

Micro Raman Scattering and GA-XRD Studies of Swift Heavy (200 MeV) Silver Ion Irradiated Gallium Phosphide



Physics

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ABSTRACT

Single crystal gallium phosphide samples were irradiated with 200 MeV Ag^{9+} ions for various fluences ranging from 1×10^{12} to 1×10^{13} ions cm^{-2} . Raman scattering and glancing angle X-ray diffraction techniques were employed in order to study the post irradiation effects. The shift in the Raman scattering peak position with respect to ion fluence indicated the stress in the irradiated sample and phonon confinement of carriers. Amount of stress in the irradiated sample calculated from Raman shift were found to be vary between 297 and 597 MPa. The glancing angle X-ray diffraction study showed increase in the full width at half maxima with increasing ion fluence. Crystallite size evaluated using Scherrer formula was found to be vary between 11.30 nm to 5.38 nm for fluence ranging from 1×10^{12} and 1×10^{13} ions cm^{-2} , respectively.

Introduction:

The irradiation of solids with swift heavy ions (SHI) has become one of the most important methods of near surface modification of solids. In SHI electronic energy in materials can be varied from tens of eV/A upto a very high value of the order of keV/A by choosing appropriate ions and their energies in the accelerator. This provides a remarkable flexibility and adequate opportunities to extend the structural, optical or mechanical characteristics of the materials. Gallium phosphide is important III-V group compound semiconductors with an indirect band gap of 2.26 eV. It has potential applications in photonic devices which operate in visible range. It is being used in the manufacture of red, orange and green light emitting diodes and semiconductor lasers. Swift heavy ion irradiation (SHI) with different ion species has been used by researchers in various ways to alter structural, electrical and optical properties of these semiconductors (1-5). Room temperature damage formation in InP, GaP, GaAs and AlAs due to 539 MeV Au^{30+} ion irradiation studied by Wesh et al.(2). The room temperature damage in GaP has been investigated as a function of the ion fluence for various species in the energy 200 keV to 10 MeV showed, higher the total energy density deposited into electronic processes, smaller the number of defects produced per vacancy (3). In our earlier work we have reported the effect of 100 MeV $^{56}\text{Fe}^{7+}$ ions on indium phosphide and gallium phosphide (4-6). The decrease in the peak intensity and shift of X-ray diffraction spectrum showed amount of disorder and defect concentration increases with ion fluence. AFM studies of 100 MeV $^{56}\text{Fe}^{7+}$ ion irradiation of gallium phosphide showed presence of presence of nanosized hills separated with valleys at the surface of irradiated sample. The density and size of these hills were found to be depending on ion fluence. Till date many reports available in the literature that have investigated the effects of SHI on gallium phosphide compound semiconductor materials. However many facets are still to be investigated. In the present work, we are reporting effects of 200 MeV Ag^{9+} ions on gallium phosphide for fluence of 1×10^{12} and 1×10^{13} ions cm^{-2} by Raman scattering and glancing angle X-ray diffraction studies.

Experimental Details:

Single crystal gallium phosphide samples were irradiated for fluences of 1×10^{12} and 1×10^{13} ions cm^{-2} with 200 MeV Ag^{9+} ions using 16 UD Pelletron facility at Inter University Accelerator Center (IUAC), New Delhi. Ion beam was magnetically scanned over $1 \text{ cm} \times 1 \text{ cm}$ area on sample surface for uniform irradiation. During irradiation, the Ag^{9+} flux was varied between 0.3 to 0.4 pA (particle nano Ampere). The vacuum inside the irradiation chamber was about 10^{-4} Pa. Samples were mounted on copper ladder target with silver paste to avoid sample heating during irradiation. Raman scattering and glancing angle X-ray diffrac-

tion (GA-XRD) techniques were employed in order to study effects of swift heavy ion irradiation in gallium phosphide. Raman scattering spectra were measured at room temperature using RENISHAW inVia microscope in backscattering geometry using 514.5 nm line of argon ion laser in the wavenumber range of 100 cm^{-1} to 2000 cm^{-1} . GA-XRD spectra were recorded on Rigaku Ultima IV diffractometer equipped with CuK radiation source of 0.154 nm wavelength for 10° incidence angle.

Results and Discussion:

Raman Scattering Studies:

Figure 1 shows the first order Raman spectra of non irradiated and as-irradiated gallium phosphide samples with various ion fluences. The spectrum of non irradiated gallium phosphide sample showed two sharp peaks at 365.26 and 402.45 cm^{-1} , which corresponds to characteristic TO and LO mode of crystalline gallium phosphide respectively. The gallium phosphide sample irradiated for the fluence of 1×10^{12} ions cm^{-2} showed appreciable decrease in peak intensity and

