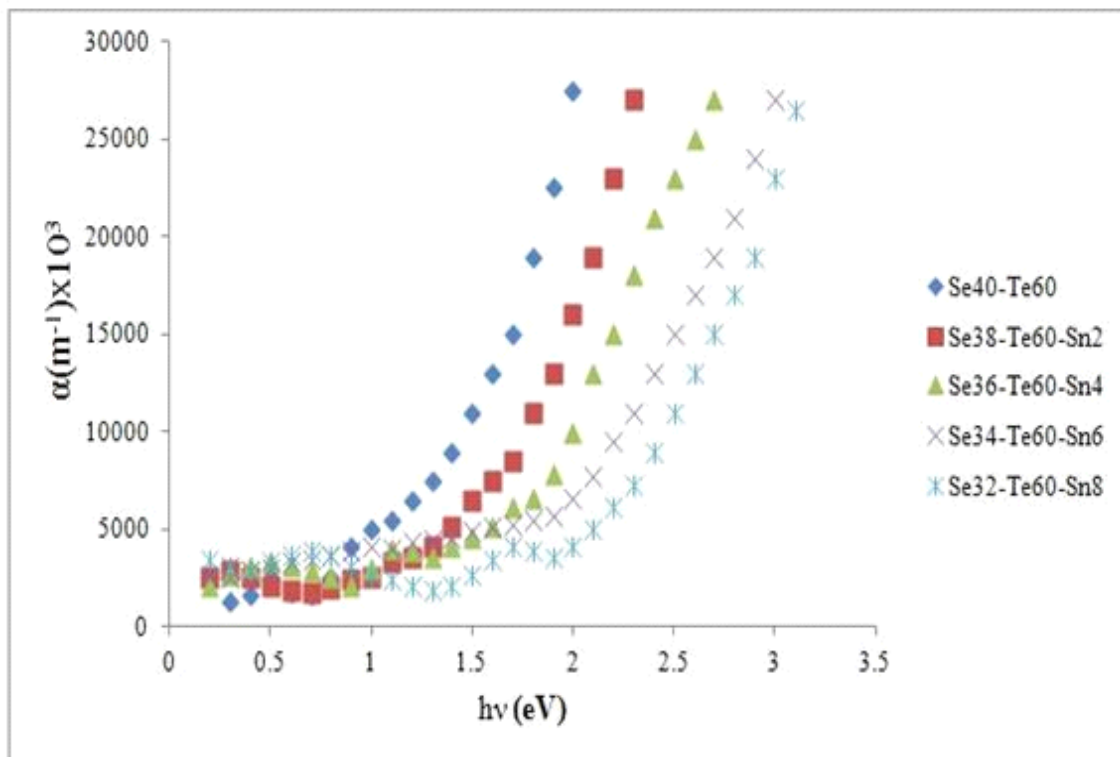
Material	Refractive Index (n)	Extinction Coefficient (k)	Absorption Coefficient $(\alpha)(m^{-1})$ x 10^3	Optical Band Gap Eg (eV)
$Se_{40}Te_{60}$	17.66	0.099	28.00	0.78
$Se_{38}Te_{60}Sn_2$	12.95	0.071	16.00	1.13
$Se_{36}Te_{60}Sn_4$	9.35	0.052	10.00	1.25
$Se_{34}Te_{60}Sn_6$	6.85	0.045	6.60	1.33
$Se_{32}Te_{60}Sn_8$	5.25	0.038	4.10	1.42

These are found that the optical band gap to increase with the increase in photon energy and also with addition of Sn impurity in the present system of a-$Se_{40-x}Te_{60}Sn_x$ thin films.

3.2 Absorption Coefficient and Optical Band Gap

The absorption coefficient (α) of amorphous $Se_{40-x}Te_{60}Sn_x$ thin films have been calculated by using relation

$$\alpha = 4\pi k / \lambda \qquad \text{(vi)}$$

Fig 3. Variation of absorption coefficient (α) with photon energy (hν) for amorphous $Se_{40-x}Te_{60}Sn_x$ thin films.

