Silicon PIN diode neutron dosimetry

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Silicon PIN neutron dosimeter has been developed by Defence Laboratory, Jodhpur. The device is a wide base, conductivity modulated PIN diode that responds to fast neutrons in the range of interest (1 cGy to 1000 cGy). The study carried out at Defence Laboratory to evaluate different characteristics of the PIN diode as a neutron dosimeter has been presented.

Keywords: Neutron sensor, PIN diode, Forward voltage, Sensitivity

1 Introduction

Semiconductor based silicon PIN diode, to detect and measure the fast neutrons irradiation in the personal dosimetry system, has been developed by Defence Laboratory, Jodhpur. The device is basically a wide base p+ n n− conductivity modulated silicon diode that responds to the fast neutron in the range 1 cGy to 1000 cGy with dual sensitivities.

Properties of a semi-conductor depend on carrier concentration and crystal defects are susceptible to radiation damages. General processes such as electronic processes and elastic collisions are responsible for radiation damage in semiconductor. The idea behind detection principle is that, when fast neutrons interact with wide base, energy loss takes place due to elastic collision between incident neutrons and silicon lattice atoms which causes displacement of atoms from its original position. The displaced atom is known as an interstitial atom and the position left behind is called a vacancy. The interstitial and vacancy together are referred to as a frankel pair. The neutron interaction cause displacement damages or lattice defects, called frankel defects in lattice structure. These defects increase the density of recombination centers in band gap of semiconductor which causes reduction in lifetime of minority carrier, injected into base region. This reduction in lifetime causes increase in resistivity of intrinsic layer. When constant current is passed through PIN diode, forward voltage across diode increases and change in forward voltage is measure of neutron dose. Change in life time is governed by the following equation:

\[ \tau = \tau_0/(1 + K \tau \Phi_0) \]

where \( \tau \) is the Post dose carrier lifetime, \( \tau_0 \) the predose carrier lifetime and \( \Phi \) the neutron influence. \( K \) is damage coefficient and depends on neutron energy, type of radiation and is independent on predose and postdose minority carrier lifetime.

2 Experimental Details

Characteristics evaluation of the neutron sensitive PIN diodes has been carried out against the fast neutrons radiated from Californium-252 source. The physical view of Cf-252 source camera is shown in Fig. 1. It is a mechanically driven source. Source inside camera can be lifted at any desired position using mechanical pulley system from outside of source room.

Diodes are exposed by neutron irradiation at 6 cm from source position and irradiation time for any predetermined dose can be calculated mathematically. To expose PIN diodes, a special wooden stand was designed and fabricated. Figure 2 shows half circular cylindrical structure of wooden stand used for exposure.

Before the exposure forward voltage of PIN diodes was measured using constant current source of 100 mA (Make: PLA, Model 15D) shown in Fig. 3. Thereafter, diodes were irradiated to different neutron doses using specially designed wooden stands. Due to neutron irradiation, forward voltage across PIN diodes increases. Post radiation forward voltage of PIN diodes is again measured at 100 mA constant current. Increase in forward voltage of PIN diode is measure of neutron dose.
3 Results and Discussion

Fabricated PIN diodes have been randomly selected from received batches and evaluated for parameters like forward voltage, linearity with neutron dose, sensitivity to neutron and gamma and fading. These diodes have been tested for entire dose range (1 to 1000 cGy). Exposed diodes have shown good linearity against neutron exposure in terms of forward voltage. Fabricated PIN diodes exhibited dual slope with neutron dose.

After experimental work and data analysis conducted on different batches of PIN diodes, following parameters were analyzed and discussed:

- PIN diodes shows forward voltage in the range 830-880 mV at constant current of 100 mA.
- Fabricated PIN diodes have exhibited dual sensitivity after neutron irradiation in ranges up to 400 cGy and 400-1000 cGy.
- PIN diodes have been evaluated for their gamma response. Diodes have been exposed up to a...
cumulative dose of 0.5, 1.0 and 2 kGy using calibrated Gamma Source (GC-4000). The Gamma sensitivity of PIN diodes has been found to be 0.0002 mV/cGy, which is almost negligible. The observations are quite obvious as interaction of gamma with Si matrix is totally different as compared to interaction of fast neutrons (Figs 4 and 5).

Figure 6 shows that percentage fading below 100 cGy neutron dose is within 20% whereas above 100 cGy is within 5%. Fading percentage below and above 100 cGy is within desired limit. The change in the forward voltage after neutron exposure below 100 cGy has very small measurable value which affects the statistical uncertainty. Therefore, while computing the percentage fading below 100 cGy indicates higher value of fading percentage as compared to neutron doses above 100 cGy.

4 Conclusions
The parametric evolution and characterization of silicon PIN diode as fast neutron dosimeter developed by us have been carried out. After evolution, it has been found that developed diodes fulfill basic
dosimetric needs like compactness, linearity, high sensitivity to neutron and insensitivity to Gamma, and extremely low fading.

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References