Evaluation of silicon dosimetry parameters in Co-60 gamma irradiation facilities

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Abstract. This work presents the preliminary results of a dosimeter based on SFH00206 (Siemens) diode for gamma radiation dosimetry from 1 Gy up to 100 Gy. The diode operated in the photovoltaic mode and the current signals as a function of the exposure time were stable and linearly dependent on the dose rate with a sensitivity of 9.43 $nA.Gy^{-1}.min$. The dosimetric response of the diode, characterized by the generated charge versus the absorbed dose, is linear within the dose range investigated.

Keywords: **Semiconductor diodes**, **Dosimetry, Gamma Irradiation Facilities.**
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INTRODUCTION

The proved efficiency of radiation processing in medical devices sterilization and food preservation has contributed for a widespread use of gamma radiation in industrial applications. In this field, the radiation dosimetry is of uttermost importance for accurately measuring the dose absorbed by the product and for the process validation within the regulatory standards [1-2]. Dosimeters of polymethylmetacrylate (PMMA) are widely used in routine dosimetry, but its limited lower range [3-4] has constrained their application in “low” doses radiation processes such as polymer crosslinking, crystal modifications, biological studies and so on. Although these irradiation procedures are quite well established, there is a lack of on-line dosimeters which can measure doses lower than 100 Gy. This fact motivated us to develop a dosimeter probe based on a commercial low cost Si photodiode for gamma radiation dosimetry from 1 Gy up to 100 Gy [5] and evaluate its response to Co-60 gamma irradiation facilities.

MATERIALS AND METHODS

The device under investigation is a photodiode type PIN model SFH-00206 manufactured by Siemens. The diode, with an active area of 7.3 mm^2 and capacity of 72 pF at 0 V, was encapsulated in a polymer plastic of 1.2 mm thickness. The device’s electrodes were directly soldered at a 3 m long coaxial cable of 50 Ω impedance. The temperature during the irradiation was monitored with a thermocouple type K, tightly

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attached to the diode's surface. This assembly was covered with 3 mm polyurethane and housed in an acrylic (PMMA) pipe with 270 x ∅ 12.5 mm. Finally the probe was involved with an insulating tape to protect the diode from the visible light and to increase the probe's resistance to mechanical damages. The dosimetric probe, presented in Figure 1, was connected in a photovoltaic mode to the input of a Keithley 617 electrometer with adjustable time resolution. Four Co-60 gamma facilities of IPEN-CNEN/SP were used in this work: a irradiator Type I (Gammacell-220 - Atomic Energy of Canada Limited) and three panoramic irradiators Type II (Gammatron – Siemens AG, Panoramic – Yoshizawa Kiko Ltd and Multipurpose). The temperature during the irradiation was 22ºC ± 1ºC.

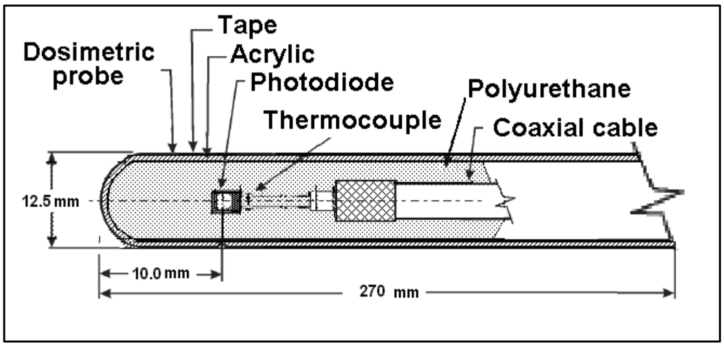

FIGURE 1 : Dosimetric probe.

RESULTS

The photocurrent generated in the sensitive volume of the diode as a function of exposure time to gamma-rays from irradiator Gammacell-220 (dose rate of 39.83 Gy/min) is shown in Figure 2. It is observed that current signals are very stable during the gamma irradiation for doses up to 100 Gy. Results obtained with a dose rate of 12 Gy/min, obtained in the Gammacell-220 with a 70 % attenuator, are presented in Figure 3.