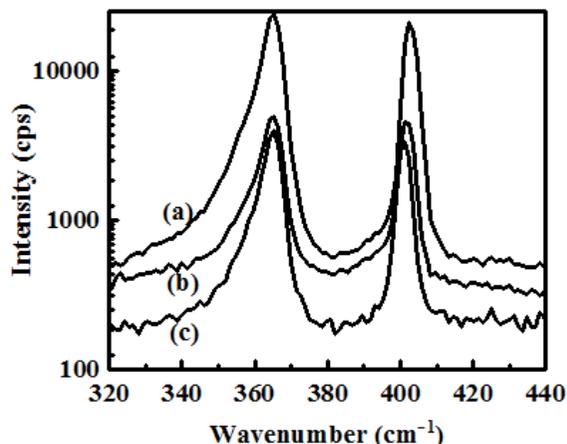


Figure 1. First order Raman spectra of (a) non irradiated gallium phosphide and samples irradiated with 200 MeV Ag^{9+} ions for the fluence of (b) 1×10^{12} and (c) 1×10^{13} ions cm^{-2} .

Shift in the Raman LO mode peak towards lower wavenumber region. The shift in the peak position indicates presence of stress in the irradiated samples and phonon confinement of carriers. The amount of stress in the irradiated samples was estimated from the following relation (7);

$$\sigma \text{ (MPa)} = -250 \Delta\omega \text{ (cm}^{-1}\text{)} \quad (1)$$

where $\Delta\omega = \omega_s - \omega_0$. In this expression ω_s & ω_0 denotes wave-numbers of LO peak of non irradiated and as-irradiated sample, respectively. For the gallium phosphide samples irradiated with fluence of 1×10^{12} , and 1×10^{13} ion cm^{-2} , irradiation induced stress evaluated from shift in the Raman LO mode was found to be 297 and 597 MPa respectively. The increase in the irradiation induced stress with respect to ion fluence may be due to presence of defects and disorder in the irradiated samples.

Glancing Angle X-ray Diffraction:

GA-XRD spectra of non irradiated gallium phosphide sample and irradiated with various fluences ranging from 1×10^{11} to 1×10^{13} ions cm^{-2} are presented in Fig.2

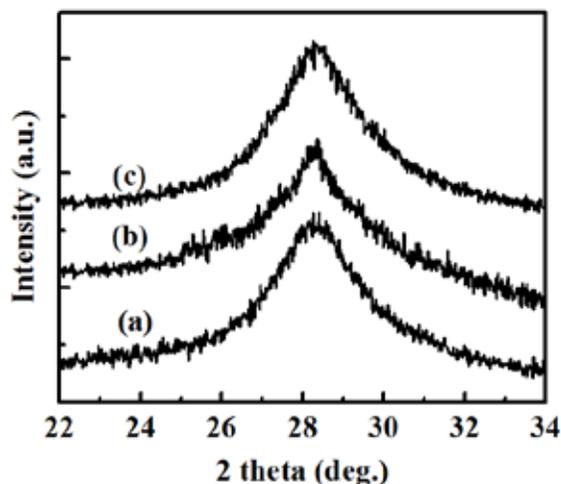


Figure 2: GIXRD spectra of (a) non irradiated gallium phosphide; and samples irradiated with 200 MeV Ag^{9+} ions for fluence (b) of 1×10^{12} and (c) 1×10^{13} ion cm^{-2} .

Non irradiated gallium phosphide sample showed sharp peak at $2\theta \sim 28.29^\circ$. The gallium phosphide samples irradiated for the fluence of 1×10^{12} and 1×10^{13} ions cm^{-2} showed shift in the peak toward higher Bragg's angle. The full width at half maxima was also found to be increased with respect to ion fluence. From FWHM of XRD peak crystallite size (D) of irradiated gallium phosphide sample was evaluated using Scherrer formula (8);

$$D = \frac{0.89\lambda}{\beta \cos\theta} \quad (2)$$

where λ is the X-ray wavelength (0.154 nm), β is the FWHM of GA-XRD peak.

Table 1: Parametres obtained from GA-XRD spectra of gallium phosphide.

Fluence (ions cm^{-2})	Non irradiated	1×10^{12}	1×10^{13}
Peak position (2θ)	28.29	28.29	28.36
FWHM (rad)	0.83	1.21	1.75
Crystallite size (nm)	11.30	7.78	5.38

The crystallite size of gallium phosphide samples irradiated for the fluence of 1×10^{12} and 1×10^{13} ion cm^{-2} was found to be ~ 7.78 and 5.38 nm respectively. Whereas corresponding estimate of non irradiated sample was 11.30 nm. The detail results are given in Table 1.

Conclusions: The irradiation of gallium phosphide samples with 200 MeV Ag^{9+} ions was carried out for the fluences of 1×10^{12} and 1×10^{13} ion cm^{-2} . The shift in the Raman peak with ion fluence indicated presence of stress in the irradiated sample. X-ray diffraction studies showed decrease in peak intensity and increase in full width at half maxima with increasing ion fluence. Crystallite size calculated from Full width at half maxima found to decrease from 11.30 nm to 5.38 nm for fluence 1×10^{12} to 1×10^{13} ions cm^{-2} .

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