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Boron ion irradiation induced defects in the bismuth

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Abstract: In this paper we are describing the homogeneous irradiation induced effects of boron ions in the bismuth samples. The samples were irradiated by boron ions with the influence of $10^{13}10^{14}$ ions/cm² at Nuclear Science Center, New Delhi. The positron life time of the samples were recorded at slow-fast coincidence system. The mean life time has been found to vary 255 to 283ps with increasing the dose. The life time spectra show a single mean life time with increased value, indicating shallow traps smaller than mono vacancies which are formed around embedded boron. The X-ray diffraction analysis shows no significant variation in the lattice parameters due to irradiation. The increase in the life time is discussed and attributed to the annihilation of positron from the defect sites due to irradiation.

Key Words: Ion Irradiation, RIDs, Defect Distribution, Characterization, Positron lifetime spectroscopy.

INTRODUCTION:

The study of defects has practical importance as they are formed during processing from different forms like implantation of ions, mechanical works etc.

Positron Annihilation Spectroscopy (PAS) is an established technique for investigating lattice defects in materials. This technique has been successfully applied for the studies of radiation induced defects in materials where it has provided useful information about the con centration of the defects i.e. vacancies, micro voids, clusters etc., produced as a result of irradiation. With this motivation the positron probe has been used to study bismuth samples where the effect of vacancy is absent.

Radiation damage in semi-metals has been extensively studied using positron annihilation technique (PAT) by a number of groups (1-3), because the implanted ion generate a disordered region in which the crystal structure has been severely disrupted.

In semi-metals the conduction band edge is slightly lower in energy than the valance band edge. A small overlap in energy of the conduction and valence bands leads to small concentration of holes in the valance band and of electrons in the conduction band. The number of electron to hole ratio in conduction band of bismuth is the order of 0.93 (4), which indicates that majority of charge carriers are holes in bismuth. When an energetic ion penetrates in the materials it looses its energy until it become thermalized and located at around its penetration range Rp. This action of ion in materials is responsible to create RID (radiation induced defects) type defects. Figure 1 shows the schematic of energy loss process during MeV energy heavy ion-implantation showing electronic and nuclear energy losses.

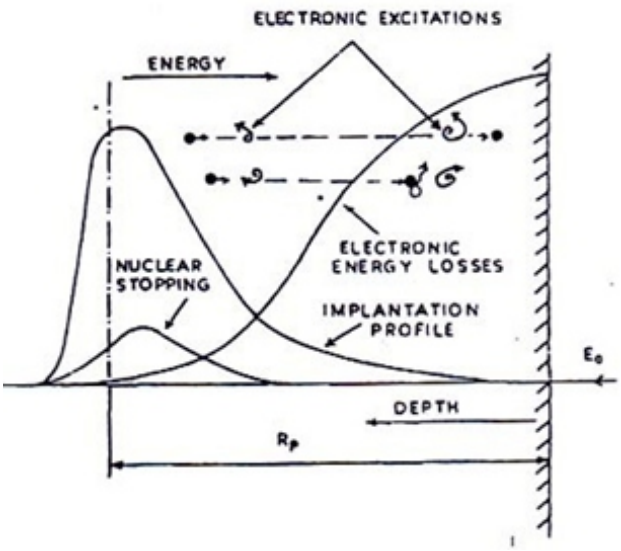

Figure. 1 A schematic diagram of energy loss and depth profile of high energy heavy ion in material.

It has been reported that the effect of vacancy is absent in bismuth (5). With this motivation it is tried to find out the RID type defects in bismuth by PAT (Positron Annihilation Technique) whether they are generated by boron ion irradiation because the range of boron ion (60 MeV) in bismuth is of the order of the range of positron emitted from Na22 source after bata decay.

EXPERIMENT:

Boron ion irradiation:

A pair of well annealed samples of bismuth pellets of thickness~2 mm, purity 99.9% were irradiated with born ion in two different modes (a) Mono energetic [60 MeV], (b) Homogeneous [0-60 MeV] at NSC Pelletron. The homogeneous irradiation was carried

out by a rotating wheel arrangement (6) having energy degrader foils. The range of boron ion of energy 60MeV in bismuth is ~70μm calculated by computer simulation program TRIM (7). Similarly the range of positron from Na22 isotope in bismuth was calculated because in the Dirac theory a positron passing through matter may be thought of as roughly analogous to a hydrogen ion (8). The range of positron (Na22 source) thus found is the order of the range of boron (60MeV) in bismuth. Thus positron can reach to defect sites that are generated by boron ions in bismuth. Figure 2 shows the depth profile of boron ion in bismuth.

