JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS, Vol. 11, No. 6, June 2009, p. 794 - 796

Optical studies of Se-Te-Bi chalcogenide thin films

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The reflectance and transmission have been performed for $Se_{80-x}Te_{20}Bi_x$ ($0 \le x \le 8$) thin films. The theory of the reflectance of light from a thin film can be expressed in terms of Fresenl's coefficient. EPMA studies have been performed on the samples.

(Received April 18, 2009; accepted June 15, 2009)

Keywords: Amorphous Chalcogenides, Thin films, Optical Properties

1. Introduction

In amorphous semiconductors there has been great interest because of their wide potential applications. Chalcogenide materials are most widely known families of amorphous semiconductors. Chalcogenide glasses are based on the chalcogen elements S, Se and Te. These glasses are formed by the addition of other elements such as Ge, As, Sb, Ga, Bi, Pb etc. Amorphous chalcogenide glasses are of great interest also due to their importance in preparing electronic memories [1] and their optical application as good IR transmitting materials [2]. Effect of optical memory applications in amorphous semi conducting films have been investigated and utilized for various applications in recent years [3-7]. Chalcogenide glasses have semiconductor type band gap which cause them to be essentially opaque through the visible spectrum and to begin transmission around 1μm, possibly to 20 μm (mid IR). This transmission is not only useful for windows in military applications, but also potentially as an optical waveguide to carry carbon dioxide laser power (10.6 μm wavelength) to ablate cardiovascular plaque and for industrial cutting applications [8].

Chalcogenide material find vast applications in infrared optical fibers, in reversible phase change optical recording etc. [9]. Among the various chalcogenide materials, Se–Te based alloys are preferred because of their higher photosensitivity, greater hardness, higher crystallization temperature (T_c) and smaller ageing effects as compared to pure selenium [10]. The addition of a third element like Sb, Sn, In, Pb has large effect on their structural, physical, optical, electronic and thermal properties [11]. In the present paper the effect of optical studies has been studied on Bismuth doped Selenium-Tellurium system.

2. Experimental

Bulk $Se_{80-x}Te_{20}Bi_x$ (x=0, 4, 6, 8) alloys were prepared by melt quenching technique. The constituent elements (99.999% purity) were weighed according to their atomic percentage and were sealed in quartz ampoule in a vacuum of ~ 10^{-5} mbar. The sealed ampoule was kept in a vertical furnace for 48 h and the temperature was raised up to 1123 K. The ampoule was rocked constantly to ensure homogeneous mixing of the melt. The ampoule containing molten alloy was quenched in ice-cold water. The bulk material was extracted from quartz ampoule by dissolving the ampoule in $HF+H_2O_2$ solution for about 48 h. Ingot so obtained was crushed into fine powder.

Thin films of the above mentioned Se-Te-Bi alloys were prepared by thermal evaporation method using Hind High Vacuum Coating Unit (Model No. 12A4D). Well cleaned glass slides were used as substrates. The substrates were maintained at room temperature during deposition and the pressure in the chamber during the deposition was below 10^{-5} mbar. The films were left inside the vacuum chamber after deposition for ~24 h to attain metastable equilibrium as suggested by Abkowitz [12].The composition of the thin film was analyzed by electron probe microanalysis (EPMA) using JEOL JXA 8600 M superprobe with accelerator voltage 15 keV, with probe diameter 5μm and probe current 50nA. The transmittance (T) w.r.t air and specular reflectance (R) of thin films were measured at room temperature using UV-VIS-NIR spectrophotometer (VARIAN Cary 500) in the wavelength range of 200-3000 nm.

3. Results and discussion

XRD of $Se_{76}Te_{20}Bi_4$ thin film sample is shown in the Fig. 1. Absence of sharp peaks in the graph shows that the material is amorphous in nature. All other samples of the composition also show the similar behaviour on XRD studies.

