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Boron and Gamma ray irradiation effects on I-V and C-V characteristics of Photo detector MRD 500

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Abstract: This paper describes the effect of 30- and 60- MeV Boron ion and Gamma ray (Co-60) irradiation effects on silicon photo detector (MRD 500 Motorola manufactured) for various fluence/doses. The devices are systematically investigated by I-V and C-V measurements. The radiation induced electrical degradation is studied from I-V measurements. C-V measurements are made to estimate the effect of irradiation on the doping concentration of the devices. The characteristics studied in this investigation show that Si PIN photodiodes are suitable for use in high radiation environment.
Keywords: Photo detectors, irradiation, defects, electrical degradation, capacitance.

Introduction

Radiation induced effects in PIN photodiodes have been investigated using gamma[1] and neutron[2], and proton[3] irradiation. It is useful to note that PIN photodiodes are similar to solar cells in that both are *pn*-junction devices which differ in their mode of operation and junction characteristics. A substantial amount of work has been carried out on the effect of electrons and gamma radiation on silicon solar cells [4,5,6] with an emphasis on the reduction of their output power. On the other hand, the work reported here is concerned with irradiation induced degradation in electrical and capacitance response of PIN diodes. This paper presents results of 30 MeV $B^{3+}$and 60 MeV B^{4+} ion and Co^{60} gamma ray irradiation effects on silicon photo detector.

Experimental details

Ion irradiation has been performed at 15 UD 16 MV Pelletron Tandem Vande Graff Accelerator facilities at Inter University Accelerator Center (IUAC), New Delhi India. Boron ion fluence is varied from 1×10^{10} to 1×10^{12} ions cm^{-2} and gamma irradiation is performed using Co-60 gamma ray source with the dose rate 7.275 KGy/hr and total dose ranging from 0–500 KGy at room temperature. I-V and C-V characteristics are measured before and after the irradiation using Keithley 2400 source meters and Bontoon – capacitance meter interfaced to a computer.

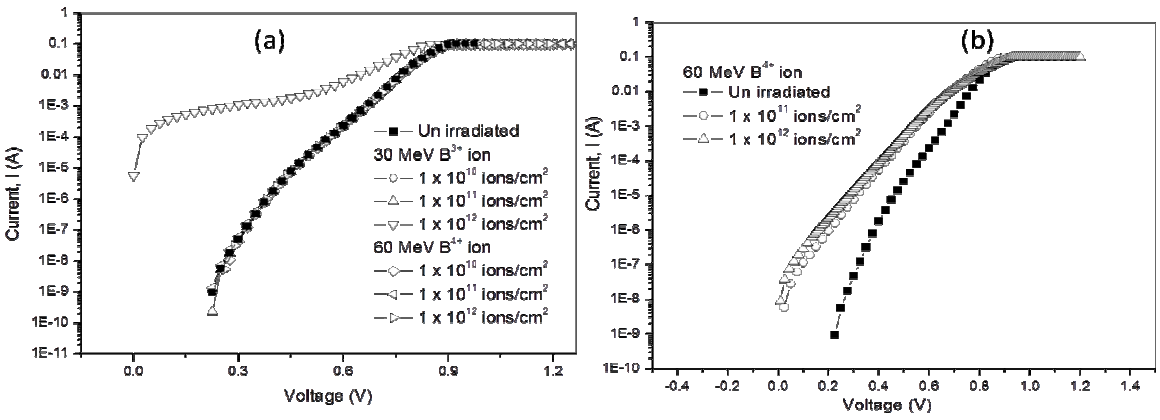

Figure 1. Variation of forward current as a function of Voltage for 30MeV and 60 MeV B ion irradiated (a) without Decaping (b) with decapped MRD-500 Photo Diode

Results and discussions

The electrical response of each diode was measured before and after irradiation to a particular fluence. In view of the fact that we express the electrical response in terms of the ratio of the photocurrents of the tested and reference diodes, it is useful to keep the absolute efficiency in mind. Figure (a) shows the variation of forward current before and after exposure to various fluences of 30 and 60 MeV boron. It seems for 30 and 60- MeV boron ion irradiation, the diode is unaffected up to 1x 10^{11} ions cm^{-2}. This shows that there is no spreading of resistance. However, for 30 MeV boron ion of fluence 1x10^{12} ions cm^{-2}, the device behaviour is abnormal, indicating an increase in the resistance of the PN junction.

In order to verify the degradation of the device for radiation, three diodes are selected whose protective caps are removed and exposed for 60 MeV boron ions, and their electrical response is presented in Figure 1(b). I-V Measurements shows there is a variation in the forward current, which may arise due to the spreading of the junction resistance.

