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Photo induced Effects on the Optical Properties of $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ Thin Film.

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Abstract. The thermally evaporated amorphous $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin film of 800 nm thickness was subjected to light exposure for photo induced studies. The as-prepared and illuminated thin films were studied by X-ray diffraction, Fourier Transform Infrared Spectroscopy and X-ray Photoelectron Spectroscopy. The optical band gap was reduced due to photo induced effects along with the increase in disorder. These optical properties changes are due to the change of homopolar bond densities. The core level peak shifting in XPS spectra supports the optical changes happening in the film due to light exposure.

Keywords: Chalcogenides, Thin films, Optical properties, XPS.

PACS: 78.66.Jg, 78.66.-w, 68.37.Xy

INTRODUCTION

Photo induced changes in amorphous chalcogenides are an object of systematic investigations with a view to better understanding the mechanisms of the phenomena taking place in them as well as their practical applications. It is well established that chalcogenide glasses undergo structural changes under the action of external influences such as laser, neutron, electron and gamma irradiation [1-3]. The knowledge of the optical properties of thin films is very important in many scientific, technological and industrial applications of thin films such as photo-conductivity, solar energy, photography, and numerous other applications. The study of the optical absorption spectra in chalcogenide glasses provides essential information about the band structure and the energy band gap. The optical band gap of the material plays a major role in the preparation of the device for a particular wavelength. The present communication reports the effect of laser irradiation on optical properties of amorphous thin films of $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$.

EXPERIMENTAL DETAILS

Thin films were prepared by thermal evaporation method at a base pressure of 1×10^{-5} Torr from the prepared bulk glass onto the glass substrates. The

nature of the film was confirmed by taking XRD. To study the photo induced changes, we irradiated the film at room temperature by a diode pumped solid state laser (DPSS) of wavelength 532 nm with a power of 40 mW. The optical absorption spectra of the as-prepared and illuminated films were taken by using the Fourier Transform Infrared (FTIR) spectrometer (Bruker Optics (IFS66v/S) in the wavelength range of 400-1200 nm at room temperature. The X-ray Photoelectron Spectroscopy (XPS) core level spectra were obtained with Mg K_{α} X-rays (1253.6 eV) at a base pressure of 3×10^{-7} Pa in Multilab 2000 Thermo Scientific UK instrument.

RESULTS AND DISCUSSION

Fig. 1 shows the X-ray diffraction patterns for the $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin films. The absence of the diffraction

FIGURE 1. XRD of $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin film.

lines in the X-ray patterns indicates that the films have amorphous structures.

Transmission spectra corresponding to the amorphous $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin films are plotted in Fig. 2, which shows a clear difference between the as-prepared and the illuminated films. According to Tauc's relation [4] for the allowed non-direct transition, the photon energy dependence of the absorption coefficient can be described by

$$(\alpha h\nu)^{1/2} = B^{1/2}(h\nu - E_g) \quad (1)$$

where B is a parameter that depends on the transition probability and E_g is the optical energy gap. The intercepts of the straight lines with the photon energy axis give the values of the optical band gap (E_g). The slope of the fitting will give the value of $B^{1/2}$.

FIGURE 2. Transmission spectra of $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin films.

The optical band gaps of the as-prepared film (1.66 eV) reduced to 1.59 eV for the illuminated film. This optical band gap change is due to photo induced effect which is caused by chemical bond redistribution [5] according to the equation

where M stands for Sb, S is for selenium or sulfur and dash denotes a chemical bond. The equilibrium of Eq. (2) can be moved in both directions, depending on the initial state of the film and the conditions of light exposure or annealing. There is a high degree of disorder in as-prepared films; the atoms are partly statistically distributed, and M-S chemical-bond formation is not fully preferred. Thus, exposures of $\text{Sb}_{40}\text{Se}_{20}\text{S}_{40}$ thin films can shift the equilibrium (Eq. 2) in both directions depending on the conditions of thin film preparation and/or the conditions of light exposure. When the as-prepared film is illuminated, the optical band gap decreases by 0.07 eV. But annealing always shifts the equilibrium more to the left. In case of illumination, the homopolar bond density increases causing more disorder which can be seen from the $B^{1/2}$ values. The $B^{1/2}$ values for as-prepared and illuminated films are 687 and $598 \text{ cm}^{-1/2}\text{eV}^{-1/2}$ respectively. The $B^{1/2}$ for illuminated film is less than the as-prepared film

which indicates the presence of more no of homopolar bonds due to disorder.

FIGURE 3. XPS spectra of Sb 4d and Se 3d peak.

The XPS spectra of the as-prepared and illuminated film for Sb 4d and Se 3d core level are shown in Fig. 3. The Se 3d peak position for as-prepared and illuminated films is at 54.37 and 54.87 eVs respectively. The peak shifts towards higher BE shows the formation of Se-Se homopolar bonds due to illumination. The peak position of Sb 4d core level spectra for as-prepared and illuminated films are at 33.76 and 33.44 eVs respectively. It is found that the peak is shifting towards the lower BE due to the formation of more Sb-Sb homopolar bonds. This is in accordance with the reduction in optical band gap of the as-prepared film due to photo induced process. Similarly, the S 2p peak (not shown) at 163.1 eV for the as-prepared film shifts to 163.4 eV when it was illuminated which shows the formation of more S-S bonds than Sb-S bonds as the electro negativity of S (2.58) is more than that of Sb (2.02).

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