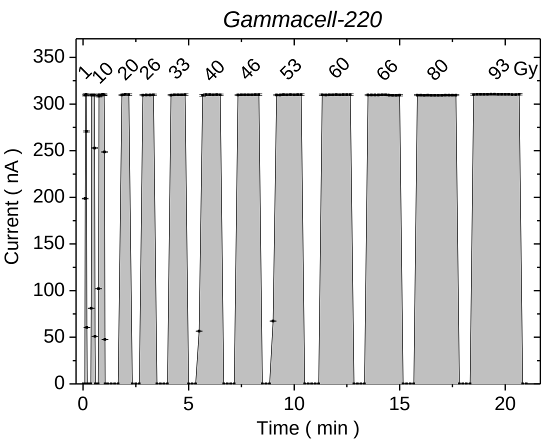

FIGURE 2. Current signal as a function of exposure time for dose rate 39.83 Gy/min.

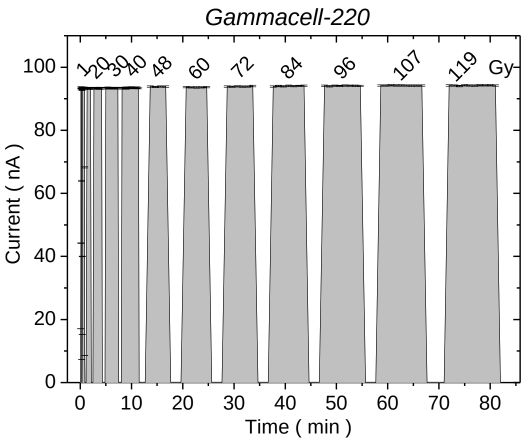

FIGURE 3. Current signal as a function of exposure time for dose rate 12 Gy/min.

The dosimetric probe was also tested in the Panoramic and the Gammatron irradiators with geometries completely different from the Gammacell-220. As in those facilities the reduction of dose rate is obtained by increasing the distance from the probe to the source, dose measurements were carried out at distances of 10 and 100 cm, which correspond to dose rates of 3.42 and 0.06 Gy/min, respectively. In such conditions, it was observed a reduction on current signals from 32.2 to 0.64 nA, as can be seen in Figures 4 and 5. Both Figures evidencing that the current signals were very stable during the irradiation with different dose rates. It is also noted that to reach the same absorbed dose, the exposure time for 0.06 Gy/min was longer than the one required for 3.42 Gy/min.

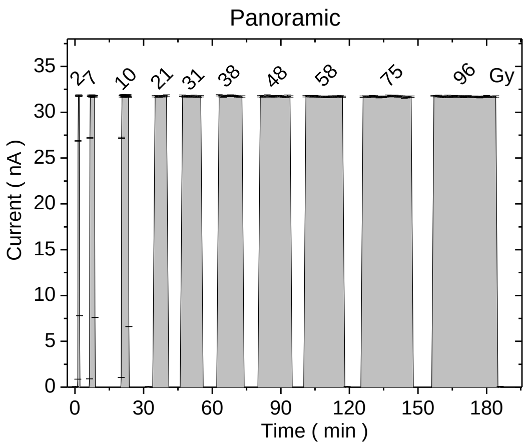

FIGURE 4. Current signal as a function of exposure time for dose rate 3.42 Gy/min.

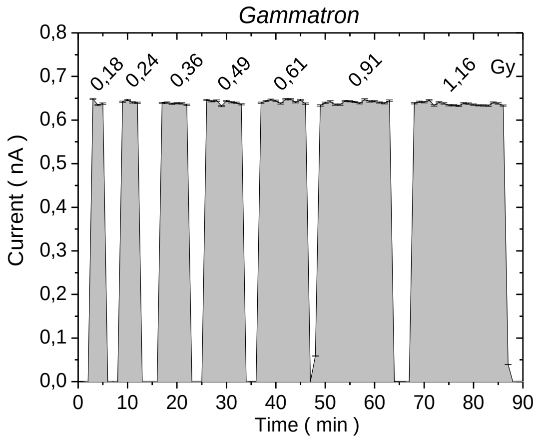

FIGURE 5. Current signal as a function of exposure time for dose rate 0.06 Gy/min.

