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RADIATION DAMAGE EFFECTS IN STANDARD FLOAT ZONE SILICON DIODES

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ABSTRACT

The aim of this work was to study the radiation damage effects on the electrical properties of standard float zone diodes (STFZ). Such effects were evaluated by measuring the current and capacitance of these devices as a function of the reverse voltage. For comparison, current and capacitance measurements were carried out with a non-irradiated STFZ device. The irradiation was performed in the Radiation Technology Center (CTR) at IPEN-CNEN/SP using a ^{60}Co irradiator (Gammacell 220 – Nordion) with a dose rate of about 2.2 kGy/h. Samples were irradiated at room temperature in steps variable from 50 kGy up 140 kGy which lead to an accumulated dose of 460 kGy. The results obtained have shown that the upper dose limit for a “damageless” STFZ diode is about 50 kGy.

1. INTRODUCTION

The widespread use of silicon detectors in high energy physics experiments has pushed researches through the development of devices with high tolerance towards radiation damage [1-2]. Among several damage effects that spoil the detector response, it has been shown that the major drawback is the increase of both the leakage current and the full depletion voltage of the device with the accumulated dose.

Therefore, measurements of these steady-state electrical characteristics of irradiated detectors are an important tool to quantify the upper dose limit in order to predict their long term stability under severe irradiation environment.

Studies have been shown that high oxygen concentration into the bulk silicon improves the tolerance towards radiation damage [3]. However, such devices are more expensive than the devices produced by standard float zone method (STFZ).

In order to evaluate the possibility of using STFZ diodes for high dose gamma dosimetry, it was investigated the radiation damage effect on the devices electrical properties, such as current, capacitance and full depletion voltage, after gamma radiation exposure.

2. EXPERIMENTAL SETUP

The STFZ diodes used, with active area of 25 mm^2, were processed on float zone Si wafer of 300 μm thickness and resistivity of 1.4 kΩ·cm. The device irradiation was performed in the Radiation Technology Center (CTR) at IPEN-CNEN/SP using a ^{60}Co irradiator (Gammacell 220 – Nordion) which delivers a dose rate of 2.2 kGy/h.

During the irradiation processes, the diode was connected through low-noise coaxial cables to the input of a KEITHLEY 617B electrometer, in order to monitor the device photocurrent as a function of the exposure time. The diode was irradiated at room temperature in dose steps variable from 40 kGy up to 460 kGy.

After each step of irradiation, current and capacitance measurements as a function of the reverse voltage were performed. For comparison, current and capacitance measurements were carried out previously with the non-irradiated STFZ device.

3. RESULTS

The diode irradiations were performed in four steps of accumulated dose of 40 kGy, 174 kGy, 314 kGy and 460 kGy. In each step of irradiation, the diode photocurrent signals were monitored as a function of the exposure time as can be seen in Fig. 1.

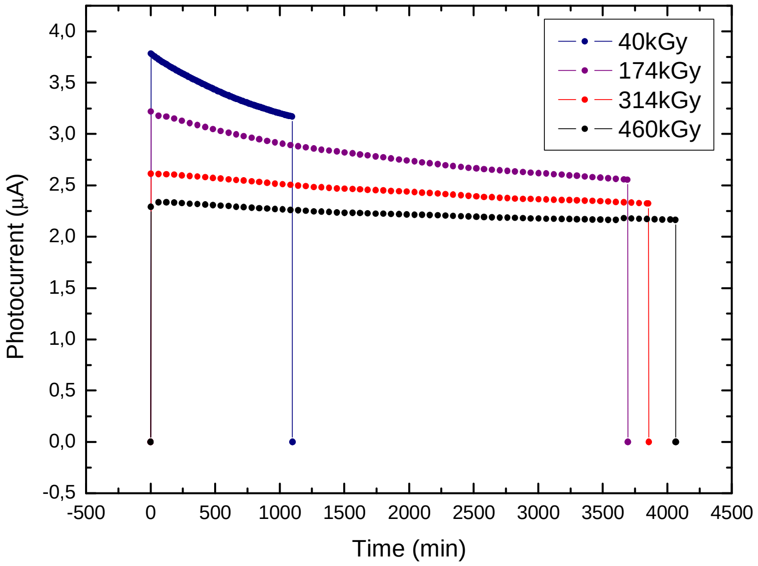

Figure 1. Photocurrent as a function of exposure time for each step.

As expected from previous work [4] the diode sensitivity decrease observed during the irradiation time was more pronounced in the low dose region. Furthermore, after being irradiated with 460 kGy the diode current response was almost stable despite of the drop of its sensivity. Indeed, the current signal decrease observed in the dose range of 40 kGy to 460 kGy was about 43%.

To study the influence of this effect on the electrical characteristics of the diode after each step of irradiation, measurements of the dark current and capacitance were carried out as a function of the reverse voltage at room temperature. The known temperature effect [3] on the dark current data was corrected adopting 20ºC as the reference temperature.

