Journal of Physics and Chemistry of Solids 117 (2018) 122–130

Contents lists available at ScienceDirect

Journal of Physics and Chemistry of Solids

journal homepage: www.elsevier.com/locate/jpcs

Effects of gamma-ray irradiation on the optical properties of amorphous $Se_{100-x}Hg_x$ thin films

Shabir Ahmad [a], Shama Islam [a], Mohd. Nasir [a], K. Asokan [b], M. Zulfequar [a,*]

[a] Department of Physics, Jamia Millia Islamia, New Delhi 110025, India
[b] Materials Science Division, Inter University Accelerator Centre, New Delhi 110067, India

ARTICLE INFO

Keywords:
Chalcogenide
Gamma irradiation
Optical property
Thin film

ABSTRACT

In this study, the thermal quenching technique was employed to prepare bulk samples of $Se_{100-x}Hg_x$ (x = 0, 5, 10, 15). Thin films with a thickness of ~250 nm were deposited on glass substrates using the thermal evaporation technique. These films were irradiated with gamma rays at doses of 25–100 kGy. The elemental compositions of the as-deposited thin films were confirmed by energy dispersive X-ray analysis and Rutherford backscattering spectrometry. X-ray diffraction analysis confirmed the crystalline nature of these thin films upto the dose of 75 kGy. Fourier transform-infrared spectroscopy showed that the concentration of defects decreased after gamma irradiation. Microstructural analysis by field emission scanning electron microscopy indicated that the grain size increases after irradiation. Optical study based on spectrophotometry showed that the optical band gap values of these films increase after the addition of Hg whereas they decrease after gamma irradiation. We found that the absorption coefficient increases with doses up to 75 kGy but decreases at higher doses. These remarkable shifts in the optical band gap and absorption coefficient values are interpreted in terms of the creation and annihilation of defects, which are the main effects produced by gamma irradiation.

1. Introduction

Amorphous Se (a-Se) is one of the most widely studied semiconductor materials and it has been employed in the photocopying industry for the last three decades. It has a wide variety of applications in optoelectronic fields such as xerography, photo rectifiers, and solar cells [1–3]. In addition, a-Se is used as a photoconductor in high-definition televisions [1] and digital radiography [4] because of its high spatial resolution, low thermal noise, and high sensitivity to a wide variety of wavelengths ranging from visible to ultraviolet [5], as well as X-rays [6,7], compared with Si-based photoconductors. In photoconductors, when X-ray photons hit an imaging plate attenuated by Se, the excitation of electrons occurs throughout the a-Se layer due to the generation of electron–hole pairs. These charges are collected by the charge-collecting electrodes and converted into an electrical signal by a thin film transistor. This electrical signal is converted into a digital signal by an analog-to-digital signal converter. Thus, the efficiency of this device depends on the absorption of the incident X-ray photons. In order to increase the absorption, one can increase the thickness of the layer without the risk of increasing the noise but the problem is that the thick- layer requires a higher voltage to capture the electrons. In practice, 10,000 V is required if the thickness is 1000 μm [8]. This requirement for a high voltage system makes the detector relatively complex and bulky.

Another parameter that directly determines the efficiency of a photoconductor is the charge carrier range $\mu\tau$, where μ is the mobility and τ is the lifetime. However, in the case of a-Se, many defect states are present in the forbidden gap, which traps these free carriers and reduces the range and the efficiency of the photoconductor. Thus, achieving the maximum efficiency for a photoconductor using advanced techniques is a major challenge for researchers. The properties of a material can be modified without changing the thickness of the material layer by using methods such as doping and irradiation techniques. In addition, Se-based compound semiconductors have been used in photovoltaic applications, e.g., Se-based compound semiconductors such as ZnSe, CZTSSe, CIGS, and CdSe. The major benefits of these compound semiconductors compared with elemental semiconductors such as Si and Ge are that they provide tunable optical and electrical properties that can meet specific requirements. For example, the optimum band gap for producing the maximum efficiency in solar cells is 1.5 eV for terrestrial power generation (AM1.5 spectrum), which is very close to the energy band gaps of compound semiconductors [9]. The single crystalline Si-based solar cells can enhance the efficiency of commercial products by up to 26.5% [10]

* Corresponding author.
E-mail address: mzulfe@rediffmail.com (M. Zulfequar).

https://doi.org/10.1016/j.jpcs.2018.02.014
Received 31 July 2017; Received in revised form 6 February 2018; Accepted 7 February 2018
Available online 8 February 2018