1. INTRODUCTION

Cadmium Selenide (CdSe), a II-VI compound semiconductor has been constantly invested during recent years for both fundamental and practical importance [1-3]. CdSe is a promising photovoltaic material because of its high absorption coefficient and nearly optimum band gap energy for the efficient absorption of light and conversion into electrical power [4-5]. The synthesis of binary metal chalcogenide of groups II-VI semiconductors in a nanoparticle form has been a rapidly growing area of research due to their important non-linear optical properties, luminescent properties, quantum-size effect and other important physical and chemical properties [6-8]. CdSe thin films have been prepared by thermal evaporation under vacuum is a very convenient method for obtaining uniform films. Currently, swift heavy ion (SHI) irradiation of material has generated significant interest in the light of application of such material in the field of electronics and optoelectronics. The beam current was mainly controlled CdSe films prepared by thermal evaporation of CdSe powder (Alfa Aesar) in a vacuum evaporation unit (HHV-12A4DU) at a pressure of 1 x 10⁻⁶ mbar on clean glass substrate. Swift Heavy ion (SHI) irradiation of the as deposited CdSe films was done using 15 UD pelletron accelerator at Inter University Accelerator Center (IUAC), New Delhi, with 100 MeV Ni⁺ ions at fluences levels 1.0 x 10¹¹, 1.0 x 10¹² and 1.0 x 10¹³ cm⁻². The beam current was maintained at 2 pA (particle nanoampere) during irradiation. The focused ion beam was scanned over an area of 1 cm² using a magnetic scanner to achieve the fluence uniformity across the sample surface. The electronic and nuclear energy loss value for 100 MeV Ni⁺ ions in CdSe, from the SRIM code simulation program (version 2003.26) are estimated to be 1.88 x 10⁶ eVÅ and 3.17 x 10⁻² eVÅ respectively. The structural analysis of films was studied by X-ray diffractometer (Model JEOL 8030, λ = 0.1541 nm). The optical absorption spectra of CdSe thin films were obtained by a UV-VIS-NIR spectrophotometer in the wavelength range of 250 to 2500 nm. Micro-Raman spectroscopy was performed using Horiba Jobin Yvon Raman Spectrometer (T64000) and measurements were performed at room temperature with a 514.5 nm line of an Ar⁺ laser.

2. EXPERIMENTAL DETAILS

CdSe thin films of thickness 200nm have been prepared from 99.95% pure CdSe powder (Alfa Aesar) in a vacuum evaporation unit (HHV-12A4DU) at a pressure of 1 x 10⁻⁶ mbar on clean glass substrate. Swift Heavy ion (SHI) irradiation of the as deposited CdSe films was done using 15 UD pelletron accelerator at Inter University Accelerator Center (IUAC), New Delhi, with 100 MeV Ni⁺ ions at fluences levels 1.0 x 10¹¹, 1.0 x 10¹² and 1.0 x 10¹³ cm⁻². The beam current was maintained at 2 pA (particle nanoampere) during irradiation. The focused ion beam was scanned over an area of 1 cm² using a magnetic scanner to achieve the fluence uniformity across the sample surface. The electronic and nuclear energy loss value for 100 MeV Ni⁺ ions in CdSe, from the SRIM code simulation program (version 2003.26) are estimated to be 1.88 x 10⁶ eVÅ and 3.17 x 10⁻² eVÅ respectively. The structural analysis of films was studied by X-ray diffractometer (Model JEOL 8030, λ = 0.1541 nm). The optical absorption spectra of CdSe thin films were obtained by a UV-VIS-NIR spectrophotometer in the wavelength range of 250 to 2500 nm. Micro-Raman spectroscopy was performed using Horiba Jobin Yvon Raman Spectrometer (T64000) and measurements were performed at room temperature with a 514.5 nm line of an Ar⁺ laser.

3. INTERPRETATION OF EXPERIMENTAL RESULTS

3.1 X-ray Diffraction Studies

The X-ray diffractogram of pristine and irradiated CdSe thin films are shown in Fig. 1, a sharp peak in XRD pattern is observed in all the films oriented in (002) plane correspond to the hexagonal phase [11]. After irradiation the films have the same orientation and it was observed that after irradiation the intensity of the peak increases with increasing fluence. Such result have been observed for the CdSe films irradiated by Au⁺ ions with energy of 100 MeV [10].

