Defect Annealing in 140 MeV Oxygen Irradiated Semi-Insulating Fe-Doped Indium Phosphide-as Studied by Positron Annihilation Technique

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Abstract

The formation of defect and its recovery with temperature in Fe-doped Semi Insulating Indium Phosphide irradiated by 140MeV Oxygen ion beam have been studied both by Positron annihilation lifetime spectroscopy and Doppler broadening annihilation line-shape measurements. After irradiation the sample has been subjected to an isochronal annealing over a temperature region of 25 – 650°C with an annealing time of 30 minutes at each set temperature. The high average positron lifetime value τ_{avg} = 263ps at room temperature after irradiation indicates the presence of defects. Two significant annealing stages in positron lifetime are observed in the temperature ranges 350 to 450°C and 500 to 650°C. A reverse annealing stage has been observed at temperature range 250 to 450°C in S-parameter indicating the migration of vacancies and the formation of vacancy clusters. Increases in R-parameter from 300 to 400°C indicate the change in the nature of the predominant positron trapping sites.

1. Introduction

In recent years InP has been considered a potentially important material for optoelectronics and space technology. Positron Annihilation Lifetime Spectroscopy (PALS) can provide quite novel and direct information about microscopic identification and quantification of vacancy like defects such as the nature, size, structure, concentration and charge state of the defects. In combination with Doppler Broadening Spectroscopy, sub lattice information around the defects can also be obtained.

It was shown by the Dlubek et al. [1] almost for all InP samples expect heavily Zn-doped ($4.5*10^{18}/cm^3$) sample the Lifetime varied between 242ps and 252ps. But for heavily Zn-doped InP, they got a longer lifetime of 325ps. This longer lifetime is due to the neutral Zn-divacancy complexes. Here radiation defect formation and their recovery with temperature are observed for 140MeV O^{+6} ions irradiated semi-insulating Fe-doped InP.

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2. Experimental Details

Fe-doped Semi Insulating InP sample with doping concentration $7.8*10^{16}/Cm^3$ is irradiated by O^{+6} ion beam of energy 140MeV having fluence 10^{16} ions/Cm^2 at room temperature(25°C) at Variable Energy Cyclotron Centre(VECC), Kolkata, India.

PALS experiment is done using a fast-fast coincident system having time resolution 316ps using ^{22}Na of activity 8μCi. Positron lifetime spectra were analyzed with proper source and background correction according to positron trapping model using PATFIT [2]. Isochronal annealing has been performed at different temperatures for 30 minutes starting from room temperature to 650°C in a vacuum of 10^{-6}Torr.

Doppler Broadening Annihilation line-shape measurement has been carried out using HPGe detector having resolution of 1.8KeV for 662KeV gamma rays from a ^{137}Cs standard source.

3. Results and Discussions

Figure 1 represents the annealing behaviour of average lifetime with temperature. A single component analysis for the reference Fe -doped InP sample gives the bulk Positron lifetime as τ=242ps at room temperature which agrees well with the earlier observations [1, 4]. After irradiation, at room temperature the observed average lifetime τ_{avg} = 263ps is 21ps higher than the reference value which indicates the presence of vacancy like defects andvacancy oxygen (VO) complexes due to high energy oxygen irradiation. In the temperature region 25 to 250^{o}C average positron lifetime value is almost stable. From 250^{o}C the average lifetime gradually increases and reaches its maximum 271ps at 350^{o}C due to the clustering of vacancy and formation of vacancy clusters. Beyond 350^{o}C annealing takes place and

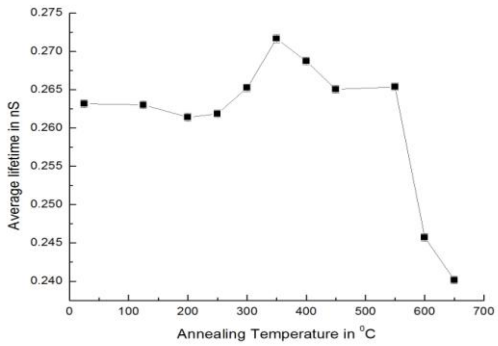

Figure 1. Annealing Behaviour of Average Lifetime with Temperature.

