2007 International Nuclear Atlantic Conference - INAC 2007
Santos, SP, Brazil, September 30 to October 5, 2007
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-02-1

PERFORMANCE OF MCz SILICON DIODES IN GAMMA-DOSIMETRY

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ABSTRACT

In this work, it is presented the preliminary results obtained with a rad-hard magnetic Czochralski (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 5 Gy to 3.5 kGy.

1. 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]. The rad-hard property of this device led us to investigate whether it can be applied in gamma radiation processing dosimetry.

In this work, it is presented 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.

2. EXPERIMENTAL ARRANGEMENTS

The MCz diode investigated was processed out of n-type bulk material with 300 μm thickness and active area of 36 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 in Fig. 1. To provide protection of this device from sources of mechanical stress and light, it was placed inside a light-tight plastic container, as showed in Fig. 2.

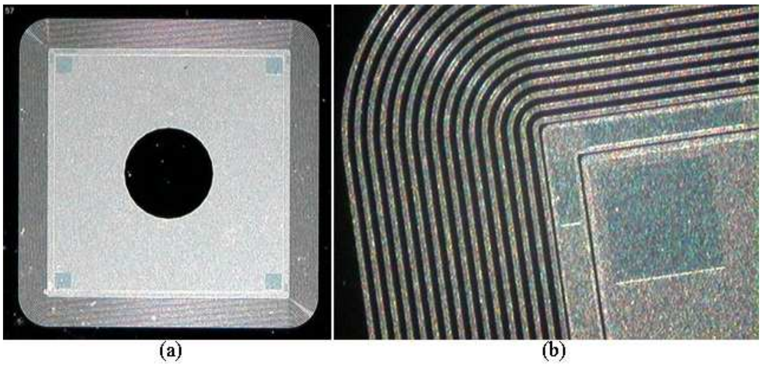

Figure 1. The MCz diode photographs. (a) General view. (b) Detail of MGR structure and pads.

Figure 2. 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 an electrometer Keithley 617. The dark current of this system, measured at room temperature, was about 3.5 pA. Gamma irradiations were performed at room temperature (25ºC) at a gamma facility, ^{60}Co-Gammacell 220, with the dose rate of 2.94 kGy/h (rastreability 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 5 Gy up to 3.5 kGy.

3. RESULTS

The photocurrent generated in the unbiased MCz diode due to its irradiation with ^{60}Co gamma sources, at a dose rate of 2.94 kGy/h, was measured during the time of exposition. Current versus time curves obtained within the dose range of 5 Gy to 3.5 kGy showed that the current signal was stable and about 10^6 higher than the dark current of the diode. Indeed, as can be seen in Fig. 3, which corresponds to a 100 Gy of total dose, the average radiation-induced current was almost constant and about 4.7 μA. Since the dosimetric parameter to be related with the total dose is the charge accumulated in the diode, all current response curves were recorded and further integrated.

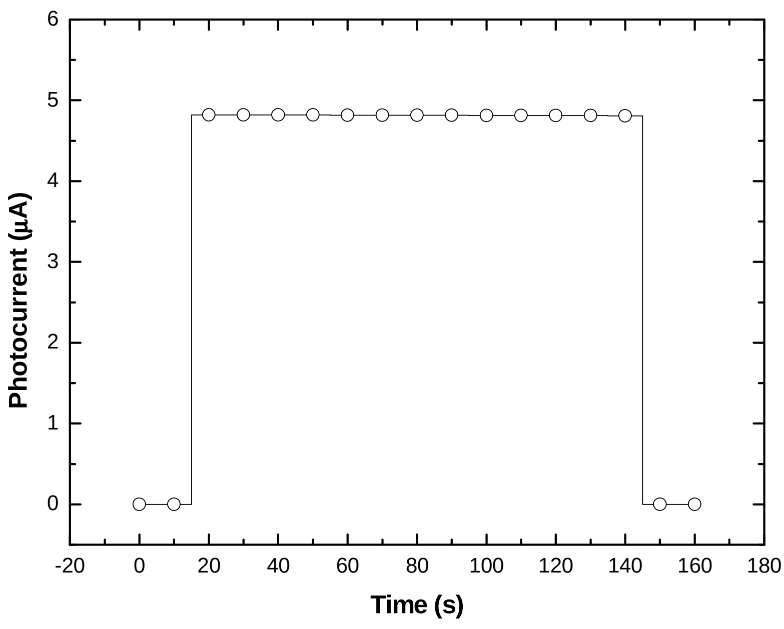

Figure 3. MCz diode photocurrent as a function of time for 100 Gy dose. The electrometer time resolution used was 10 s.

The charge accumulated in the MCz diode as a function of the gamma-ray doses is presented in Fig. 4, which shows a linear behavior within the dose range of 5 Gy to 3.5 kGy. It should be point out that these results are preliminary what has required more investigation about the response reproducibility and the dose range of operation of this device without radiation damage effects. These studies are under way.

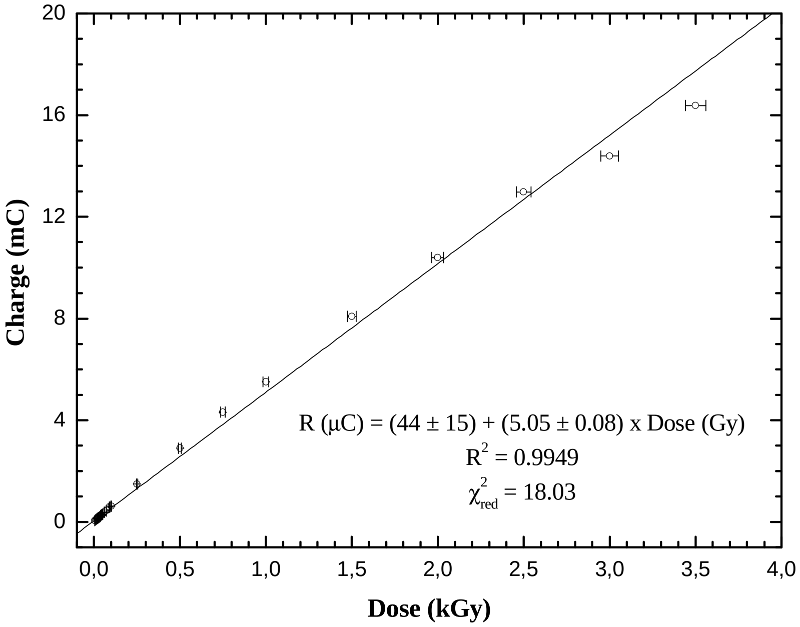

Figure 4. MCz diode response as a function of doses at room temperature.

4. 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 2.94 kGy/h is stable during the irradiation tests even under a total dose of 3.5 kGy. Furthermore, the dosimetric response of the device has shown a good linearity within the dose range of 5 Gy to 3.5 kGy.

ACKNOWLEDGMENTS

F. Camargo is grateful to FAPESP for the award of scholarship. This work was supported by FAPESP (project 03/12720-6) and partially by CNPq (contract 303138/2006-8).

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