Investigation of Electrical Properties of CNT- $Se_{90}S_5Zn_5$ bi-layer Structure Mixed by Swift Heavy ions Irradiation

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ABSTRACT

Multi-walled carbon nanotubes (MWCNTs) thin films were grown on cleaned glass substrate by spin coating technique. The dispersed solution from which the MWCNTs thin films are grown contains 0.05 mg of carbon nanotubes in 5 ml DMF solution. $Se_{90}S_5Zn_5$ thin films has been deposited by thermal evaporation technique above the prepared MWCNTs layer. The investigated thin films of CNT- $Se_{90}S_5Zn_5$ bi-layer system were irradiated by 70 MeV Ni^{7+} ions in the fluence range of 1×10^{12} ions/cm^2 to 5×10^{13}ions/cm^2 for mixing the bi-layer system. The surface morphological analysis was carried out by FESEM which clearly shows $Se_{90}S_5Zn_5$ coating above carbon nanotubes. Temperature dependence of dc conductivity show an enhancement of the electrical conductivity and a reduction in activation energy after irradiation.

Keywords*: *Bi-layer thin film; Swift Heavy Ion Irradiation; Electrical Properties.

I. INTRODUCTION

In the last several decades, compound semiconductors develops more interest of researchers because they have potential applications in optoelectronic fields such as displays, sensors, microwave communication, solar cells, optical communication and radiation detector [1- 7] etc. Devices based on chalcogenide compounds like CdSe, CdTe, CIGS, CZTSSe etc. show good advantages over silicon based devices because of their physical properties. This study investigated effect of SWCNTs on $Se_{90}S_5Zn_5$ compound semiconductor material for property modification. Because there are several factors like lower absorption due to lattice mismatch, lower mobility etc. which could affect the physical properties of $Se_{90}S_5Zn_5$. Here we have choose SWCNT as dopant material for $Se_{90}S_5Zn_5$ compound, because multi-walled carbon nanotubes have the features like tunable band gap, high absorption coefficient, and high intrinsic charge carrier mobility [10- 13].

II. EXPERIMENTAL STUDIES

Thermal quenching technique has been used for the preparation of bulk sample of amorphous selenium. Fine powder of pure Se, S and Zn having purity (99.999%) was put into quartz ampoule. This ampoule was sealed under a vacuum of 10^{-6} Torr. After sealing, the ampoule was placed in a Muffle Furnace, where the temperature was increased at a constant heating rate of 4 ℃/min up to 850℃ and the material within the ampoules is allowed to melt at 850 ℃ for 14 h. During heating, the ampoule was constantly rocked, by rotating a ceramic rod to which the ampoule was tucked away in the furnace. After rocking for about 14 hours, the obtained melt of $Se_{90}S_5Zn_5$ was rapidly quenched in ice-cooled water. After quenching, ingot has been removed by breaking the ampoule and grinded into a fine powder with the help of pastel and mortol. Multi-walled carbon nanotubes with the diameter in the range of 20-40 nm and several micrometers in length was used. To make dispersed solution, 0.05 mg of carbon nanotubes were dispersed in 5 ml DMF using ultrasonicator for 8 hours. After this thin layer of ~ 300 nm of multi-walled CNT was deposited on cleaned glass substrate by spin coating technique (with 2000 rpm). The glass substrates were cleaned ultrasonically first by water and then by acetone. After this, thin layer of ~ 250 nm of $Se_{90}S_5Zn_5$ was deposited by thermal evaporation technique above the CNT layer through molybdenum boat under a vacuum of 10^{-5} Torr. The investigated thin films of CNT-Se were irradiated by 70 MeV Ni^{6+} ions in the fluence range of 1×10^{12} ions/cm^2 to 5×10^{13}ions/cm^2 using 15UD Pelletron Accelerator facility at IUAC, New Delhi, India. The ion beam was scanned over an area of 1 cm^2 and beam current was 1 pnA (particles nanoampare).The energy straggling parameters and projectile range was calculated by SRIM software, which showed feasible range for ions to traverse the entire film thickness. Surface morphological effects of the investigated thin films has been analyzed by using Field Emission Scanning Electron Microscope (FESEM) (Model:Σigma by Carl Zeiss employed with Gemini Column (Patented technology of Corl Zeiss). For electrical measurements, electrodes with 1 mm gap was made by using the silver paste on the investigated thin films. Dark dc conductivity and measurements were carried out in the temperature range of 310-390 K at constant voltage of 1.5 V by mounting the thin films in a specially designed metallic sample holder.

