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XRD and UV-VIS- NIR Study of Mn/GaAs Implanted by Ar^{+2} Ion Followed by Post Annealing

Sharad Tripathi[1], S. K. Dubey[2], R. Rathi[3], Amit Singh[4]

[1]*Department of Physics, Guru Nanak Khalsa College Matunga Mumbai-19*
[2]*Department of Physics, University of Mumbai, Santacruz (E)-94*
[3]*Ruia College of Arts, Science and Commerce, Matunga, Mumbai-19*
[4]*Thakur College of Science and Commerce, Kandivali, Mumbai-104*

***Corresponding Author E-Mail:** srdtripathi@gmail.com

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Abstract

In the present work, Mn/GaAs samples were implanted with argon ions at 250 keV for the various fluences (5 x 10^{15} to 5 x 10^{16} ions cm^{-2}). XRD spectra of the samples implanted for ion fluences 1 x 10^{16} showed the formation of (GaMn)As at 2θ value of 65.34 deg and also shows the formation of 2^{nd} phases like α–Mn, Mn_3Ga, Mn_2As and $Ga_{5.2}Mn$ after annealing at 450 ^0C. Optical transmittance of the implanted samples was found to decrease with increase in argon ion fluence. Optical band gap was found to be shifted. This shift in band gap is possible due to the strain induced in GaAs lattice due to Mn deposition and Ar incorporation

Keywords: GaAs, Implantation, XRD, UV

Introduction:

In the presence of ferromagnetic transition metals into the semiconductor matrix have shown to exhibit ferromagnetic behavior along with semiconductor properties. These types of materials are very imortant for the next generation of electronics devices which combine charge and spin of the electrons [1]. These materials have potential application in spin field transistors, spin valves, spin qubits and so on. Among them gallium arsenide with transition metal is very important because it has potential application in electronics and optoelectronics device, such as blue ultra – violet LEDs [2] and laser diodes, as well as high temperature devices [3]. High energy Mn^+ ions are implanted in GaAs and annealed in a nitrogen atmosphere. XRD shows many more binary phases, while FTIR study shows a shift in band gap due the Mn incorporation in GaAs [4] . Precipitated $Ga_{1-x}Mn_xAs$ ferromagnetic thin films were grown with solid – source MBE on semi-insulating Gallium Arsenide substrates and showed a magnetic structure [5].This paper deals the 250 keV Ar^{2+} implantation effect on the optical and structural properties of Mn deposited GaAs.

Experimental Techniques:

Cleaned wafer of gallium arsenide is cut in size of 1.5 cm x1.5 cm using sharp diamond cutter. Samples of GaAs (1.5 cm x 1.5 cm) again cleaned by chemical method and ringed in De-Ionized water & kept in vacuum desiccators to avoid the oxidation. The uniform manganese (Mn) thin film of 25 nm

thickness was deposited on the GaAs samples in high vacuum having pressure 3.0 x 10^{-6} mbar using HINDHIVAC Unit at Department of Physics, University of Mumbai. The thickness of the Mn film was controlled by using the quarts crystal detector. These Mn/GaAs samples (25 nm) were implanted by 250 keV Ar^{2+} ions with various fluences varying from 5 x10^{15} to 5 x 10^{16} ion cm^{-2} using Low Energy Ion Beam Facility (LEIBF) at Inter University Accelerator Centre (IUAC), New Delhi. Variation of Nuclear energy loss and electronics energy loss with respect to energy of argon ion in GaAs substrate are shown in Figure -1. Depth profile of argon in GaAs are also calculated and shown in Figure-2. Optical and structural characterizations of these samples were performed using single crystal X-ray diffractometer (JEOL model JDX-8030).Transmittance spectra of the prepared samples were obtained in the photon energy range between 0.5–7.0 eV using the UV-VIS-NIR spectrometer (Shimadzu UV-3600). Samples were annealed at 450 ^{0}C using the rapid thermal annealing (RTA) system for 2 min in flowing N_2 gas environment at Department of Physics, University of Mumbai.