Irradiation of semiconductors with high energy particles displaces atoms and damages the lattice,

thereby introducing new energy levels in the band gap. These defects act as recombination centres which decrease the minority carrier lifetime. Since PIN diodes have large depletion widths, irradiation induced changes in this region have a significant effect on the diode photocurrent. When silicon surface barrier detectors are irradiated with protons, damage produced in the depletion region increases the depletion width capacitance. The capacitance is proportional to the dopant density; the observed increase indicates that the created defects have a net positive charge (donor behaviour). I-V measurements for gamma irradiated photo detector shows a small increase in current with increase in gamma dose. Heavy ions can directly produce displacement damages in bulk of photo diode similar to electrons, neutrons and protons. Displacement damage studies performed using heavy ion irradiation, which produce predominantly isolated defects, are important both from basic science as well as technological point of view. Majority of the displacement damage is due to the non-ionizing energy loss (NIEL). To strengthen this study one has to perform the mono energetic irradiation by γ-rays. In other words, these devices need to be tested for Co-60 gamma irradiation to determine their sensitivity to Total Ionizing Dose (TID).

Figure 2 (a) exhibits a plot of capacitance verses voltage of photo diode. Upon irradiation, there is a considerable decrease in the capacitance with increase in fluence for 30 MeV ion. On the other hand, there is a decrease in capacitance for 60 MeV ion irradiation. For the decapped devices, decrease in capacitance is still larger. Figure 2(b) exhibits a plot of capacitance versus voltage of photo diode irradiated with ^{60}Co gamma ray. Upon irradiation, there is no considerable degradation in capacitance. For decapped device there is decrease in capacitance. This would indicate that there is a partial loss of charge carriers in the *pn*-junction upon irradiation. The decrease in capacitance for decapped device may lead to an increase in doping concentration. This variation plays an important role in conduction of the device. The effect of variation of the doping concentration of the device may also vary spreading resistance of the *pn*-junction.

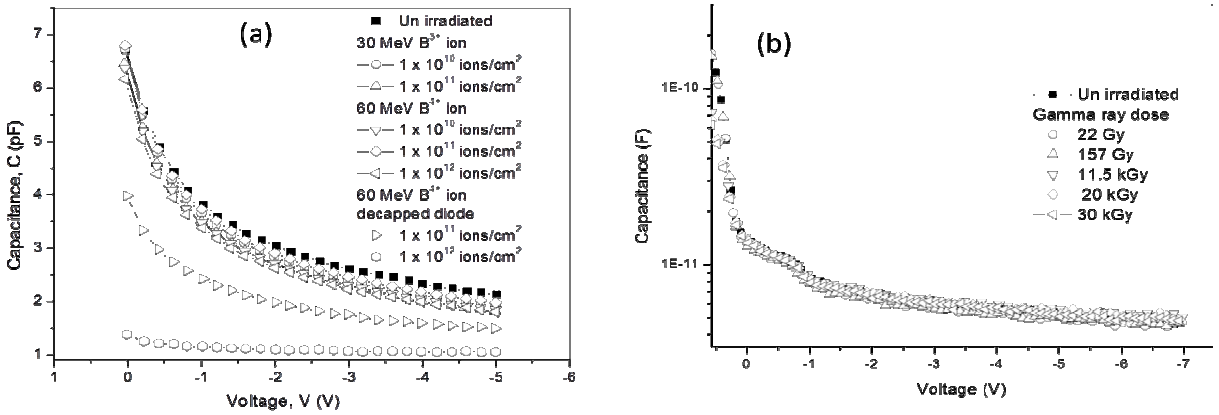

Figure 2. (a) Capacitance measurements for B ion irradiated MRD 500 photo diode. (b) Co-60 gamma irradiated MRD 500 photo detector

Conclusion

In this study, 30, 60 MeV boron ion and 60Co gamma (7.275 KGy/hr) irradiation effects on photo detector (MRD-500) have been investigated through I-V and C-V measurements. It is observed that for 30- and 60-MeV boron ion irradiation, the diode is unaffected up to 1x 10^{11} ions cm^{-2}. This shows that there is no spreading of resistance. However, for 30 MeV boron ion of fluence 1x10^{12} ions cm^{-2}, the device behaviour is abnormal, indicating an increase in the resistance of the *pn*-junction. MRD 500 photo detectors are sensitive to gamma irradiation above the total dose of 11.5 kGy. For decapped device, there is a considerable degradation in capacitance. This would indicate that there is a partial loss of charge carriers in the *pn*-junction upon irradiation. The decrease in capacitance for decapped device may lead to an increase in doping concentration. This variation plays an important role in conduction of the device. The effect of variation of the doping concentration of the device may also vary spreading resistance of *pn*-junction.

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