Here an increase in the value of absorption coefficient (α) with the increase in photon energy for a-$Se_{40-x}Te_{60}Sn_x$ thin films and it is also observed that the value of absorption coefficient increases with the increase of Sn content. Due to the large absorption coefficient these materials may be suitable for optical memory storage devices.
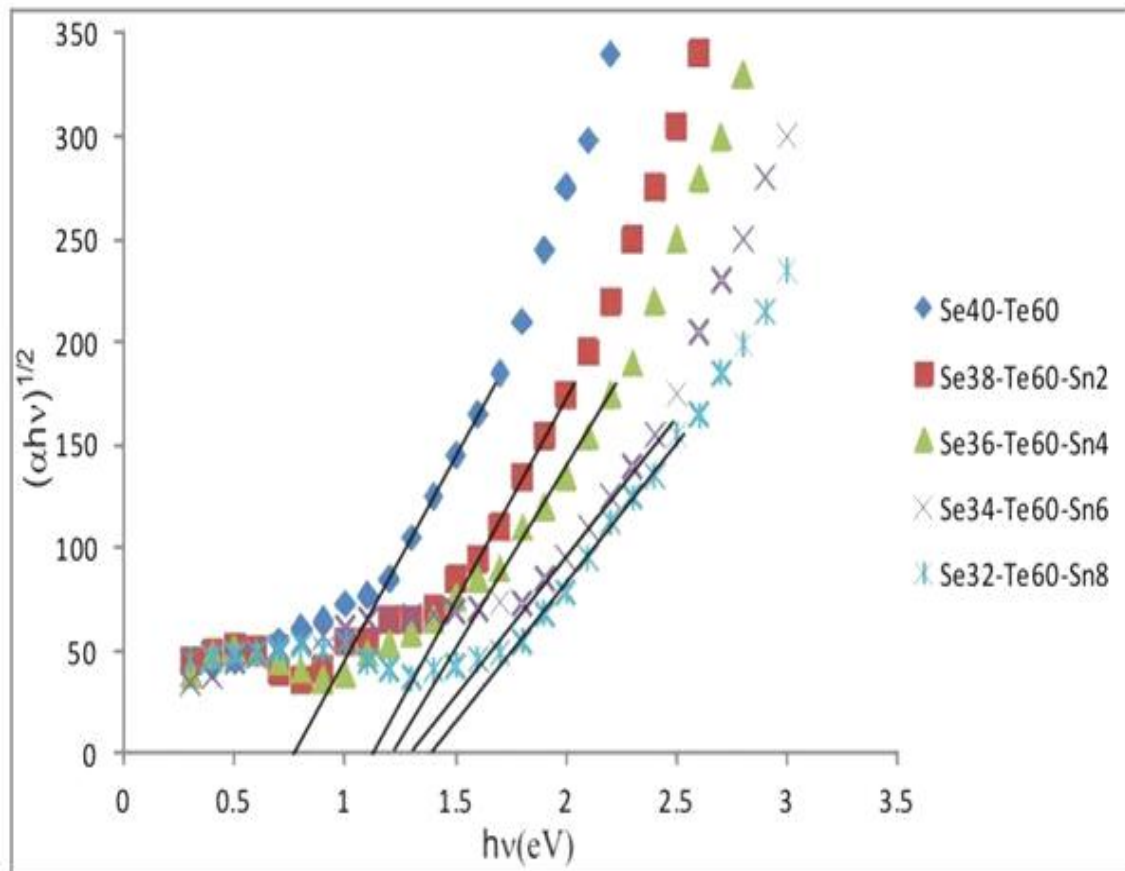
The optical band gap is calculated from absorption coefficient data as a function of energy (hν) by using relation

$$\alpha = A(h\nu - E_g)^n / h\nu \qquad\qquad (vii)$$

Here A is a constant, E_g is the optical band gap of the material and the exponent *n* depends on the type of transition and have values 1/2, 2, 3/2 and 3 corresponding to the allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions, respectively.

The present system of a-$Se_{40-x}Te_{60}Sn_x$ obeys the rule of allowed indirect transition. The values of optical band gap (E_g) is calculated by extrapolating the straight line portion of ($\alpha h\nu$)$^{1/n}$ *vs.* hν by taking n = 2 as shown in Fig.4. The calculated values of E_g for all samples are given in Table 1. It is evident from Table 1, that the optical band gap (E_g) increases with increase of the Sn content. The increase in optical band gap with increase of the Sn content can be explained on the basis of Mott and Davis Model [22]. According to this technique, chalcogenide thin films contain a high concentration of defect states and these defects are responsible for the presence of localized states in the band gap. The increase in optical band gap with increase of the Sn content may be due to decrease in the density of defect states in the mobility gap or increase in disorderness. The increase in optical band gap along with the decrease in the density of defect states may also be correlated with

electronegativity of the elements involved. The electronegativity of Se, Te and Sn are 2.4, 2.1 and 1.96 respectively and Sn has higher electronegativity than Se. .

