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PANORAMIC IRRADIATOR DOSE MAPPING WITH PIN PHOTODIODES

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ABSTRACT

In this work we study the possibility of using commercial silicon PIN photodiodes (Siemens, SFH 00206) for dose mapping in the Panoramic Irradiator facility at IPEN-CNEN/SP. The chosen photodiode, that is encased in 1.2 mm thickness polymer layer, displays promising dosimetric characteristics such as small size (sensitive area of 7.00 mm^2), high sensitivity and low dark current ($\cong$ 300 pA, at 0 V) together with low-cost and wide availability. The Panoramic facility is an irradiator Type II with absorbed dose certificated by International Dose Assurance Service (IDAS) offered by the International Agency Energy Atomic (IAEA). The charge registered by the diode as a function of the absorbed dose was in excellent agreement with that one calibrated by IDAS. Besides this, the easy handling and fast response of the SFH00206 diode compared to Fricke chemical dosimeters encouraged us to perform dose mapping around the source.

1. 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 [1-3]. The measurement of absorbed dose by routine dosimetry system in industrial irradiation facilities should be traceable to national or international standards laboratory. The Laboratory of Dosimetry in Irradiation Processes (LDPI) at Center of Radiation Technology (CTR) - IPEN/CNEN-SP meets the qualifications required by the International Atomic Energy Agency (IAEA) for calibrations of routine dosimeters system through the use of techniques submitted to the International Service Assurance Dose (IDAS) [4-5]. The Fricke chemical dosimeter is well established as reference standard dosimeter for certifying absorbed dose of the Panoramic Co-60 irradiator (IPEN/CNEN-SP), but time-consuming to prepare and has very large size for precise positioning [6]. The necessity of providing the dose mapping in the Panoramic irradiator for Facility Qualification allied with the possibility of improving the irradiation processes motivated us to use SFH00206 diodes as on-line dosimeters [7-10].

2. MATERIALS AND METHODS

The dosimeter was constructed by using a commercial Si photodiode type PIN model SFH-00206 manufactured by Siemens. The diode, with an active area of 7.00 mm^2 and dark current (≅ 300 pA, at 0 V), was encased in 1.2 mm thickness polymer layer. The terminals were soldered at a 20 m long coaxial cable of 50 Ω of impedance. The diode was involved with 2 mm layer of polyurethane and placed inside of an acrylic pipe 170 x Ø 8 mm. This probe was projected to facilitate handling, prevent the influence of the visible light, humidity and increase the resistance to mechanical damages. Each Si diode was connected in the photovoltaic mode to the input of a Keithley 617 electrometer with adjustable time resolution (Figure 1a). The Panoramic facility (Yoshizawa Kiko Ltd) positioned in the center of a room with six square meters is show in Figure 1b. The Co-60 source is exposed remotely in the center of a table which has five places where there are five positions with absorbed dose certificated by IDAS offered by the International Agency Energy Atomic. This irradiator delivers dose rates in the range of 14.2 – 147.6 Gy/h.

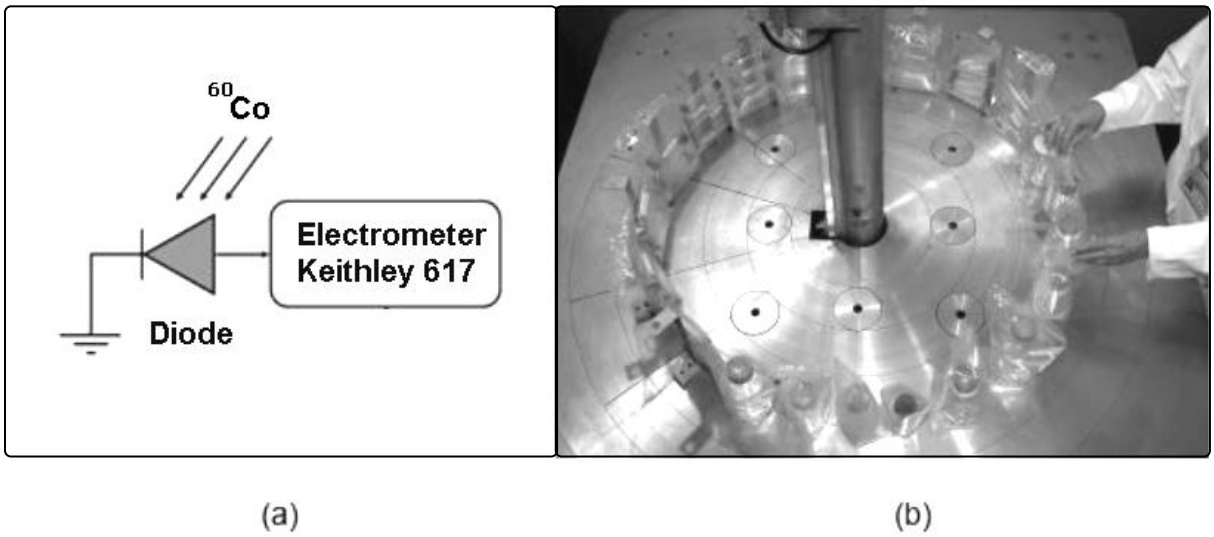

Figure 1. a) Connection diode-electrometer b) Panoramic facility.