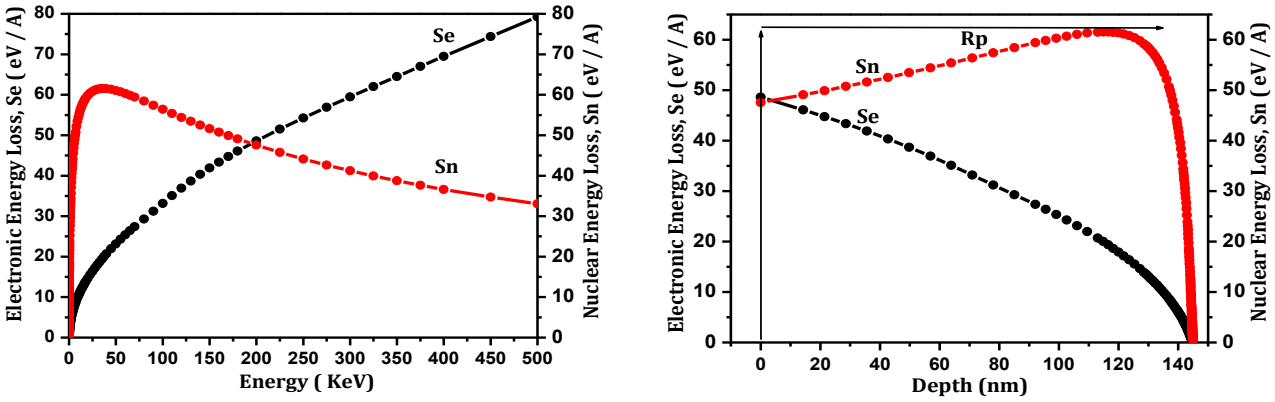

Fig. 1: Variation of Se and Sn of argon ion in GaAs with respect to energy and its depth profile

Results and Discussion:

Figure-2 shows the X-ray diffraction spectra of GaAs, sample deposited by Mn thin film of 25 nm on GaAs and this sample implanted by Ar^{+2} ion with energy of 250 keV.Figure1(a) shows a GaAs substrate peak (004) at 2θ=65.72^0. However, the spectra recorded for the other samples as said show an additional peak towards the lower angle, indicating damaged caused by argon ion implantation. The X-ray diffraction peak towards the higher angle side (seen in all the samples) is due to the Cu-Kα_2 radiation. Figure-3 shows the X-ray diffraction spectra recorded for the Ar^{+2} ion implanted sample and after rapid thermal annealing at 450 ^{0}C for 2 min in N_2 ambient. It shows the formation of 2nd phases like α–Mn, Mn_3Ga, Mn_2As and $Ga_{5.2}Mn$ [2].

In order to investigate the optical properties, UV-VIS- NIR transmission spectra of non-implanted sample and implanted samples were recorded in the spectral region 200 nm to 1600 nm. The value of transmittance of the Ar^{+2} ion implanted samples were found to increase with increase in ion fluence. During the sample growth, a number of defects may be generated due to the bombardment and introduction of Mn ions, under this condition, a series of quasi-continuous. Defects level may appear in the band gap, which can be responsible for the 1.36 eV emission band.

It also indicates the growth of defect in the samples as ions fluences are increasing. The sample (1x 10^{16}) was annealed at 450^{0}C, transmittance spectra of this sample increased as shown Fig.4 c, showing the recovery of recrystallization of the sample and Fig.4 shows the transmittance spectra of these samples Transmittance of Mn deposited GaAs is very low but implanted with Ar^{2+} ions, transmittance of the

samples increases means absorbance of the samples are decreasing. Fig.5 shows α^2 versus energy curve, where α is the absorption coefficient (cm^{-1}).Pure GaAs shows a band gaps of 1.385 eV,

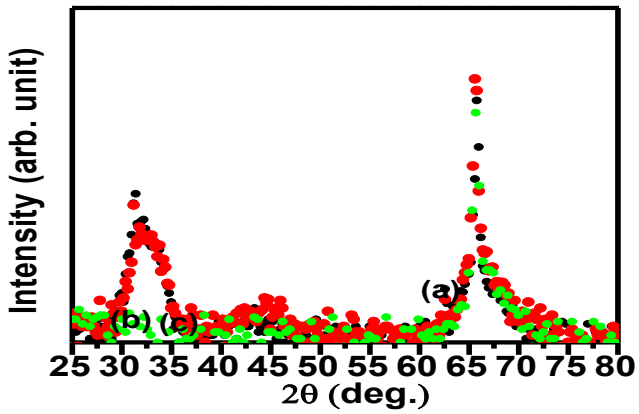

Fig. 2: X-ray diffraction spectra of (a) GaAs,(b) Mn deposited GaAs (c) Mn deposited GaAs + implanted with Ar^{+2} ($1x10^{16}$)