III. RESULTS

3. 1.Elemental composition analysis

EDX makes use of the X-ray spectrum obtained by a solid sample when bombarded with a focused beam of electrons in order to obtain a localized chemical analysis. The elemental composition of investigated thin films of CNT- $Se_{90}S_5Zn_5$ bilayer system has been verified by EDAX analysis which confirms the presence of both CNT, Se, S and Zn in the prepared bi-layer thin film.

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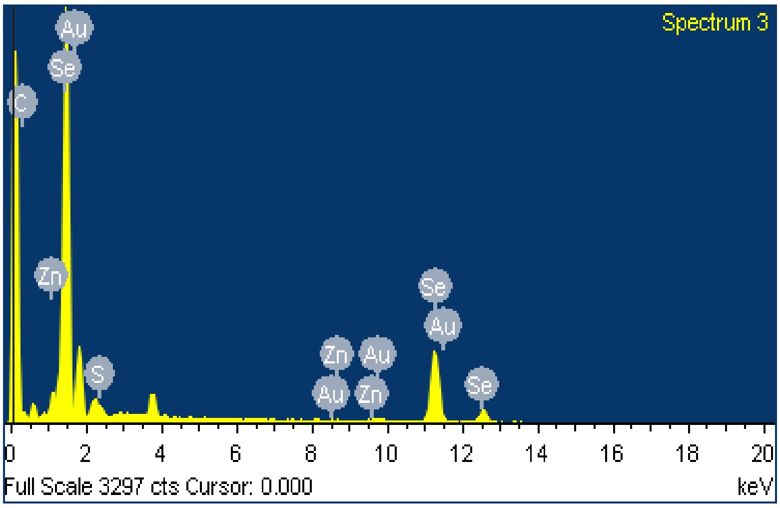

Figure 1. EDX spectra of of as-prepared thin films of CNT- $Se_{90}S_5Zn_5$ bi-layer system.

3. 2. Surface Morphological Analysis

Furthermore the surface effects occurred due to irradiation has been analyzed by FESEM, the obtained micrographs are shown in Fig.1. Scanning electron microscopy is a widely used technique for analyzing the morphology of the solid samples. This technique probes the surface structure of samples using a focused beam of high energy electrons. The SEM images of as-prepared thin film have been recorded at different magnifications which clearly show the $Se_{90}S_5Zn_5$ coating above the MWCNTs covering the surface of CNTs. The irradiated thin films displayed the $Se_{90}S_5Zn_5$ layer is embedded into the MWCNTs layer and hence two layers are mixed.

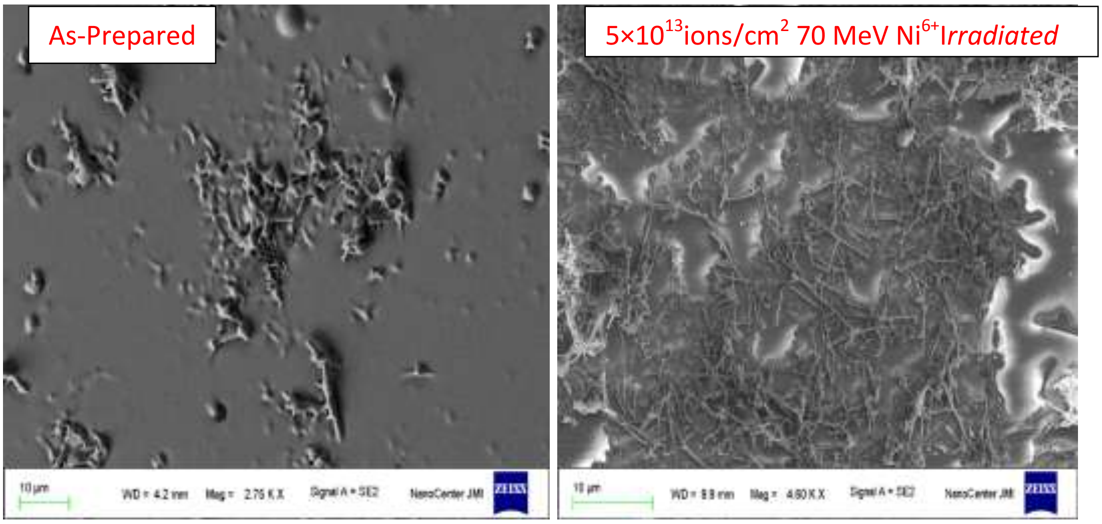

Figure 2. Scanning electron micrograph images of of as-prepared and SHI irradiated thin films of CNT- $Se_{90}S_5Zn_5$ bi-layer system.