3. RESULTS

The photocurrent generated in sensitive volume of the photodiode as a function of exposure time to gamma-rays from irradiator Panoramic is shown in Figure 2 for a dose rate of 147.6 Gy/h. It can be observed that current signals are very stable during the gamma-irradiation for doses up to 100 Gy. The dosimeter calibration curve was achieved by the accumulated charge in the diode, obtained through the integration of recorded current signals during a time interval, versus the total absorbed dose. The linear dependence of the generated charge on dose, with a correlation coefficient of about 0.998, is presented in Figure 3.

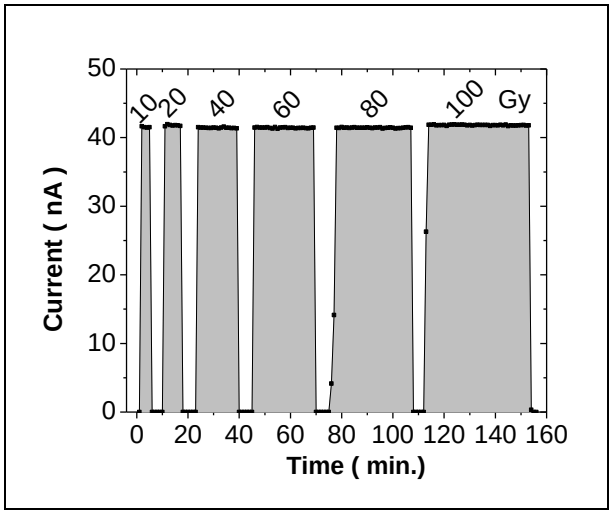

Figure 2. Current signal as a function of exposure time for a dose rate of 147.6 Gy/h

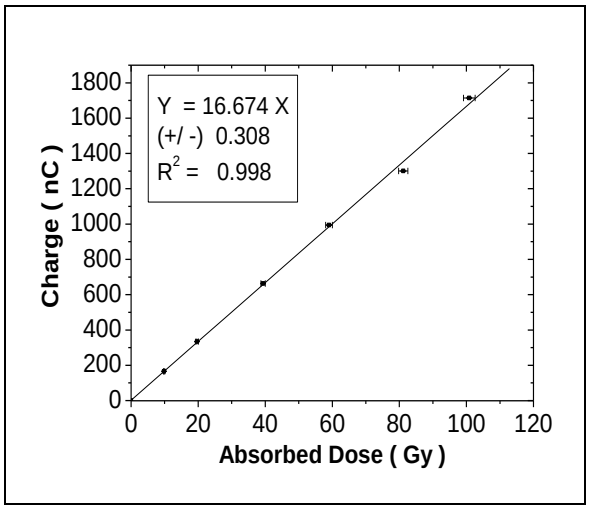

Figure 3. Calibration curve obtained for Panoramic Irradiator

3.1. Sensitivity

Due to the fact that in irradiator Type II a large number of geometric factors influences the field of radiation inside the room, each position of irradiation provides a single dose rate. As in Panoramic irradiator facility the reduction of dose rate is obtained mainly by increasing the distance from the probe to the source, the measurements were carried out at distances of 10 up to 50 cm. The diode photocurrents generated by gamma rays from Co-60 as a function of the dose rate within the range of 14.2 – 147.6 Gy/h are presented in Figure 4. The results showed a linear response of the dosimeter (correlation coefficient of 0.999) corresponding to a sensitivity of about 0.28 $nA.Gy^{-1}.h$. This behaviour encouraged us to perform dose mapping around the Panoramic Co-60 source.

