Asian Journal of Chemistry Vol. 21, No. 10 (2009), S028-032

Transient Photoconductivity of Amorphous $Se_{85-X}Te_{15}Bi_x$ Thin Films

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Photoconductive properties of a-$Se_{85-x}Te_{15}Bi_x$ (where x = 0, 1, 2, 3, 4, 5) glassy thin films prepared by vacuum evaporation technique are recorded at room temperature (303 K) using Keithley 6487 picoammeter. Temperature dependent dark conductivity is studied in the temperature range 303-333 K and it shows that conduction for the studied composition is through an activated process, having single activation energy. Optical band gap (E_g) as determined from Tauc extrapolation method is found to follow the similar trend as that of dark activation energy (ΔE_d) except for Bi = 1 at. %. The decay of photocurrent with time is also studied for the samples. The differential life time $\boldsymbol{\tau_d}$ as determined from the decay of photocurrent w.r.t. time is found to increase with increasing Bi content.

Key Words: Chalcogenide glasses, dark conductivity, transient photoconductivity.

INTODUCTION

In contrast to amorphous silicon and other group IV tetrahedrally bonded semiconductors, the chalcogenide glasses have attracted much attention due to their interesting optical, electrical and physical properties which can be controlled by changing their chemical composition. This property of chalcogenide glasses makes these materials useful for technological applications including phase change memories. The interest in these materials arises particularly due to their ease of fabrication in the form of bulk and thin films. Furthermore, one can easily change the properties of these glasses by varying their chemical composition (synthesis regime) [1, 2] or irradiating them by light (photoinduced phenomena) [3-5]. In the present paper an attempt has been made to study the transient photoconductive properties $Se_{85-x}Te_{15}Bi_x$ system. Temperature (303-333K) dependent dark conductivity measurements have been carried out for all the compositions and results are compared for varying composition of Bi. The rise and decay of photocurrent have also been measured at room temperature and 1035 lx intensity for all compositions.

EXPERIMENTAL

Glassy alloys of the $Se_{85-x}Te_{15}Bi_x$ system have been prepared by the quenching technique as described elsewhere [6]. Thin films of the glassy alloys have been prepared by the vacuum evaporation technique. The amorphous nature of the bulk samples and thin films was confirmed by the x-ray diffraction technique as no sharp peak was observed in the spectra. Predeposited thick indium electrodes on well-degassed Corning 7059 glass substrates have been used for the electrical contacts. A planar geometry of the film (length ~ 1.78 cm; electrode gap ~ 8×10^{-2} cm) is used for the electrical measurements. The samples were kept in dark for about 24 h before mounting them in the sample holder. The temperature dependent dark conductivity and transient photoconductivity of the amorphous films were studied by mounting it in a specially designed metallic sample holder where heat filtered white light (200 W tungsten lamp) can be shone through a transparent quartz window. The results were recorded by using a digital picometer (Keithley, model 6487). The temperature was measured by mounting a copper- constant thermocouple near to the sample. The light intensity is measured using a digital Luxmeter (Testron, model TES-1332). The photocurrent is obtained after subtracting the dark current from the current measured in the presence of light.

RESULTS AND DISCUSSION

Dark conductivity and optical band gap

Figure 1 shows the temperature dependence of dark conductivity (σ_d) for $Se_{85-x}Te_{15}Bi_x$ thin films. The plots of ln (σ_d) versus 1000/T are found to straight lines indicating that the conduction is through an activated process having single activation energy in the temperature range 303-333 K. In most of the chalcogenide glasses, σ_d can therefore be expressed by Arrhenius relation

$$\sigma_d = \sigma_0 \exp\left(\frac{-\Delta E_d}{kT}\right) \quad (1)$$

Where, σ_0 is the material related pre exponential factor ΔE_d, is the activation energy for dc conduction, *k* is the Boltzman constant and *T* is the temperature. The value of ΔE_d is estimated from the slope of ln (σ_d) versus 1000/T curves. The calculated value of σ_d and ΔE_d at room temperature is inserted in table 1.

The composition dependent dark conductivity is studied and it is observed that σ_d decreases first as Bi is introduced in the host $Se_{85}Te_{15}$ glassy alloy. However, further increase in the Bi (≥ 2 at. %) content enhances the dark conductivity.

