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Ion Beam-Induced modification in the optical properties of the bilayer of nano-structured amorphous selenium and multi-walled carbon Nanotubes: A study by 70 MeV Ni Ions

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ABSTRACT

In this study, we report improved physical properties of selenium with multi-walled carbon nanotubes (MWCNTs) resulting from a homogeneous mixture of CNT-Se bi-layer thin film by using swift heavy ion irradiation. FESEM micrographs clearly showed the inter-diffusion of Se nanoparticles into MWCNTs following swift heavy ion (SHI) irradiation, EDX validates the elemental composition. The existence of different phonon modes (LO mode and D, G, G' bands) has been found in the Raman spectra of the investigated bi-layer thin films. UV–Visible spectroscopic analysis of pristine CNT-Se thin films show two sharp absorption edges at ~670 nm and ~340 nm. After swift heavy ion irradiation, the sharp absorption edge at ~670 nm exhibits a blue shift, whereas the absorption edge at ~340 nm exhibits a red shift, confirming the homogeneous mixing of two layers. These remarkable shifts found in the optical properties of CNT-Se bi-layer make the investigated material feasible for many optoelectronic device applications.

1. Introduction

Chalcogenide glasses have gained recognition as vital components for optoelectronic device applications such as photoconductors, solar cells, displays, sensors etc., over the past 70 years [1,2]. Due to its potential for the fabrication of various solid-state devices, compound semiconductors based on selenium have been extensively studied in recent decades. Researchers are becoming more interested in this critical material primarily due to its remarkable applications. Numerous studies investigated the way various dopants, such as Cu, Sn, etc, could alter the physical properties of selenium [1–5]. Few of them demonstrated how CNTs in bulk form can alter the properties of this important material. Researchers find it difficult to produce a homogenous CNT-Se combination in thin film form. Due to the significant differences in their melting points, it is extremely challenging to combine CNTs with selenium in thin film form using existing deposition processes. This work showed the use of the SHI irradiation technique to produce a homogeneous mixture of CNT-Se in thin film form. Due to the characteristics of MWCNTs, which include a high intrinsic charge carrier mobility, tunable band gap, and high absorption coefficient. Irradiation also aids in predicting the reliable performance of nanodevices in challenging environments and the consequences of high radiation exposure. The modifications are due to ion beam mixing in which atoms of one layer mingled with the atoms of other layers with the help of energy deposited by the incident ions.

2. Experimental Studies

Fine powder of 5 g selenium (99.999 % purity) was sealed under a vacuum of 10^{-6} Torr in a quartz ampoule. The sealed ampule was placed inside a Microprocessor-Controlled Programmable Muffle Furnace at a constant heating rate of 4 °C/min up to 900 °C. The material within the ampoules is allowed to melt at 900 °C for 15 h. After 15hrs, the obtained melt of selenium was rapidly quenched in ice-cooled water. The obtained ingot was removed by breaking the ampoule and grinding it into a fine powder with the help of pastel and mortol. Multi-walled carbon nanotubes with the diameters in the range of 20–40 nm and several micrometers in length were used. To make a dispersed solution, 0.05 mg of carbon nanotubes were dispersed in 5 ml DMF using an ultrasonicator for 8 hours. A thin layer of ~300 nm of multi-walled CNT was deposited

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