Gamma-Radiation Dosimetry with Magnetic Czochralski Silicon Diode

F. Camargo, J. A. C. Gonçalves, H. J. Khoury, E. Tuominen, J. Harkönen and C. C. Bueno

***Abstract*–This work presents the preliminary results obtained with a rad-hard MCz silicon diode as a high-dose gamma dosimeter. This device is a $p^+/n/n^+$ junction diode, made on MCz Si wafer manufactured by Okmetic Oyj., Vantaa, Finland and processed by the Microelectronics Center of Helsink University of Technology. The results obtained about the photocurrent registered and total charge accumulated on the diode as a function of the dose are presented. The dosimetric response of the device has shown a good linearity within the dose range of 500 Gy to 6 kGy.**

I. Introduction

Despite of the small leakage current, moderate capacitance and thin dead layers exhibited by silicon diodes, the low tolerance to radiation damage of these devices imposes constraints on their applicability in harsh environments such as those found in high energy physics (HEP) experiments [1]. This requirement brought to a deep and broad research to enhance the radiation tolerance of semiconductor detectors. Among several approaches to perform this task, it was developed, in the framework of CERN RD50 Collaboration, a high resistivity magnetic Czochralski (MCz) Si detector which is a good candidate for improved radiation hardness [2]. This device is a $p^+/n/n^+$ junction diode, made on MCz Si wafer manufactured by Okmetic Oyj., Vantaa, Finland and processed by the Microelectronics Center of Helsink University of Technology [3], [4]. The rad-hard property of this device led us to investigate whether it can be applied in gamma radiation processing dosimetry [5].

This work presents the preliminary results obtained with this rad-hard MCz silicon diode as a high-dose gamma dosimeter. The article is outlined as follows: the experimental setup and procedure utilized to study the response of the diode as a high dose gamma dosimeter are described in section 2. The results obtained and discussion about the photocurrent registered and total charge accumulated on the diode as a function of the dose are presented in section 3. The last section is reserved for conclusions.

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II. Material and Methods

The MCz diode investigated was processed out of n-type bulk material with 300 µm thickness and active pad implanted area of 5×5 mm^2. The device is a $p^+/n/n^+$ junction with a multiple guard ring (MGR) structure around the contact pads as can be seen elsewhere [5]. To provide protection of this device from sources of mechanical stress, light and moisture, it was placed inside a light-tight plastic container (black PMMA), as showed in Fig. 1.

Fig. 1. Photographs of the plastic container for diode MCz.

In order to study the MCz diode's dosimetric response, its guard rings were left floating while the front p^+ and back n^+ sides were connected, in the photovoltaic mode, to the input of a 189 Fluke multimeter. The data were acquired with the software FlukeView® Forms (time resolution = 1 s).

Gamma irradiations were performed at room temperature (25ºC) at a gamma facility, ^{60}Co-Gammacell 220 (MDS Nordion), with the dose rate of 2.69 kGy/h (traceability through the International Dose Assurance Services, from IAEA). The diode was placed in the central position of the Gammacell and the photocurrent was registered during the irradiation process. The current measured as a function of time, i.e. the current response curve, was related to the dose rate which enabled to verify the stability of the system during the process. Furthermore, the total charge generated in the sensitive volume of the diode, obtained through the integration of the respective current response curves, was related with the total dose in the range of 500 Gy up to 6 kGy.

A schematic diagram of the experimental setup used during the measurements is showed in the Fig. 2.

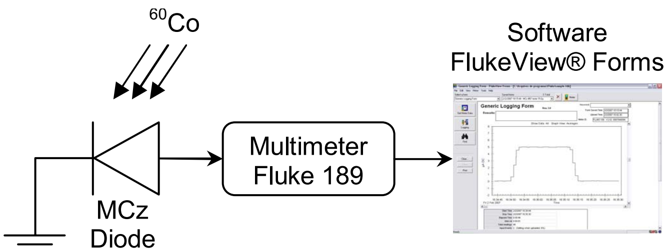

Fig. 2. Schematic diagram of the experimental setup.

III. Results

Dynamic current and capacitance measurements of the device were performed at a voltage range between 0 and 500 V. Leakage current of the unbiased diode at room temperature was ~ 5 pA. The capacitance results obtained [5] showed that for voltages above 305 V the capacitance does not changes significantly and the diode is fully depleted (~ 300 µm).