The diode photocurrent generated by the gamma rays from Co-60 as a function of the doses rate within the range of 0.06 to 192 Gy/min is presented in Figure 6. In order to achieve the widest dose rate range possible, all gamma facilities (Multipurpose, Gammacell-220, Panoramic and Gammatron) at IPEN-CNEN/SP were used in these measurements. As can be seen in the Figure 6, the device response is linear with a current sensitivity of 9.43 $nA.Gy^{-1}.min$.

The dose response of the diode presented in Figure 7 was obtained through the integration of the recorded current signals versus exposure time as a function of the total absorbed dose. The average calibration curve, obtained with the different dose rates delivered by Gammacell-220, Panoramic and Gammatron facilities, shows a linear dependence of the generated charge on the total dose, with a correlation coefficient of 0.998. It is worth noting that the calibration curve obtained with different dose rates is coincident within the experimental errors.

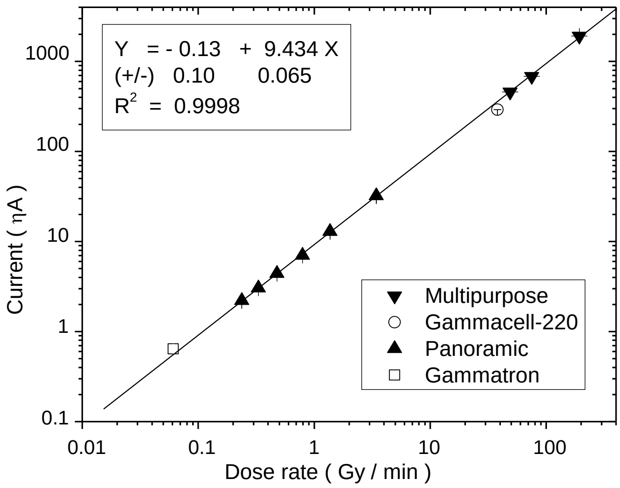

FIGURE 6. Current sensitivity versus dose rate.

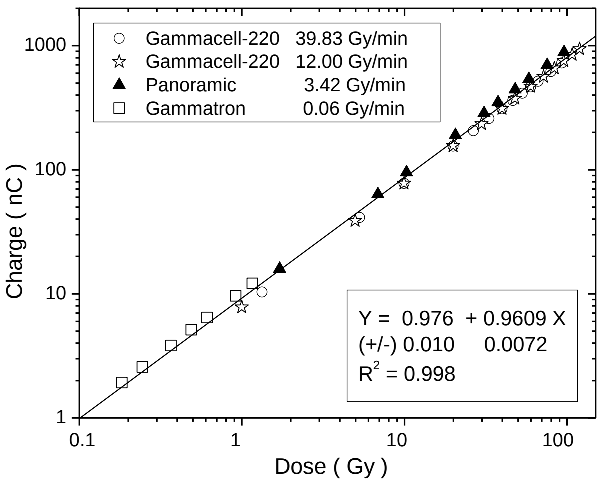

FIGURE 7. The dose response curve of the diode.

CONCLUSIONS

The results obtained with the SFH00206 diode, operating in a photovoltaic mode, have shown stable current signals during gamma irradiation with Co-60. The device dosimetric response, given by the accumulated charge in the diode as a function of the absorbed dose, was linear (correlation factor of 0.998) for doses up to 100 Gy. The total independence of the diode sensitivity (9.43 nA.Gy^{-1}.min) with dose rates from 0.06 to 192 Gy/min allied to the current signals stability during the exposure times indicates that the SFH00206 diode can be used for dosimetric purposes in irradiation processes that involve absorbed doses up to 100 Gy.

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