ISSN 1087-6596, Glass Physics and Chemistry, 2013, Vol. 39, No. 3, pp. 276–278. © Pleiades Publishing, Ltd., 2013.

Optical Studies of Se-Bi-Te-Sb Thin Films by Single Transmission Spectrum[1]

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Received January 25, 2012

Abstract—Chalcogenide glasses are interesting materials on account of their infrared application. In present paper, thin films of quaternary chalcogenide glasses, $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$, where $x = 0, 2, 4$, has been investigated for their optical properties using transmission spectra in the spectral range of 500–2500 nm. The refractive index shows the normal dispersion behavior and found to increase with increase in Sb content. Extinction coefficient has been observed decreases with Sb content.

Keywords: chalcogenide glasses, refractive index, extinction coefficient, dielectric constant

DOI: 10.1134/S1087659613030048

INTRODUCTION

Chalcogenide glasses have tremendous applications in various technological and commercial sectors [1, 2]. In particular, thin films of these glasses have been actively studied as holographic recording media [3, 4]. Se based glasses are preferred over any other types of alloys in semiconductor industry due to its unique property of reversible transformation used in optical memory devices [5, 6]. Pure Se is a good glass former, but it has some drawbacks which restrict its wide applicability. Pure selenium is not stable in standard operational condition because its glass transition temperature is close to room temperature. In order to make these glasses stable it is useful to add certain additives which act as cross linking agents and increase the stability and dimensionality in the structure of the materials. The addition of metal impurities changes the electronic structure and properties of these materials. Among these materials, selenide materials have been as possible materials for non-linear optical application [7]. Alloying elements in these materials produce the characteristics effects which depend on the electronic structure of these elements. Sb addition improves the thermal stability of material and changes their electrical properties considerably. It has been observed [8] that the introduction of Sb leads to a strong dependence of *ac* conductivity at high temperatures. The present work aims to investigate quaternary thin films of $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$, where $x = 0$, 2, 4 for optical properties i. e., refractive index (n), extinction coefficient (k), dielectric constants (ε_r real part and ε_i imaginary part), and optical conductivity (σ).

EXPERIMENTAL PROCEDURE

The glassy alloys of $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$, where $x =$ 0, 2, 4 in bulk form were prepared by melt quenching technique. Materials were weighed as per their at wt %. Ampoules containing materials were sealed in a vacuum of 10^{-5} Torr and heated in a vertical furnace up to a temperature of 1000°C for 20 h. During heating the ampoules were rocked frequently to ensure homogenization of the melt. The ampoules were then quenched in ice cooled water. The material was separated from the ampoule by placing it in a $HF + H_2O_2$ solution for approximately 50 h. Thin films of glassy alloys prepared were deposited on the well cleaned microscopic glass substrates by the thermal evaporation technique [HINDHIVAC 12A4D Model] under a vacuum of 10^{-5} Torr. The amorphous nature of the thin films was confirmed by X-ray diffraction technique. The transmission spectra of deposited thin films in the transmission range 500–2500 nm were obtained by using UV-VIS-NIR spectrophotometer [Perkin Elmer Lamda-750]. All the measurements were carried out at room temperature (300 K).

RESULTS AND DISCUSSION

The XRD pattern of $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ thin films shown in Fig. 1 reveal the amorphous nature as no striking peaks is observed in the spectra. To determine the optical constants for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ thin films, the variation of the transmission (T) with wave-

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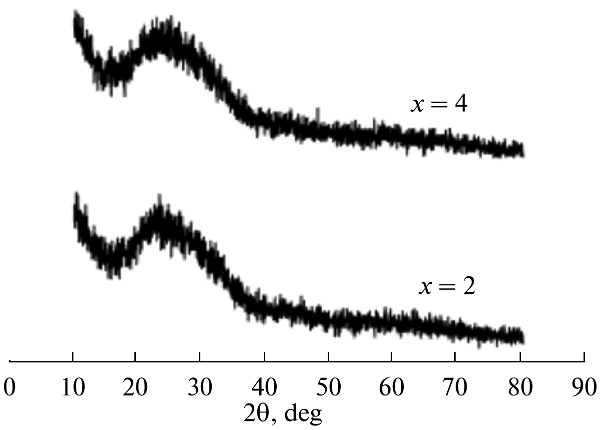

Fig. 1. XRD pattern in $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ (x = 2, 4) thin films.

length λ were carried out at room temperature and is shown in Fig. 1.