The results obtained for IxV and CxV are presented in Fig. 2 and Fig.3, respectively. For comparison, in Fig.2 it is also presented the IxV results obtained with the STFZ diode before the irradiation (0 kGy).

The analysis of the Fig.2 evidences that the dark current increases with the accumulated dose due to the defects presented in the bulk of the device. These defects can be play as trapping center and moreover, they also can emit alternatively electrons and holes which leading to the increase of the dark current [2].

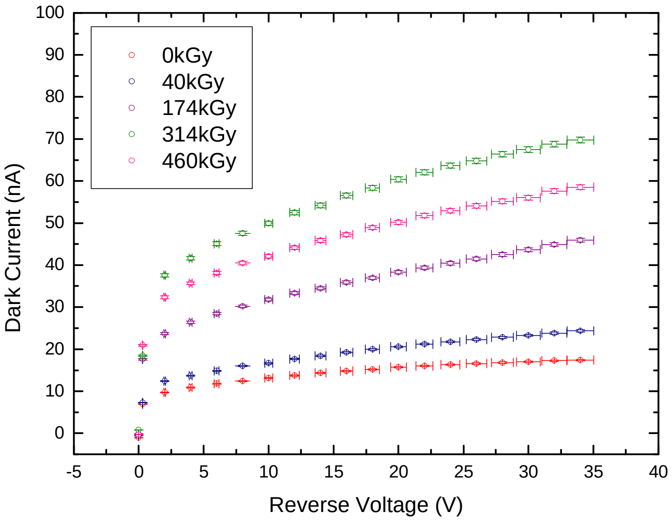

Figure 2. Dark current of the diode as a function of reverse voltage.

The CxV curve depicted in Fig.3 shows the typical dynamic capacitance response of junction diodes due to the increase of the depletion layer thickness with the reverse voltage. As can be seen in Fig. 3, the results obtained with the diode irradiated at different accumulated doses agree within the experimental errors. These results are confirmed in Fig. 4 where are presented the full depletion voltage, obtained from the CxV curves, as a function of the accumulated dose.

From Fig. 4, it is possible to conclude that there is no change in the full depletion voltage of the STFZ diode even when it is irradiated with doses up to 460 kGy.

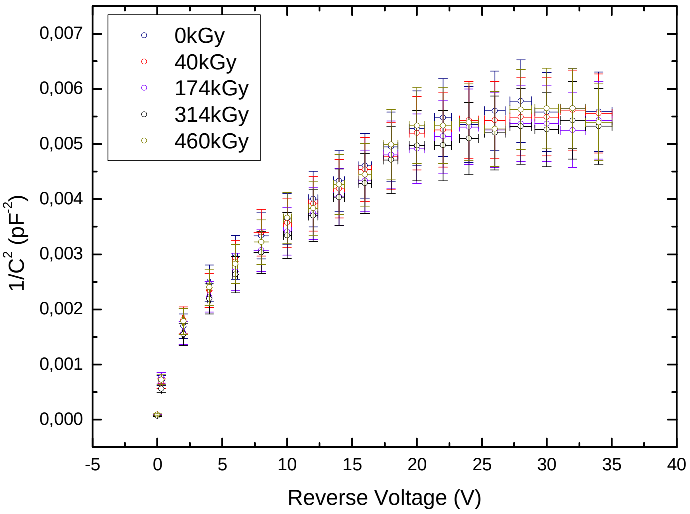

Figure 3. Variation of the diode capacitance as a function of reverse voltage.

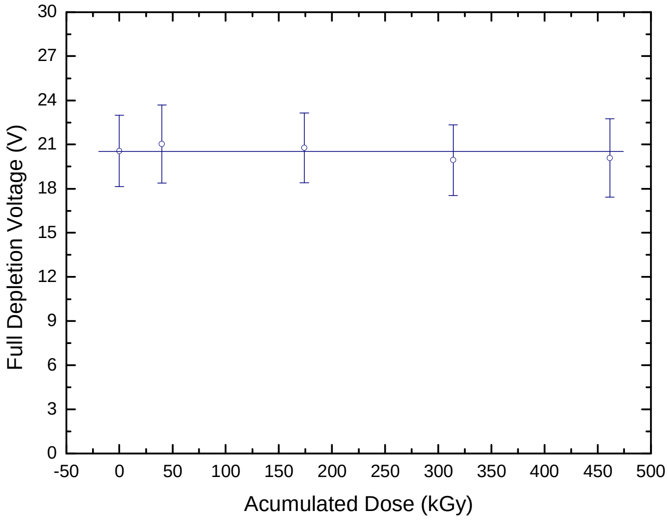

Figure 4. Full Depletion Voltage as a function of the accumulated dose in the device.

3. CONCLUSIONS

The preliminary results show that the STFZ diode dark current increases as a result of the radiation damage effect produced by gamma rays from ^{60}Co sources. Conversely, it was not observed any change on capacitance and full depletion voltage of the diode irradiated with accumulated doses up to 460 kGy. This result indicates that this device is a good candidate for semiconductor dosimetric applications in harsh radiation environment.

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