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Swift Heavy Ion (SHI) Irradiation on the Structural Properties of Cadmium Telluride Thin Films

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Abstract: CdTe thin films grown by thermal evaporation on quartz substrates were irradiated with Swift heavy ion (100 MeV) Ni^{+4} ions for various fluences in the ranges 1.0×10^{11} to 1.0×10^{13} cm^{-2}. The modification in the structural properties has been studied as a function of ion fluence using X-ray diffraction (XRD) and Micro-Raman spectroscopy. XRD studies revealed phase transformation after irradiation. XRD peak intensity and the grain size were found to decrease with increase in fluence. In Micro Raman spectrum, weak LO and TO modes of CdTe and A_1 and E modes of Te were observed with blue shift which was found to increase with increase in fluence.

Keywords: CdTe, Thermal evaporation, thin films, Swift heavy ion irradiation, XRD, Micro-Raman.

I. INTRODUCTION

Swift heavy ion (SHI) beam irradiation of materials has been the subject of current research due to its ability to induce phase transformation in materials and to modify optical, electrical and optoelectronic properties. CdTe has been studied for a long time as an ideal material for the fabrication of high-efficient electronic devices such as solar cells, gamma and X-ray room-temperature nuclear detectors, and electro-optic modulators. SHI irradiation induced defects in CdTe crystals and thin films have been studied [1,2]. In present work, we report the study of the effect of SHI irradiation (100 MeV Ni^{+4}) ion on the thermally evaporated CdTe thin film of 100 nm. thickness.

II. RESEARCH METHODOLOGY

CdTe thin films were evaporated on quartz substrates using molybdenum boat at a pressure of 5.0×10^{-7} mbar. The thickness of the film was monitored by quartz crystal thickness monitor. Ion beam irradiation was done using 15 UD Pelletron tandem accelerator at Inter University Accelerator Centre (IUAC),New Delhi. CdTe films of 100nm thick were subjected to 100 MeV Ni^{+4} ion irradiation for different fluences ranging from 1.0×10^{11} to $1.0\times10^{13}cm^{-2}$. The beam current was maintained at 2 pnA (particle nanoampere) during irradiation. The structural properties were studied by X-ray diffraction technique using CuKα radiation and Micro-Raman spectroscopy using Horiba Jobin Yvon Raman Spectrometer T64000.The measurements were performed at room temperature with a 514.5 nm line of an Ar^+ laser.

III. RESULTS AND DISCUSSION

1. X-ray Diffraction Studies

Fig.1 shows the X-Ray diffractogram of the pristine and irradiated CdTe thin films. As deposited CdTe films were oriented along the (111) and (201) planes in cubic and hexagonal phases respectively. After irradiation, films were found to be oriented along the (100) and (311) planes in hexagonal and cubic phases respectively. The lattice constant was found to increase with fluence. The lattice parameters of the films were calculated using the Bragg's formula. The peak intensity was found to decrease with increase in fluence. The decrease in peak intensity and the increase in the peak width are attributed to the reduction in crystallinity of the material, formation of point defects, defect clusters, additional grain boundaries and amorphization of the film [2]. On irradiation a phase transformation from cubic to hexagonal phase was observed with increase in lattice constant. The lattice expansion might be due to modification of strain in the grains. Also the lattice vibrations induced by the heavy ions result in the re-orientation of area between the grains so that the interfacial energy between the grains reduced and resulted in the modification of strain. The internal pressure accumulated in grains by the energy deposited due to irradiation could also lead to fragmentation of bigger grains. The grain size of the crystallites was calculated from the XRD using Scherrer's relation. For as prepared films, the grain size was 107 nm and after irradiation, it reduced to 16 nm at fluence $10^{13}cm^{-2}$ and found to decrease with increase in fluence.