Fig 4. Variation of $(\alpha h\nu)^{1/2}$ with photon energy $(h\nu)$ for amorphous $Se_{40-x}Te_{60}Sn_x$ thin films

These indirect band gap materials may have potential applications in optical recording media, infrared spectroscopy, laser fibers, xerography, fiber optical telecommunication and electrographic applications. Moreover, their refractive index and transparency in the infrared region are good indicators for integrated optics and detection in the near-infrared spectral domain.

IV. CONCLUTION

The optical gap increases with an increase of Sn concentration in $Se_{40-x}Te_{60}Sn_x$ (where $x = 0, 2, 4, 6$ and 8) systems. The results prove that optical gap strongly depends upon the film composition. The absorption coefficient for the film exhibits a linear dependency on photon energy. In the wide range of wavelength the absorption coefficient follows Urbach relation[23]. It is also found that the values of the optical constants increase with increasing Sn content at room temperature. An increase in the optical band gap with increasing Sn content is probably due to the increase in grain size, reduction in the disorder and decrease in the density of defect state which results in the reduction of tailing of bands.

REFERENCES

[1] S. O. Kasap, T. Wagner, V. Aiyah, O. Krylouk, Berkirov, L. Tichy J. Mater.Sci. 34, (1999) 3779.

[2] J. S. Sanghera, L. B. Shaw, I. D. Aggarwal, Comptes Rendus Chimie 5, (2002) 873 .

[3] N. Mehta, D. Sharma, A.Kumar, Physica B 391, (2007) 108.

[4] R.S. Kundu, K.L. Bhatia, Nawal Kishore, V.K. Jain, Physica B 74, (1996) 317.

[5] R. Swanepoel, J.Phys.E: Sci.Instrum. 16, (1983) 1214.

[6] D. P. Gosain, T. Shimizu, M. Ohmuru, M. Suzuki, T. Bando, S. Okano, J. Mat. Sci. 26,(1991) 3271.

[7] K. Uchino, K. Takada, T. Ohno, H. Yoshida, Y. Kobayashi, Jpn. J. Appl. Phys. 31, (1993)5354.

[8] N. Nobukuni, M. Takashima, T. Ohno, M. Ohrie, J. Appl. Phys. 78, (1995) 6980.

[9] M. Nakamura, Y. Wang, O. Matsuda, K. Inoue, K. Murase, J. Non-cryst. Solids 740, (1996)198-200.

[10] L. Men, F. Jiang, F. Gan, Mater Sci. Eng. B 18, (1997) 47.

[11] R. V. Woudenberg, Jpn. J. Appl. Phys. 37,(1998) 2159.

[12] T. Z. Babeva, D. Dimitrov, S. Kitova, I. Konstantinov, Vacuum 58,(2000) 96.

[13] I. V. Mikla, I. P. Mikhalko, V. V. Mikla, Mater Sci. Eng. B 83,(2001) 74.

[14] A. K. Kolobov, J. Tominaga, J. Optoelectron. Adv. Mater 4 (3), (2002) 679.

[15] S. A. Khan, M. Zulfequar, M. Hussain, Vacuum 72, (2003) 291.

[16] K. Tanaka, J. Non-cryst. Solids 1179, (1993)164.

[17] T. Kawaguchi, S. Maruno, S.R. Elliot, J. Appl. Phys. 79, (1996) 9096 .

[18] M. Ohto, Phys Status Solidi A 159, (1997) 461.

[19] A. Kumar, P. B. Barman, R. Sharma, Adv. Appl. Sci. Research 1(2), (2010) 47.

[20] A. Kumar, M. Lal, K. Sharma, S. K. Tripathi, N. Goyal, Chalc. Lett. 9, (2012) 275.

[21] Arpit Kaistha, V.S. Rangra and Pankaj Sharma,Chalc. Glass Vol. 41, No. 2, (2015) 175-179

[22] N. F. Mott, E. A. Davis, Electronic Processes in Non-Crystalline Mat., Clarendon, Oxford, (1979) 428.

[23] Urbach Source: Physics Review,13 (1953) 92