The effect of irradiation with increasing fluences is summarized in Table 1. The grain size (D) is calculated for peak at 2θ = 25.40° using the Scherer formula from the full-width half-maximum (FWHM) (δ):

\[
D = 0.94 \lambda / (\beta \cos \theta),
\]

(1)

where λ is the wavelength of X-ray used, θ is the half the angle between incident and the scattered X-ray beam. It is observed that the grain size increases with the increasing fluences which indicate improvement in crystallinity.

The strain value (c) can be evaluated by using the following relation:

Keywords: CdSe thin films, Swift heavy ion irradiation, XRD, UV, Micro-Raman.

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Fig. 1 – X-Ray diffractogram of pristine and SHI irradiated thin films of CdSe (a) Pristine (b) $1 \times 10^{11}$ (c) $1 \times 10^{12}$ (d) $1 \times 10^{13}$ cm

\[ \varepsilon = \beta \cos \theta / 4 \tag{2} \]

The dislocation density ($\delta$) has been calculated by using the following formula

\[ \delta = 15 \beta \cos \theta / 4aD \tag{3} \]

The lattice spacing ($d$) is calculated from the Bragg’s formul

\[ d = \lambda / 2 \sin \theta \tag{4} \]

By this study it was observed that strain and dislocation density in the film decreases with the increases with fluencies [12].

Table 1 – Structural parameters of CdSe films irradiated at various fluences

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\theta$</th>
<th>Lattice spacing $D$ [$\text{Å}$]</th>
<th>Grain size $D$ [nm]</th>
<th>$\delta$ [$10^{-4}$]</th>
<th>Strain $\varepsilon$ [$10^{-6}$]</th>
<th>$\delta \theta \varepsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>25.40</td>
<td>3.504</td>
<td>27</td>
<td>15.34</td>
<td>1.737</td>
<td>0.02</td>
</tr>
<tr>
<td>$1 \times 10^{11}$</td>
<td>25.37</td>
<td>3.508</td>
<td>42</td>
<td>12.57</td>
<td>1.182</td>
<td>0.02</td>
</tr>
<tr>
<td>$1 \times 10^{12}$</td>
<td>25.35</td>
<td>3.510</td>
<td>56</td>
<td>9.43</td>
<td>0.753</td>
<td>0.02</td>
</tr>
<tr>
<td>$1 \times 10^{13}$</td>
<td>25.32</td>
<td>3.513</td>
<td>69</td>
<td>7.28</td>
<td>0.474</td>
<td>0.02</td>
</tr>
</tbody>
</table>

3.2 UV-VIS Spectroscopy Studies

The transmission spectra of the as grown and irradiated CdSe film at different fluencies was measured in the wavelength range 250 to 2500 nm. The absorption coefficient ($\alpha$) was calculated from transmission spectra in order to calculate the band gap ($E_g$). It is observed that $E_g$ value decreases with increasing fluencies as shown in Fig. 2. Decrease in band gap energy which, in turn, depends on the increase of grain size of the CdSe films with increasing fluencies. The decrease in band gap energy of high-energy irradiated sample leads to ionization of atom, due to which change in the local structure order of films, as well as it induce lattice damage and creates defect energy levels below conduction band [13].

3.3 Raman Spectroscopy Studies

Fig. 3 shows the Raman spectra of as deposited and irradiated CdSe films at increasing fluencies. Raman spectrum for as deposited and irradiated films show two peak, 1LO and 2LO Raman peak at 209 cm$^{-1}$ and 416 cm$^{-1}$. Second overtone of LO phonon mode is observed with decreasing intensity and also it was ob-
erved that intensity of Raman peak increases with increase in ion fluence. It is well known that the higher the intensity of the overtone, the better crystalline structure of the films [14]. Thus Raman spectra confirm formation of nanocrystalline CdSe thin films.

4. CONCLUSION
CdSe thin films deposited on glass substrate were irradiated using $\text{Ni}^{+7}$ ions with energy of 100 MeV at different fluences of $1.0 \times 10^{11}$, $1.0 \times 10^{12}$ and $1.0 \times 10^{13}$ cm$^{-2}$ has been investigated using XRD analysis, UV-VIS-Spectroscopy and Micro-Raman spectroscopy. CdSe thin film exhibits a hexagonal structure highly oriented with (002) plane. The grain size increases with increasing fluences. With the increase in fluences the average crystallite size increased whereas optical band gap deceased. Raman spectra measurements showed the presence of LO and 2LO phonon peaks.

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