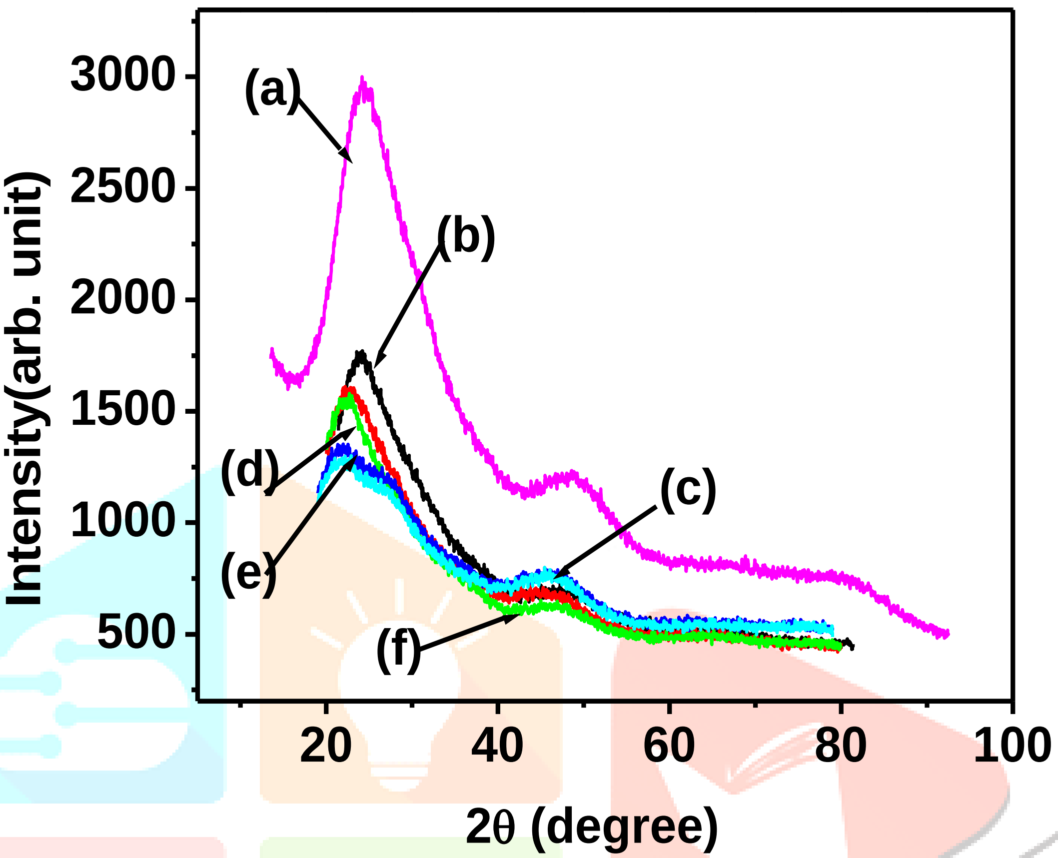

Figure 1. X-Ray Diffractogram: (a) Pristine, (b) 1.0×10^{11}, (c) 5.0×10^{11}, (d) 1.0×10^{12}, (e) 5.0×10^{12}, (f) 1.0×10^{13} cm^{-2}

2. Raman Spectroscopy Studies

Fig. 2 shows the Raman spectra of pristine and SHI irradiated CdTe thin films. Several Raman modes with peak at ~ 122 cm^{-1}, 135 cm^{-1}, 143 cm^{-1}, 160 cm^{-1}, 200 cm^{-1} [3] are observed in as-prepared sample. The Raman modes observed in the present studies show stronger Te Raman peak as shown in fig 2. The CdTe scattered light is absorbed by the tellurium precipitates, resulting in relatively stronger Raman peak [3]. The intensity of Raman band decreases with increase in fluence and at the fluence of 5.0×10^{12} cm^{-2} the spectrum did not show all Raman bands (fig. 2). This might be due to either change in the phase or surface amorphization. A large decrease in intensity might be attributed to high defect concentration. Further, Raman spectra suggest that there is structural damage to CdTe lattice upon ion irradiation. The irradiated ions are expected to break the Cd-Te bonds in CdTe surface of the crystallites but X-ray diffraction showed that cadmium and tellurium were still bonded. The disordered lattice will contribute to the internal stress and thus the Raman peak intensity decreases.

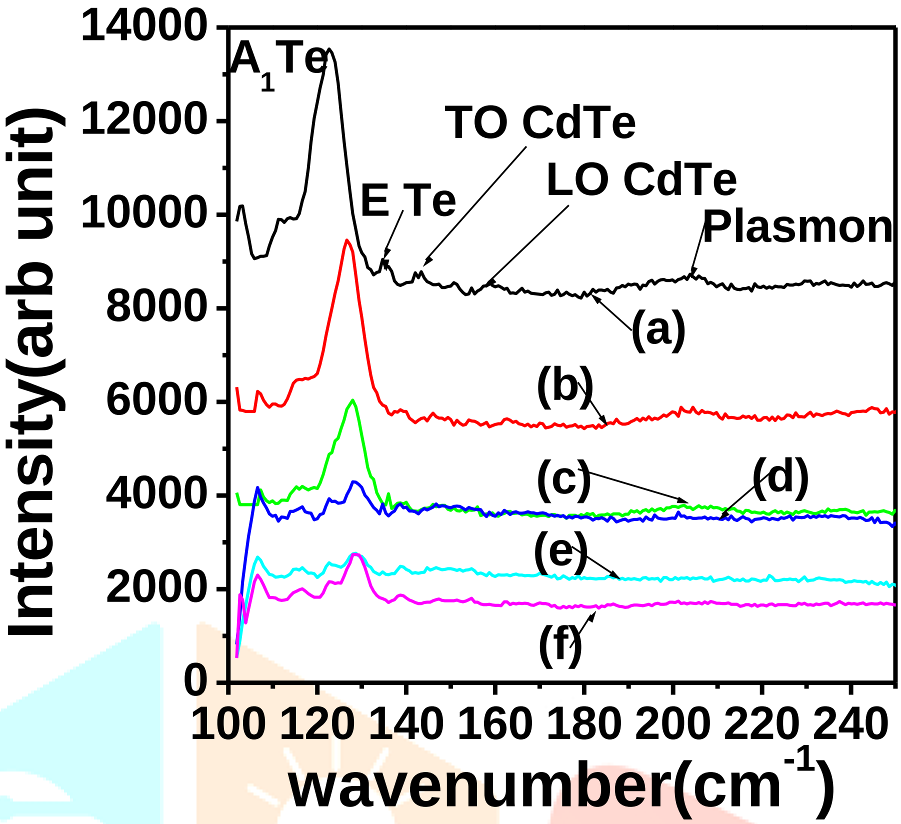

Figure 2. Micro Raman studies: (a) Pristine, (b) 1.0×10^{11}, (c) 5.0×10^{11}, (d) 1.0×10^{12}, (e) 5.0×10^{12}, (f) 1.0×10^{13} cm^{-2}

IV. CONCLUSION

The effect of SHI irradiation with 100 MeV Ni^{+4} ions on the structure and optical properties of CdTe thin films has been investigated at different fluences. The phase transformation was observed on irradiation. The size of the grain was considerably reduced after irradiation.

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