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Effect of swift heavy ion (SHI) irradiation on the structural and optical properties of N implanted CVT grown ZnSe single crystals

P. Kannappan [a], K. Baskar [a], J.B.M. Krishna [b], K. Asokan [c], C.L. Dong [d], C.L. Chen [d], Y.R. Lu [d], R. Dhanasekaran [a,*]

[a] *Crystal Growth Centre, Anna University, Chennai 600 025, India*
[b] *UGC-DAE Consortium for Scientific Research, III-/LB-8, Bidhan Nagar, Kolkata 700 098, India*
[c] *Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110 067, India*
[d] *National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan*

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ABSTRACT

Present study reports the variation of structural and optical properties of N implanted ZnSe single crystals grown by a Chemical Vapor Transport (CVT) technique due to120 MeV Au ion irradiation. The grazing incidence X-ray diffraction (GIXRD) results show that the full width at half maximum (FWHM) increases on irradiation. The surface morphology of irradiated sample shows the pits and islands by AFM studies. The optical absorption cut off wavelength is 493 nm for as grown ZnSe whereas for the implanted and irradiated samples cut off wavelength shift towards red region. The photoluminescence spectrum shows the emission wavelength is at 592 nm whereas for the implanted-irradiated samples PL emission shift towards red region. The intensity of defect level emission decreases due to Au irradiation. The FT-Raman spectrum shows the peak at 252 cm^{-1} due to LO mode of Zn–Se lattice vibrations. The X-ray absorption near edge structure (XANES) study was performed for the as grown and irradiated samples. The detailed investigation on the structural and optical properties of the N implanted and Au irradiated ZnSe single crystal was carried out.

1. Introduction

ZnSe is an important and well known II–VI compound semiconductor with direct band gap energy of 2.67 eV at room temperature [1]. This semiconductor received a great attention due to different types of optoelectronic applications, namely blue light emitting diodes, laser diodes and other non-linear optoelectronic devices in the ultraviolet region [2]. Additionally, it is also an important material for detectors of ionizing radiation, X-and γ-rays in the high energy radiation environments [3]. ZnSe has high radiation stability (10^7 rad) and high upper limit of working temperature, thus showing that is a very promising material for 'scintillator photodiode' detectors of radiation in harsh environments [4]. On the other hand, the extensive use of ZnSe in electronic devices has been hindered by the difficulty in obtaining low resistive p-type doping [5]. The possibility of tuning the physical properties of ZnSe using the ion beam implantation and the irradiation techniques is quite interesting and challenging [6]. Thus, the increase of knowledge concerning the behavior of this material in harsh environment is very important for potential applications.

* Corresponding author. Tel.: +91 44 2235 8317; fax: +91 44 2235 2774.
E-mail address: rdcgc@yahoo.com (R. Dhanasekaran).

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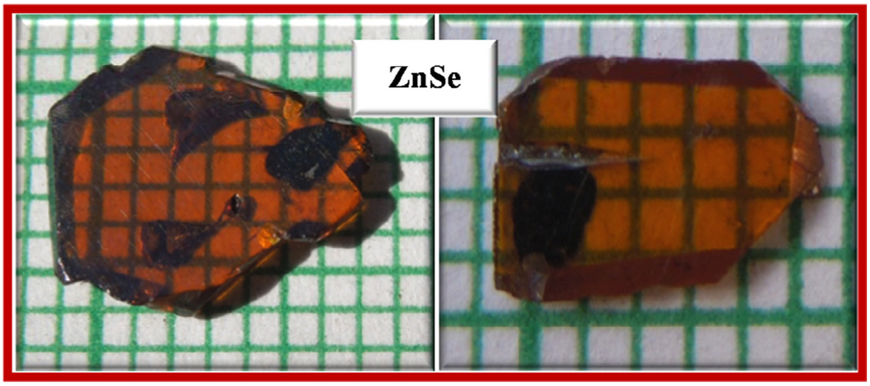

Fig. 1. Polished CVT grown ZnSe single crystals.