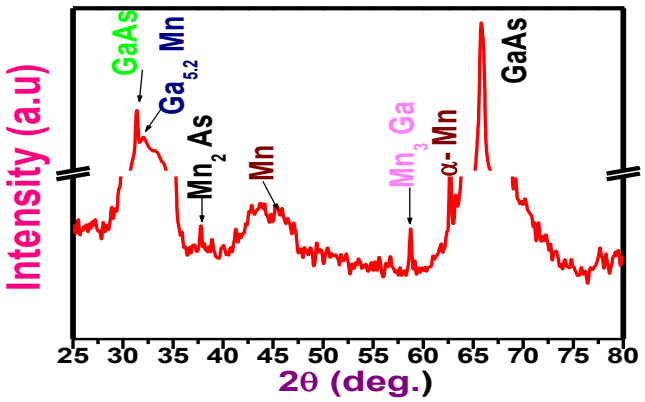

Fig. 3: X-ray diffraction spectra of Mn deposited GaAs + implanted with Ar^{+2} ($1x10^{16}$) and annealed at 450^0C.

whereas as-implanted with Ar^{+2} ($1x10^{16}$) and annealed at 450^0C sample shows band gaps of 1.380 eV ,which clearly shows a shift in band gap. This shift in band gap is possible due to the strain induced in GaAs lattice due to Mn deposition and Ar incorporation.

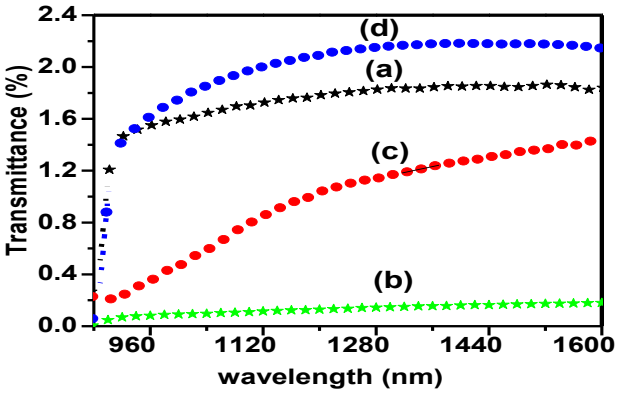

Fig. 4: Transmittance spectra of the (a) GaAs,(b) Mn deposited GaAs (c) Mn deposited GaAs + implanted with Ar^{+2} ($1x10^{16}$) (d) before and after annealed at 450^0C.

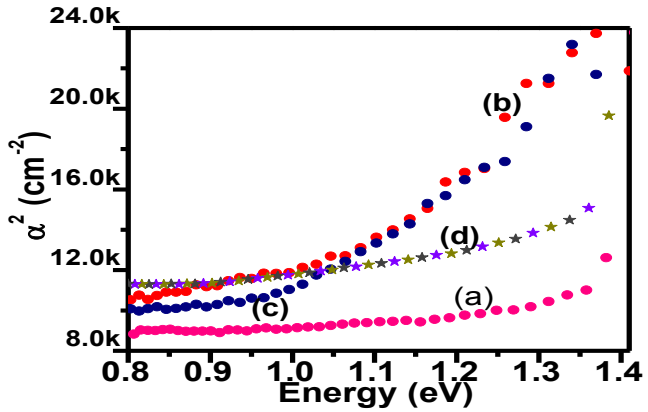

Fig. 5: α^2 versus energy curve of the (a) GaAs,(b) Mn deposited GaAs (c) Mn deposited GaAs + implanted with Ar^{+2} ($1x10^{16}$) (d) before and after annealed at 450^0C.

Conclusions:

In conclusion, the XRD and UV measurement were employed for structural and optical study of implanted deposition grown Mn/GaAs. The XRD result showed that $Ga_{5.2}Mn$, Ga_5Mn_8, Mn_3Ga and α-Mn were obtained in the sample grown at the substrate temperature of 450^0c. The strong and sharp Ga_5Mn_8 peak indicated that the growth conditions were quite suited to the nucleation and growth of Ga_5Mn_8. After annealing at 450^0C, Mn_3Ga and α-Mn disappeared, Ga_5Mn_8 tended to disappear, $Ga_{5.2}Mn$ crystallized better and new phase Of Mn_2As was generated, which showed that the annealing was beneficial to the growth of$Ga_{5.2}Mn$ and Mn_2As.[3]

Acknoledgment:

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