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Laser irradiation induced photo-crystallization in nano-structured amorphous $Se_{90-x}Hg_xS_{10}$ ($x = 0, 5, 10, 15$) thin films

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The present study focuses on the influence of laser irradiation induced photo crystallization on the modification of the optical and electrical properties of thermally evaporated amorphous $Se_{90-x}Hg_xS_{10}$ ($x = 0, 5, 10, 15$) thin films. The chemical composition and amorphous nature of the as-prepared thin films were examined by energy dispersive X-ray analysis and X-ray diffraction (XRD) respectively. However, the XRD analysis revealed the crystalline nature of the thin films irradiated using a 337.1 nm pulsed laser. These results were further investigated by surface morphological techniques, namely atomic force microscopy (AFM) and scanning electron microscopy (SEM). An enhancement in the average grain sizes after laser irradiation was observed. The absorption spectra obtained using a UV-vis-spectrophotometer were evaluated using the Urbach's edge method. As the duration of laser irradiation was increased, the optical energy gap and tail energy width for all the compositions decreased. Further, it has been observed that the value of the optical energy gap decreases with Hg content in the Se–S alloy. These results have been interpreted on the basis of laser irradiation-induced photo-crystallization in the film. Electrical analyses such as dark dc conductivity and photoconductivity in the temperature range 310–390 K show an enhancement of the electrical conductivity and a reduction in activation energy as the irradiation time increases and specify that the density of defect states decreases after irradiation. Temperature dependent photoconductivity measurements show similar trends to that of dark conductivity. This is because the photo-created carriers can move easily in laser irradiated thin films due to the crystallinity of the material.

1. Introduction

Metal based chalcogenides possess most desirable physical properties, especially optical properties, for potential applications. A major advantage of chalcogenide semiconductor thin films is the controlled response to external stimuli such as heat treatment, laser irradiation, gamma irradiation, swift heavy ion irradiation *etc.* which makes them feasible for several advanced applications like optical computing, optical data storage, ultrafast optical switches, optical sensors *etc.*[1–4] During the process of light–matter interaction, electrons and holes are created; these photo-created carriers may not remain free but can become trapped, or localized in one way or another in the band tail states of amorphous semiconductors. Such localized states exhibit a strong electron–phonon coupling which may lead to a structural rearrangement of the lattice, and hence changes in the physical properties causing photo-darkening, photo-expansion, photo-crystallization, *etc.*[5–8] Knowledge of the optical and electrical properties of these chalcogenide glasses is obviously necessary for exploiting their potential for very interesting technological applications. However, due to their outstanding performance in the technological field, various investigations have been reported so far regarding the study of the optical properties of chalcogenide thin films.[9–12] Optical absorption data provide information on the band structure and the energy gap of semiconductors and hence understanding and developing the energy band diagram is possible for both crystalline and amorphous materials.

In the present study, the influence of pulsed laser irradiation on the structural, optical and electrical parameters of Se_{90-x}-Hg_xS_{10} ($x = 0, 5, 10, 15$) thin films has been investigated by analyzing the absorption spectra in the spectral range 400–800 nm for the optical study and the temperature range 310–390 K for the electrical study. We have used selenium (Se) as a major component as it has wide commercial applications in many industrial fields, such as Xerography, photo rectifiers, solar cells,[13–15] photoconductors for high-definition television (HDTV),[13] digital radiography (DDR)[16] *etc.* This is because Se based photoconductors have high spatial resolution, low thermal noise and high sensitivity against a wide variety of wavelengths from visible to ultraviolet[17] as well as X-rays[18,19] as

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