During the preliminary studies the diode was exposed at accumulated dose of about 353 kGy. The radiation-induced current of the unbiased MCz diode under 0.5 and 6.0 kGy of total doses are shown in Fig. 3.

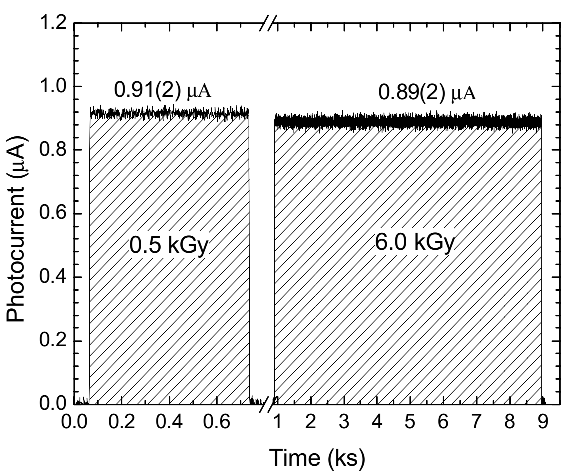

Fig. 3. MCz diode photocurrent as a function of time for 0.5 and 6.0 kGy of total doses. Time resolution of multimeter was 1 s.

As can be seen in Fig. 4, the average photocurrents (~ 0.9 µA) measured in the range of total doses from 500 Gy to 6 kGy were fairly stable with a expanded uncertainty less than 3%. Furthermore, the current signal was about 10^6 higher than the leakage current of the device.

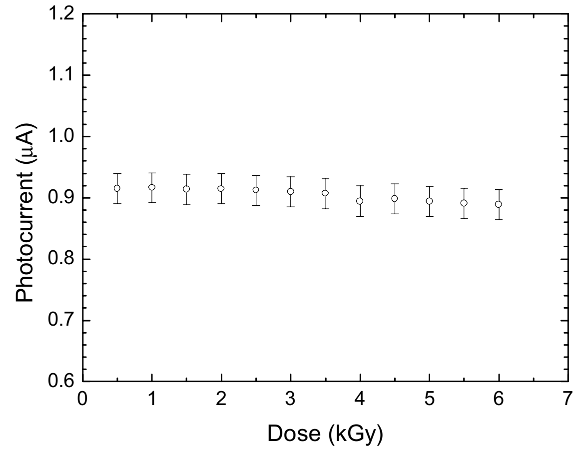

Fig. 4. Photocurrents measured in the range from 500 Gy to 6 kGy for MCz diode.

The relation between the accumulated dose and the charge generated by the γ-radiation was accomplished through the integration of the current response of the device as a function of the time. These results yielded the dosimetric system calibration curve presented in Fig. 5, which exhibited good linearity. However, it still remains to be investigated the reproducibility and reliability of the MCz diode measurements as well as the radiation damage related to higher total doses. These studies are under way.

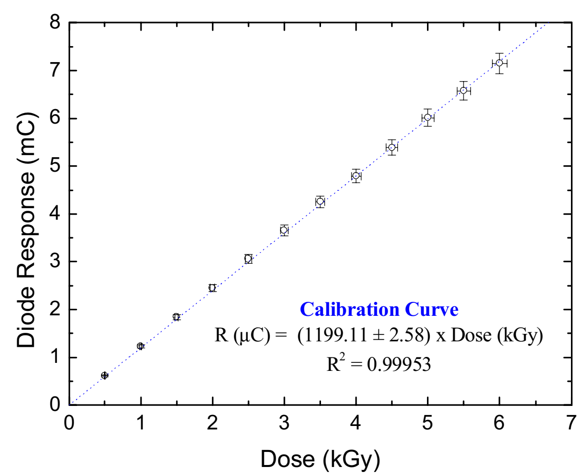

Fig. 5. Dosimetric calibration curve for MCz diode.

IV. Conclusions

Despite of being preliminary, these results have shown that the MCz diode can be applied for high gamma dose dosimetry. The current signal obtained for a dose rate of 2.69 kGy/h is stable during the irradiation tests even under a total dose of 6 kGy. Furthermore, the dosimetric response of the device has shown a good linearity within the dose range of 500 Gy to 6 kGy.

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