TABLE 1
VALUE OF CONDUCTIVITY Σ_D, ACTIVATION ENERGY ΔE_d, OPTICAL BAND GAP E_g AND DIFFERENTIAL LIFE TIME τ_d FOR $Se_{85-x}Te_{15}Bi_x$ THIN FILMS.

x	σ_d ($\Omega^{-1}cm^{-1}$)	ΔE_d (eV)	E_g (eV)	τ_d (sec)
0	8.01×10^{-12}	0.51	1.46	109
1	3.29×10^{-12}	0.55	1.39	115
2	1.22×10^{-11}	0.48	1.33	143
3	1.68×10^{-11}	0.45	1.30	151
4	2.29×10^{-11}	0.41	1.27	154
5	5.67×10^{-11}	0.33	1.24	165

Activation energy ΔE_d is found to follow the opposite trend as that of σ_d . As Bi (=1 at %) is introduced in the host $Se_{85}Te_{15}$ glassy alloy, its atoms may enter into Se chain and rearrange the network of host Se. It makes bonds with host Se to satisfy their bonding states and therefore reduces the number of defects states. The reduction of defect states results in the increase in activation energy and hence decreases the conductivity. With the further increase of Bi (≥ 2 at. %) content, conductivity increase and activation energy decreases. This behavior may be explained on the basis that Bi atoms act as impurity centers in the mobility gap and induces structural changes in the network which may disturb the balance of charged defects and consequently change the electric conduction. The optical band gap (E_g) is also estimated for the films under consideration [6] by using Tauc extrapolation method [8] and it has been observed that E_g decreases with increasing Bi content (table 1). Moreover, the dark activation energy and optical band gap follows the same trend with Bi concentration as given in table 1, except for Bi = 1 at. %.

Transient photoconductivity

In order to understand the recombination and trapping mechanisms, transient photoconductive measurements are conducted by exposing all the samples to light (1035 lx intensity) at 303 K. To understand the trapping effects, the persistent photocurrent is subtracted from the measured photocurrent and then the corrected photocurrent against time (t) is plotted for all compositions and shown in figure 2. Since the slope goes on decreasing continuously as the time of decay increases, this indicates that the traps exist at all the energies in the band

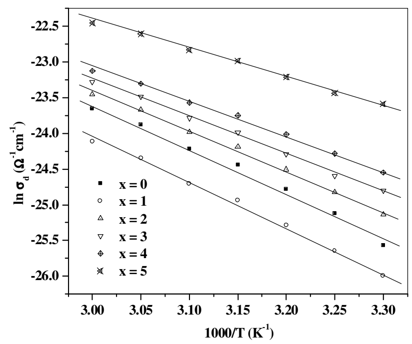

Figure 1 Plots of σ_d vs 1000/T for $Se_{85-x}Te_{15}Bi_x$ thin films

gap which have different time constants and hence give the non exponential decay of photoconductivity. To analyse the decay rates in the case of non-exponential decay, the differential lifetime (τ_d) has been calculated using the relation given by Fuhs and Stuke [9]:

$$\tau_d = -\left[\frac{1}{I_{ph}}\left(\frac{dI_{ph}}{dt}\right)\right]^{-1} \quad (2)$$

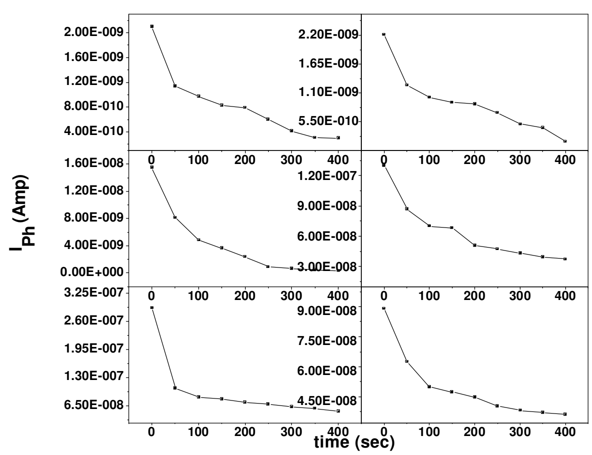

Figure 2 Plots of Iph vs time for $Se_{85-x}Te_{15}Bi_x$ thin films

From the slope of I_{ph} versus time curves (figure 2), the values of τ_d have been calculated using equation 2 at t = 50 s for the samples under investigation (given in table 1). The values of τ_d is found to increase with increasing Bi content, indicating the slower rate of decay of $I_{ph.}$ Similar behavior has been observed by Sharma et. al. [10] while studying the effect of Bi incorporation on the electrical properties of a-Ge-Se-In thin films. Addition of Bi gives rise to defect centres. These defects could induce more localized states which might act as trapping centres. Because of the involvement of electron and hole traps in the recombination process, additional processes of trap filling during the rise and trap emptying during the decay get involved. These traps 'store' the charge carrier and hence delay the recombination rate corresponding to the increase in the differential lifetime with the increase in the Bi content [11].

Conclusion

The study of dark conductivity of $Se_{85-x}Te_{15}Bi_x$ thin films as a function of temperature (303-333 K) reveals that the conduction is through an activated process with single activation energy. Dark conductivity is found to decrease as Bi is introduced to the host $Se_{85}Te_{15}$ glassy alloy whereas it's further addition (> 1 Bi at. %) causes the conductivity to increase. The transient photoconductivity measurements for investigating thin films at room temperature and 1035 lx intensity shows that after cessation of illumination, photocurrent follows a non-exponential decay. An increase in the differential lifetime is also observed with the increase in the Bi concentration.

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