3. 3. Electrical Studies

The dc conductivity measurements of as-prepared and Swift heavy ion (SHI) irradiated CNT- $Se_{90}S_5Zn_5$ bilayer system were performed in temperature range (310 K- 390 K). Fig.3 shows the plots of ln σ_{dc} versus 1000/T are

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found to be straight lines and indicate the semiconducting nature of all the films. For semiconductors, dc conductivity can be expressed by Arrhenius relation [14] as:

$$\sigma_{dc} = \sigma_0 \exp[-\Delta E_{dc}/KT] \qquad (1)$$

Where $\boldsymbol{\sigma_0}$ is pre-exponential factor related to the material, $\boldsymbol{\Delta E}$ is activation energy, K is the Boltzmann constant and T is the temperature. Activation energy $\boldsymbol{\Delta E}$ is calculated by the slope of ln $\boldsymbol{\sigma_{dc}}$ versus 1000/T and using eqn (1). Slope of the curve is estimated by using linear fit. Values of activation energy $\boldsymbol{\Delta E}$, dc conductivity $\boldsymbol{\sigma_{dc}}$ and pre-exponential factor ($\boldsymbol{\sigma_0}$) are given in Table1.The dc conductivity (σ_{dc}) of as-deposited CNT- $Se_{90}S_5Zn_5$ thin film is calculated to be $1.5\times10^{-4}\ \Omega^{-1}cm^{-1}$. It has been shown that the conductivity oh the investigated thin films increases after swift heavy ion (SHI) irradiation. Similar effect of increase in conductivity in CNT-Se network is reported [15] when the system is subjected to heat. According to Davis and Mott the pre exponential factor for conduction in localized states should be two or three orders smaller than the conduction in extended states. The value of pre exponential factor σ_0 in the present system is of order $10^{-1}\ \Omega^{-1}\ cm^{-1}$. From this we can conclude that the conductionin the nonirradiated CNT- $Se_{90}S_5Zn_5$ bilayer system is mainly due to hopping of charge carriers in localized states but after irradiation of the sample it shift to extended states.

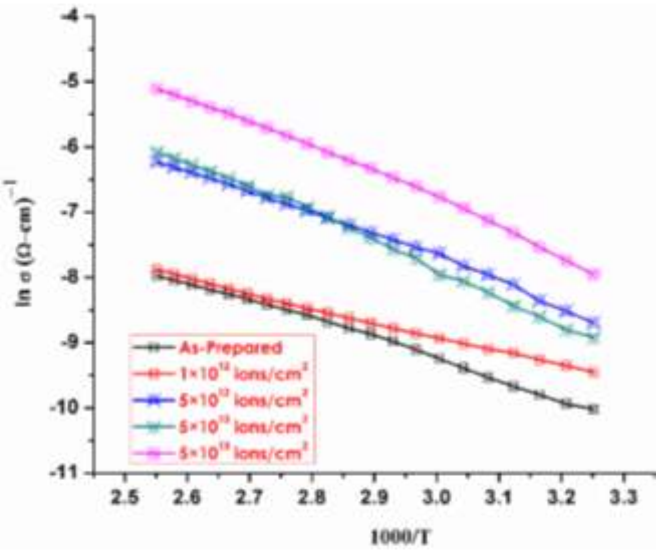

Figure 3. Variation of dark d. c. conductivity ($\boldsymbol{\sigma_{dc}}$) with 1000/T of as-prepared and SHI irradiated thin films of CNT- $\boldsymbol{Se_{90}S_5Zn_5}$ bi-layer system.

Table.1. Electrical parameters at a temperature of 350 K of as-prepared and SHI irradiated thin films of CNT- $Se_{90}S_5Zn_5$ bi-layer system.

Irradiation details	$\sigma_{dc}(\Omega^{-1}cm^{-1})$	$\sigma_0(\Omega^{-1}cm^{-1})$	$\Delta E_{dc}(eV)$
As-deposited CNT- $Se_{90}S_5Zn_5$ bilayer	1.5×10^{-4}	8.2×10^{-1}	0.249
1×10^{12}	1.8×10^{-4}	1.9×10^{1}	0.242
5×10^{12}	7.5×10^{-4}	1.9×10^{-1}	0.210
1×10^{13}	7.1×10^{-4}	5.8×10^{-1}	0.200
5×10^{13}	2.2×10^{-3}	6.5×10^{-1}	0.198

IV. CONCLUSION

In this study, the results of the CNT- $Se_{90}S_5Zn_5$ bi-layer system deposited on glass substrate, mixed swift heavy ion irradiation techniques. Surface morphology of the investigated thin films show selenium coating above MWCNTs. Electrical analysis shows the enhancement of dc conductivity after irradiation. It was found that the value of activation energy decreases after irradiation. Therefore such a material may be feasible for many optoelectronic device applications because of higher values of large conductivity.

V. ACKNOWLEDGEMENTS

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