The swift heavy ion irradiation (SHI) has attracted a lot of attention in recent years due to its potential to change the physical properties of materials in a controlled manner [6]. The incident ion induces defect annealing and different kind of lattice defects [7]. The studies involving irradiation with MeV ions have been taken up in electronic devices to study the effect of lattice damage on the performance of those devices in high radiation environment [7,8]. The ion irradiation in materials produces different kinds of lattice defects in the materials [6] and due to the very high energies involved, the stopping of the incident particles is much higher than for considerably lower energy ions.When an energetic heavy ion penetrates in the crystal lattice, it creates the excitation and an ionization process that lead to the creation of wide variety of defect states in the materials and changes their physical properties in a controlled manner [6–8]. The creation of the defects strongly depends on the mass of the incident ions, energy and fluence [8]. For the swift heavy ion irradiation the electronic energy loss is the dominant process due to inelastic collision. Besides, ion implantation is one of the methods to dope in a controlled way [6–8] in which the nuclear energy loss is the dominant process due to elastic collision involving the incident ions [6].

In literature, there are several reports on the influence of SHI or ion implantation on the physical properties of II–VI semiconductors based thin films [9–13] and single crystals [14–16]. In the particular case of ZnSe, the optical studies of N implanted ZnSe single crystals [15] and of 120 MeV Au ion irradiated ZnSSe single crystals [16], have been reported. They performed photoluminescence studies which reveal the N acts as shallow acceptors in ZnSe and the ionization energy of acceptor center was found to be about 105 meV [15]. In addition, the optical properties of Au irradiated ZnSSe reveals the intensity of photoluminescence decreases and red shift of PL was observed with increasing ion fluences [16]. However, the simultaneous ion irradiation and implantation were never investigated in ZnSe. We must stress that the use of ZnSe in harsh environments requires the investigation of the behavior of the implanted species under a huge density of defects. To the best of our knowledge this is the first report on the influence of ion irradiation on N implanted ZnSe single crystals.

The main objective of this work was to evaluate the structural and optical properties of N implanted ZnSe single crystals after Au ion irradiation. Generally, the ion implantation followed by SHI is quite interesting because it allows the simulation of a harsh environment. The crystallinity, surface roughness, band gap energy, defect level emission and lattice vibrations of as grown, irradiated and implanted with irradiated ZnSe single crystals were investigated by grazing incidence X-ray diffraction (GIXRD), surface morphological, optical absorption, photoluminescence, FT-Raman and X-ray absorption near edge (XANES) studies. The significant changes were observed in the structural and optical properties of N implanted ZnSe after Au irradiation. In particular photoluminescence studies, the intensity of defect level emission was decreased and the emission was shifted towards red region due Au irradiation. The reduction of defect level emission after Au irradiation in ZnSe can be used for the electronic devices in harsh environments.

2. Experimental details

The synthesis and growth of ZnSe single crystals was performed by a CVT method according to the procedure described elsewhere [17]. The polished CVT grown ZnSe single crystals have a thickness of ~1 mm and these are shown in Fig. 1. The ion implantation was performed with the 6.4 GHz Electron Cyclotron Resonance (ECR) plasma ion source at Variable Energy Cyclotron Center (VECC), Kolkata, India. N implantation was carried out on as grown ZnSe crystals, at room temperature, for energy of 45 keV and in different ion fluences: 1×10^{15}, 5×10^{15}, 1×10^{16} and 5×10^{16} ions/cm^2. The ZnSe crystals were fixed on the sample holder using silver paste. The chamber pressure of $\sim2.6\times10^{-6}$ torr and the current in the range of 2.5–5 μA were maintained during implantation experiment. The previous samples as well as non-implanted ones, were irradiated at room temperature in the 15UD Pelletron accelerator at Inter University Accelerator Center (IUAC), New Delhi, India. The 120 MeV Au ion was used at a constant fluence of 1×10^{13}ions/cm^2. The samples were mounted on a vacuum shielded vertical sliding copper ladder having rectangular faces. The ion beam was magnetically scanned over an area of sample surface in a