defect recombines through vacancy interstitial (V-I) complexes [3].Doppler broadening line-shape measurement is analysed in terms of S-parameter, W-

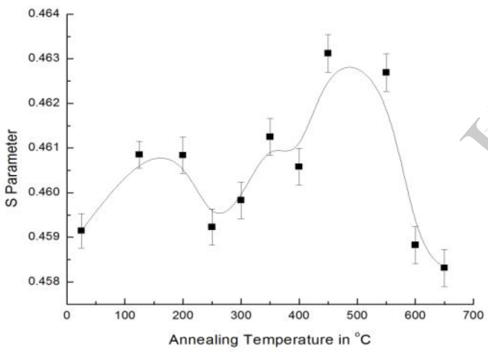

Figure 2. Doppler Broadening Annihilation Line-Shape Parameter(S) with Annealing Temperature.

parameter & R-parameter having their usual definitions [4]. In Figure 2, the Doppler broadening annihilation line-shape parameter(S) has been plotted against annealing temperature. S-parameter detects the change in nature of defect sites. From 250^{o}C S-parameter increases gradually and reaches its maximum at 450^{o}C. This reverse annealing takes place due to the migration of vacancies and the formation of vacancy clusters. Similar step was observed for S-doped InP [4].During the reverse annealing the positron trapping rate for such defects is probably sufficiently large. The variation in S-parameter resembles the behaviour of average lifetime. Figure 3 shows the variation of defect specific parameter(R) with annealing temperature. R parameter is independent on the size of the predominant defects. During annealing R-parameter is

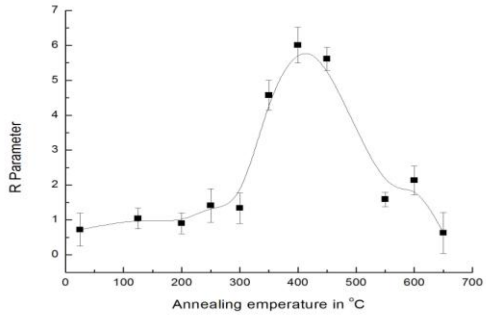

Figure 3. Variation of Defect Specific Parameter(R) with Annealing Temperature.

stable from 25 to 300^{o}C and it follows the similar behaviour as observed for average positron lifetime. R-parameter increases from 300 to 400^{o}C indicating that the size of the predominant defect has changed and higher order defect is formed. It follows the similar behaviour as average lifetime. Beyond 550^{o}C average lifetime, S-parameter and R-parameter start decreasing and reach almost the bulk value indicating that the defects are being annealed out.

4. Conclusion

At room temperature high energy oxygen produces vacancy like defects and vacancy-oxygen complexes in InP as evident from high average lifetime value τ_{avg} = 263ps. Average lifetime and R-parameter follow more or less similar behaviour from 25 to 250^{o}C. In the temperature region 250 to 350^{o}C average lifetime increases to a maximum indicating the migration of vacancies, vacancy-oxygen complexes and the formation of vacancy clusters. R-parameter increases from 300 to 400^{o}C and reaches to a maximum at 400^{o}C indicating the increase in size of defect. Finally at 650^{o}C average lifetime, S-parameter and R-parameter show that all defects are being annealed out.

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References

[1] G. Dlubek: "Vacancy-Zn complexes in InP studied by positrons", Appl. Phys. Lett. Vol. 46, 1985, pp. 1136.

[2] P .Kirkegaard, "A versatile program for analyzing positron lifetime spectra"Comput. Phys. Commun.vol. 3. 1972, pp. 240-55

[3] S. K. Chaudhuri, "Isochronal annealing behaviour of defects induced by swift oxygen ions in high-resistivity p-type silicon," in J. Phys.: Condens. Matter. vol. 19. 2007, pp. 216206.

[4] A K Saha, "Identification of vacancy type defects in high energy oxygen irradiated III-V compound semiconductors using positron annihilation spectroscopy" in *Acta Cincia Indica,Vol XXXV, pp. 2265*.