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The impact of Zn-doping on the physical properties of nano-structured Se-Sn-Al thin films: A beneficial study for optoelectronic device applications

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ABSTRACT

This work reports the investigation of structural, optical and electrical properties of $Se_{90-x}Sn_5Al_5Zn_x$ (x = 0, 5, 10, 15) thin films. Melt-quenching technique was employed for bulk sample synthesis and the corresponding thin films were deposited by thermal evaporation technique in order to examine the impact of zinc (Zn) doping on Se-Sn-Al compound at nanometric scale. Energy-dispersive X-ray analysis and scanning electron microscopy verified elemental composition and morphological evolution with Zn incorporation. XRD and FESEM analysis showed comparative enhancement of particle size with increasing the Zn content in Se-Sn-Al compound. Optical observations revealed the investigated thin films follows a rule of direct transition. Furthermore, this analysis displayed significant tuning of optical bandgap values from 2.05 eV to 2.73 eV. The electrical measurements favour the Arrhenius-type behaviour, indicating Zn works as a network modifier improving the conductivity. This makes Zn-modified Se-Sn-Al quaternary glassy system useful for many optoelectronic device applications.

1. Introduction

Most of the research on glasses has emphasized on lenses made of quartz and silicate, which use the visible spectrum to transmit electromagnetic radiation. But need for glasses that can transmit in infrared region up to a wavelength of around 12 μm has increased due to their applications in optics, photonics, and optoelectronics [1].Semiconductors called chalcogenide glasses generally made of chalcogen elements like tellurium, selenium, or sulphur in which other elements like Ge, As, Sb, Ga, Sn, and so on are added to manufacture these glasses. They typically show transparency from the visible to the infrared spectrum and are materials having low phonon-energy. These glasses also show large nonlinear properties up to an order of two to three times greater than that of the oxide glasses by making themselves a viable candidate in nonlinear optics, [2–4]. Oxide glasses have lower refractive indices (1.5-2.5) as compared to chalcogenide glasses (2.0-3.5) and increase in the order of sulphur-, selenium-, and tellurium-based glasses which enable enhanced light confinement, stronger nonlinear optical responses, and greater design flexibility in photonic devices, particularly for applications in the mid-infrared region such as sensing, thermal imaging, and all-optical signal processing [5].

Among the chalcogenides, amorphous selenium (a-Se) is the most studied chalcogenide because of crystallization behaviour it shows and its unique polymeric structure [6]. Selenium-rich chalcogenide glasses are more nonlinear than their sulphur-rich counterparts, but because of their intrinsic bandgap characteristics, at normal working wavelengths (1.3 and 1.55 μm), tellurium-rich glasses are not appropriate for telecommunications applications, despite having desirable optical qualities [7–11]. Bulk chalcogenides find application in windows, fibre optics, lenses, and other parts. On the right substrates, they can serve as non-crystalline films as well. These films are used in high-resolution photoresists, components of diffractive optics and planar waveguides, and optical recording discs [12–14]. The properties of chalcogenides can be modified by the addition of different doping agents. Significant changes in the glassy matrix make the chalcogenide system perfect for devices that are photoconductive. Zinc has been a potential candidate because Zn's significant network modifying properties in the glass matrix increase the potential for a number of chalcogenide amorphous

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