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Influence of composition on electrical and optical properties of new chalcogenide thin films from Ge–Se–Tl system

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ABSTRACT

Bulk $Ge_{20}Se_{80-x}Tl_x$ (x ranging from 0 to 15 at%) chalcogenide glasses were prepared by conventional melt quenching technique. Thin films of these compositions were prepared by thermal evaporation, on glass and Si wafer substrates at a base pressure of 10^{-6} Torr. X-ray diffraction studies were performed to investigate the structure of the thin films. The absence of any sharp peaks in the X-ray diffractogram confirms that the films are amorphous in nature. The optical constants (absorption coefficient, optical band gap, extinction coefficient and refractive index) of $Ge_{20}Se_{80-x}Tl_x$ thin films are determined by absorption and reflectance measurements in a wavelength range of 400–900 nm. In order to determine the optical gap, the absorption spectra of films with different Tl contents were analyzed. The absorption data revealed the existence of allowed indirect transitions. The optical band gap showed a sharp decrease from 2.06 to 1.79 eV as the Tl content increased from 0% to 15%. It has been found that the values of absorption coefficient and refractive index increase while the extinction coefficient decreases with increase in Tl content in the Ge–Se system. These results are interpreted in terms of the change in concentration of localized states due to the shift in Fermi level. DC electrical conductivity of $Ge_{20}Se_{80-x}Tl_x$ thin films was carried out in a temperature range 293–393 K. The electrical activation energy of these films was determined by investigating the temperature dependence of dc conductivity. A decrease in the electrical activation energy from 0.91 to 0.55 eV was observed as the Tl content was increased up to 15 at% in $Ge_{20}Se_{80-x}Tl_x$ system. On the basis of pre-exponential factor, it is suggested that the conduction is due to thermally assisted tunneling of the carriers in the localized states near the band edges.

1. Introduction

Great attention has been paid to the development and characterization of amorphous chalcogenide glasses. The importance of these glasses is due to their interesting optical properties for their potential use as optical fibers, where they show high transparency to infrared radiation. These glasses have attracted a great deal of attention because of their technical importance in various solid state devices. It has long been believed that chalcogenide glasses show p-type conduction only and the control of the conduction type is impossible using the doping technique. The reason is that the valence of doped atoms is always satisfied in the glasses. According to the band model of amorphous semiconductors developed by Street and Mott [1], Mott et al. [2] and Kastner et al. [3], the situation above is explained by the pinning of the Fermi energy due to the equilibrium between negatively and positively charged dangling bonds. Physical properties of these chalcogenide semiconducting glasses are strongly dependent on their composition and hence, composition is of special importance in studying their physical properties. Besides, the physical properties of chalcogenide semiconducting glasses are strongly dependent on their compositions [4–6]. Chalcogenide semiconductors have truly emerged as multipurpose materials and have been used to fabricate technological important devices: IR detector, electronic and optical switches and optical recording media [7]. Such wide-ranging applications are possible due to some unique phenomena like photo-induced structural transformations [4]. In recent years, efforts are being made to develop chalcogenide-based erasable optical storage media. The common feature of these glasses is the presence of localized states in the mobility gap, as the result of the absence of long-range order and various inherent defects. The trend of using amorphous semiconducting materials, rather than carefully prepared crystalline semiconductors, in electronic devices necessitates further investigation of such materials.

The optical and electrical studies of chalcogenide thin films are of considerable interest and offer critical information about the electronic band structure, optical transitions and relaxation mechanisms. These thin films can be used as optoelectronic device materials [8], for optical fibers preparation [9], for thin film waveguides [10], as materials for ion-selective electrodes [11], as well as optical recording media [12] because of their transparency

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