Refractive index and extinction coefficient. When light passes through a medium, some part of it will always be absorbed. This can be conveniently taken into account by defining a complex index of refraction, $n^* = n - ik$. Here, the real part of the refractive index n indicates the phase speed, while the imaginary part k indicates the amount of absorption. The refractive index n is calculated from the fringe patterns in the transmittance spectrum (Fig. 2) by using the well known Swanepoel's method [9] and reported in Table. The value of refractive index (n) of thin film in the weak and medium absorption region ($\alpha \neq 0$) are obtained by using the relation [9]

$$n = \left[N + (N^2 - s^2)^{\frac{1}{2}}\right]^{\frac{1}{2}}, \quad (1)$$

where

$$N = 2s\frac{T_M - T_m}{T_M T_m} + \frac{s^2 + 1}{2}, \quad (2)$$

where T_M and T_m are the transmission maxima and corresponding minima at a certain wavelength λ and s is the substrate refractive index and in the present case $s = 1.5$. The refractive index follows the normal dispersion law. The value of refractive index increases with the increase in Sb content. The increase of refractive index with increase in Sb content may be explained by an increase of total polarizability of the material. The extinction coefficient (k) for the thin films is calculated by the well established relation, $k = \alpha\lambda/4\pi$ where α is the absorption coefficient. The spectral dependence of k is shown in Fig. 3. It is observed that the extinction coefficient decreases with increase of Sb content which can be related with the decrease of optical transmittance.

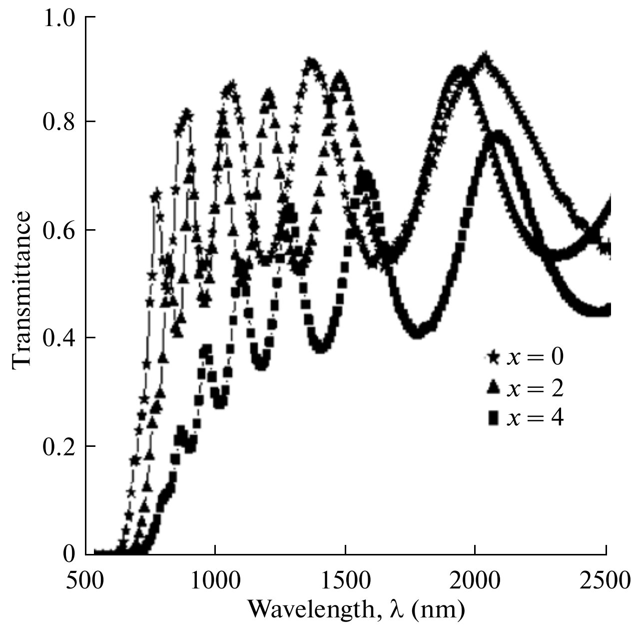

Fig. 2. Transmission spectra for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ (x = 0, 2, 4) thin films.

Dielectric constant and optical conductivity. The dielectric constant is a complex quantity and the real part of the dielectric constant explains what amount of the material will slows down the velocity of light passing through it, and the imaginary part of the dielectric constant shows how a dielectric material absorbs the energy from electric field due to dipole orientation. The values of refractive index and extinction coefficient are used to determine [10] the dielectric response of the material. The real and imaginary parts of the dielectric constants for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ thin films are obtained by using the relation [11] $\varepsilon_r = n^2 - k^2$ and $\varepsilon_i = 2nk$.

The values of dielectric constants, i.e. ε_r and ε_i are reported in Table. From Table it is clear that the values of the real and imaginary parts of dielectric constant increases with the increase in Sb content. Optical conductivity (σ) of the thin films directly depends on the refractive index and absorption coefficient of the material. It shows the optical response of the material and has the dimension of the frequency. The optical

Values of refractive index n, dielectric constants ε_r and ε_i and optical conductivity (σ) at 800 nm for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ thin films

x	n	ε_r	ε_i	$\sigma \times 10^{14}$ (s^{-1})
0	2.80	7.63	2.77	4.62
2	2.86	8.05	2.07	3.50
4	3.67	13.30	2.68	4.47

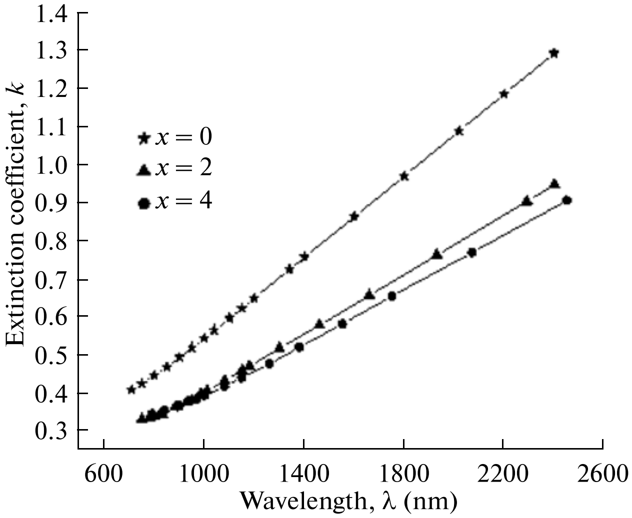

Fig. 3. Plot of extinction coefficient (k) with wavelength for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ ($x = 0, 2, 4$) thin films.