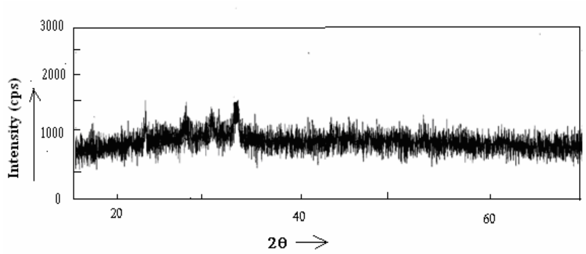

Fig. 1. XRD of $Se_{76}Te_{20}Bi_4$ sample

EPMA studies have been performed on the samples and it has been noted that the actual compositions of the elements in thin films differ from that of bulk glass by about 3%, 4% and 1% for bismuth, tellurium and selenium respectively.

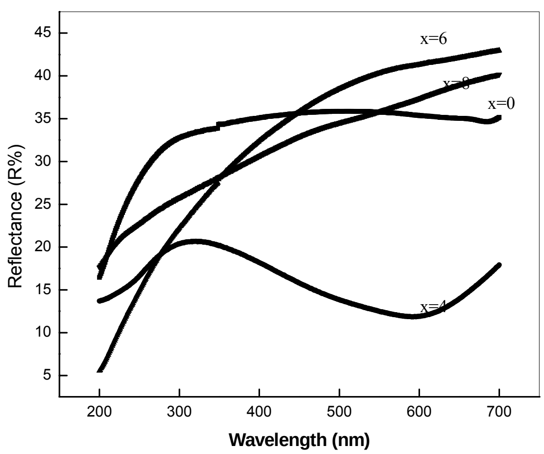

Fig. 2. Reflectance spectra for $Se_{80-x}Te_{20}Bi_x$ chalcogenide thin films

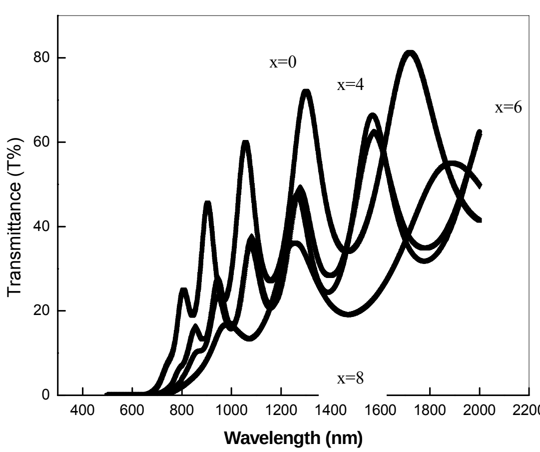

Fig. 3. Transmission spectra for $Se_{80-x}Te_{20}Bi_x$ chalcogenide thin films

Fig. 2 shows the graph between reflectance and wavelength for the different samples of $Se_{80-x}Te_{20}Bi_x$ where x varies from $0 \le x \le 8$. The theory of the reflectance of light from a thin film can be expressed in terms of Fresenl's coefficient [13]. According to this theory the refractive index (n) and extinction coefficient (k) are given as

$$n = \frac{1+R}{1-R} \pm \left[\left(\frac{1+R}{1-R} \right)^2 - \left(1+k^2\right) \right]^{1/2} \quad \text{and} \quad k = \frac{\alpha\lambda}{4\pi}$$

The spectral dependence of the transmittance for the $Se_{80-x}Te_{20}Bi_x$ ($0 \le x \le 1$) is shown in the Fig. 3. The fringes shown in the plot are formed due to constructive and destructive interference of light reflected from the surface and film substrate interface. In the region of the fringes the film behaves as partial transparent film. The small fringe amplitude represents the strong absorption, amplitude close to maxima represents medium absorption and the parallel set of maxima and minima represent completely a transparent wavelength region. It is clear from the transmission vs. wavelength graph that peaks decreases with the addition of Bi content in the Se-Te system. This may be due to the rearrangement of defects and disorders in the chalcogenide system.

4. Summary

XRD studies reveal that the samples are amorphous in nature. The transmittance of the samples has been explained on the basis of defects and disorders in the system.

Acknowledgements

The authors wish to thank all the members of the Hybrid microcircuits group for their support and to the Director CEERI for his encouragement and permission to publish the results. The authors are extremely thankful to the Dr.T.S.Sathiaraj for his help in performing the reflectance and transmittance studies.

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