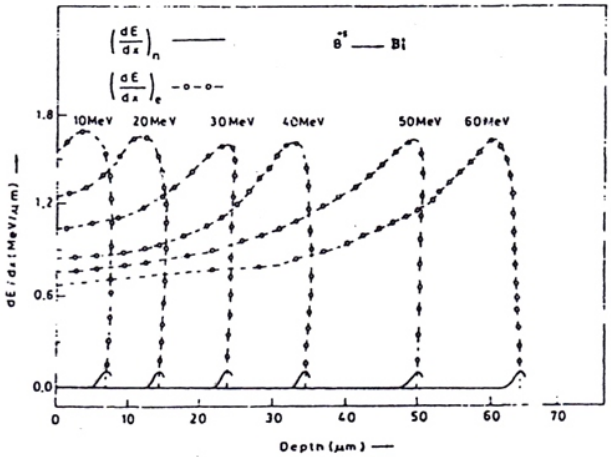

Figure. 2 Depth profile of Boron ion in bismuth

Positron life time measurements

The lifetime of a positron is measured by observing the time difference between two gamma quanta signaling the birth & death of the positron. The birth signal is a gamma emitted simultaneously with the positron from the source nucleus (1.28 MeV for the Na22 isotope) and the death signal is the 0.511 MeV annihilation quantum. The positron lifetime measurements were obtained at room temperature by a slow-fast coincidence spectrometer. The positron lifetime spectra were analyzed using the programme POSFTT (9) and modified for PC by Granata.

RESULTS AND DISCUSSION:

All lifetime spectra were analyzed in terms of two spectral components. The spectra are characterized by the decay rate of their exponential term $\lambda = \tau - 1$, where τ is the positron lifetime in the samples. The typical value of positron life time in boron ion irradiated in bismuth samples are listed in Table 1.

Table 1. Positron life times in boron ion irradiated bismuth

Sample	Dose (ions/cm³)	τ_1 (ps)	τ_2 (ns)	I_1	I_2
Bismuth (Un-Irradiated)		255±1	1.43±.04	98	2
Bismuth (Homogeneous Irradiation)	2.17×10^{14}	263±1	1.45±.05	98	2
	5.42×10^{14}	276±1	1.63±.07	98	2
	1.08×10^{15}	283±1	1.65±.08	98	2
Bismuth (Mono-energetic Irradiation)	5.42×10^{14}	258±1	1.52±.07	98	2

The value of τ1, in bismuth (un-irradiated) is 255ps in good agreement with Vijay et al (5). After irradiation the value of τ1, increases with the dose (in homogeneous) while τ1, remains constant in mono-energetic irradiation. In case of samples irradiated with mono-energetic boron ion in bismuth, the electronic stopping effects are uniformly distributed from 0 to

60μm of the sample and boron ion induced effects are localized to only 60-70μm which is the projected range RP, including straggling effect. However, when the samples are irradiated with moderated beam, the boron ion is homogenously distributed in the bismuth from 0- 70μm, and effects due to nuclear stopping are dominant. The increase in the life time component τ1, in homogeneous irradiation is indicating that nuclear stopping induced defects have been generated. The life time data do not show any variation due to mono-energetic irradiation indicating the electronic loss in bismuth do not change in the defect configuration. However, the boron induced effects are responsible to change in life time parameter due to homogeneous irradiation. The change in lifetime value is from 255-283 ps indicating presence of some shallow traps smaller than mono vacancies are generated in bismuth. The X-ray diffraction analysis does not show any significant variation in lattice parameters due to irradiation which indicates that there is no change in the crystalline phase of bismuth after boron ion irradiation.

CONCLUSION:

Based on the present study the following conclusions can be drawn:

(I) Homogeneous irradiation of boron ion bismuth is responsible to generate some shallow trap type of defects.

(II) Mono energetic irradiation of boron ion in bismuth samples gives no change in lifetime

parameters signifies that there is no effect of electronic stopping in bismuth due to irradiation.

(III) X-ray diffraction analysis of both type of irradiated and un irradiated bismuth do not show any significant change. This implies that there is no change in crystalline phase of bismuth after boron ion (60MeV) irradiation.

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