conductivity for thin films is calculated by using the relation [12], $\sigma = \alpha nc/4\pi$, where α is the absorption coefficient, n is refractive index and c is the velocity of light. The values of optical conductivity for thin films at a wavelength 800 nm are listed in table. Value of optical conductivity may be due to the increased density of localized states in the gap [13].

CONCLUSION

The refractive index for $Se_{80.5}Bi_{1.5}Te_{18-x}Sb_x$ ($x = 0, 2, 4$) thin films shows normal dispersion behavior and found to increase with increase in Sb content. The high refractive index values for the investigated films have advantage for strong optical field confinement, which allows small waveguide bend radii leading to compact circuit designs and enhances the optical intensities for non-linear interaction. The transmittance has been found to decrease with increase in Sb content. Extinction coefficient has been observed to decrease with Sb content. The dielectric constants, ε_r and ε_i, are found to increase with increase in Sb content.

REFERENCES

1. Tanaka, K., Structural phase transitions in chalcogenide glasses, *Phys. Rev. B: Condens. Matter*, 1989, vol. 39, pp. 1270–1279.
2. Seddon, A.B., Chalcogenide glasses: A review of their preparation, properties, and applications, *J. Non-Cryst. Solids*, 1995, vol. 184, pp. 44–50.
3. Spektor, B., Lisiansky, M., Shamir, J., Klebnov, M., and Lyubin, V., On the linearity of holographic recording in amorphous As_2S_3 films, *J. Appl. Phys.*, 2000, vol. 87, pp. 3234–3239.
4. Teteris, J., Holographic recording in amorphous chalcogenide semiconductor thin films, *J. Optoelectron. Adv. Mater.*, 2002, vol. 4, pp. 687–697.
5. Shaaban, E.R., Kaid, M.A., Moustafa, E.S., and Adel, A., Effect of compositional variations on the optical properties of Sb–Ge–Se thin films, *J. Phys. D: Appl. Phys.*, 2008, vol. 41, article 125301 (7 pages).
6. Seddon, A.B., Pan, W.J., Furniss, D., Miller, C.A., Rowe, H., Zhan, D., McBrearty, E., Zhang, Y., Loni, A., Sewell, P., and Benson, T.M., Fine embossing of chalcogenide glasses—A new fabrication route for photonic integrated circuits, *J. Non-Cryst. Solids*, 2006, vol. 352, pp. 2515–2520.
7. Nasu, H., Kubodera, K., Kobayashi, M., Nakamura, M., and Kamiya, K., Third-harmonic generation from some chalcogenide glasses, *J. Am. Ceram. Soc.*, 1990, vol. 73, pp. 1794–1796.
8. Mehta, R.M., Kaur, G., and Mathur, P.C., Antimony-doping effect on the ac conductivity of the amorphous Se–Te system, *Phys. Rev. B: Condens. Matter*, 1991, vol. 43, pp. 12388–12392.
9. Swanepoel, R., Determination of the thickness and optical constants of amorphous silicon, *J. Phys. E.: Sci. Instrum.*, 1983, vol. 16, pp. 1214–1222.
10. Sharma, P., Sharma, V., and Katyal, S.C., Variation of optical constants in $Ge_{10}Se_{60}Te_{30}$ thin film, *Chalcogenide Lett.*, 2006, vol. 3, pp. 73–79.
11. Sharma, P. and Katyal, S.C., Effect of Cd and Pb impurities on the optical properties of fresh evaporated amorphous $(As_2Se_3)_{90}Ge_{10}$ thin film, *Appl. Phys. B: Lasers Opt.*, 2009, vol. 95, pp. 367–373.
12. Sharma, P. and Katyal, S.C., Determination of optical parameters of a-$(As_2Se_3)_{90}Ge_{10}$ thin film, *J. Phys. D: Appl. Phys.*, 2007, vol. 40, pp. 2115–2120.
13. Mott, N.F. and Davis, E.A., Conduction in non-crystalline systems: V. Conductivity, optical absorption, and photoconductivity in amorphous semiconductors, *Philos. Mag.*, 1970, vol. 22, pp. 903–922.