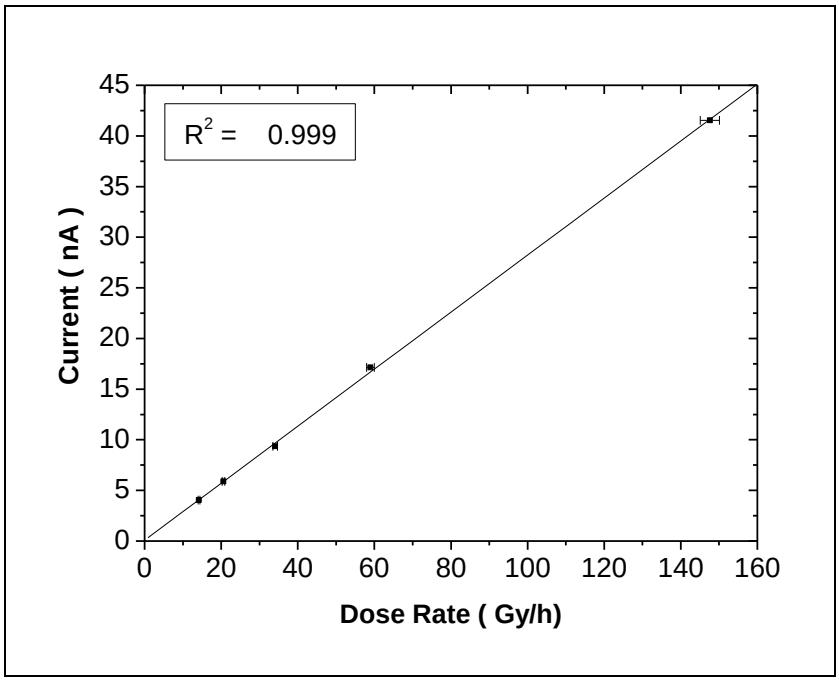

Figure 4. Sensitivity curve obtained for the Panoramic Irradiator.

3.2. Dose mapping

In radiation processing is important to know the distribution of the dose rate the most often positions used during the irradiation. In the ideal case, the dosimeter should be as small as possible in order to not disturb the radiation field and at the same time provides good spatial resolution. These conditions are satisfied by the SFH00206 photodiode. The distribution of dose with distance was made with the diode positioned 10 cm above the table, approximately half the height of Co-60 source. The doses absorbed were measured from 10 to 50 cm in positions previously certified (0º degree in table). The variation of accumulated charge (absorbed dose) as a function of distance presented in Figure 5 does not obey the law of the inverse square of the distance, mainly due to the large size of the source relative to the size of the diode, as well as the scattering of radiation inside the room.

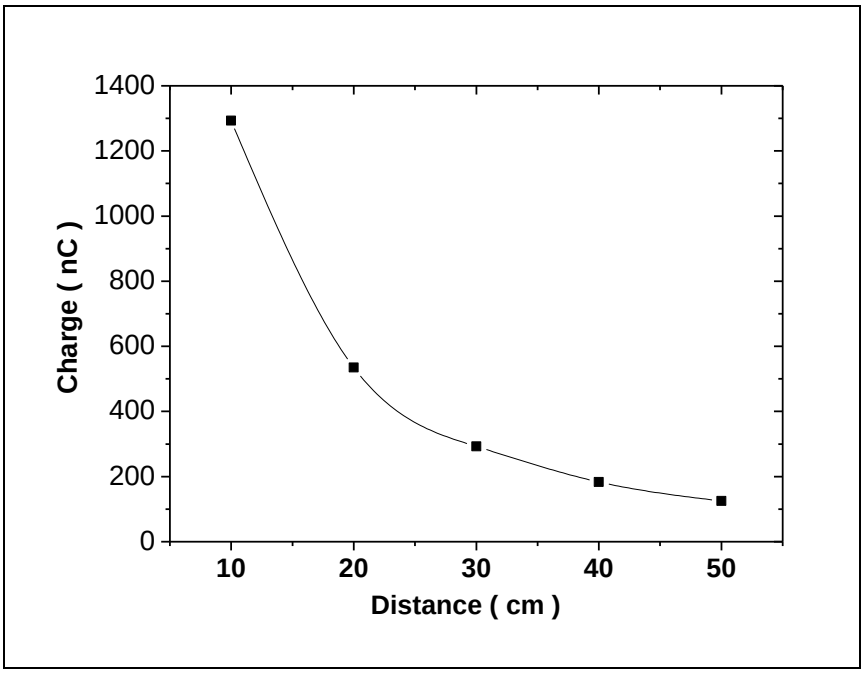

Figure 5. The distribution of dose with distance for the Panoramic facility.

The distribution of dose rate around the source was measured with the probe positioned 10 cm above the table and 10 cm distance the source. The diode rotated at angles of 9º degrees around the source on total scan angle of 360º degrees. It was observed that source emits radiation homogeneously across the table, unless between 135º and 225º degrees (Figure 6). Variation in shape of dose rate behind certified position (0 º degree) was expected due shielding of the elevator from Panoramic irradiator facility, which exposes the Co-60 source in center of table.

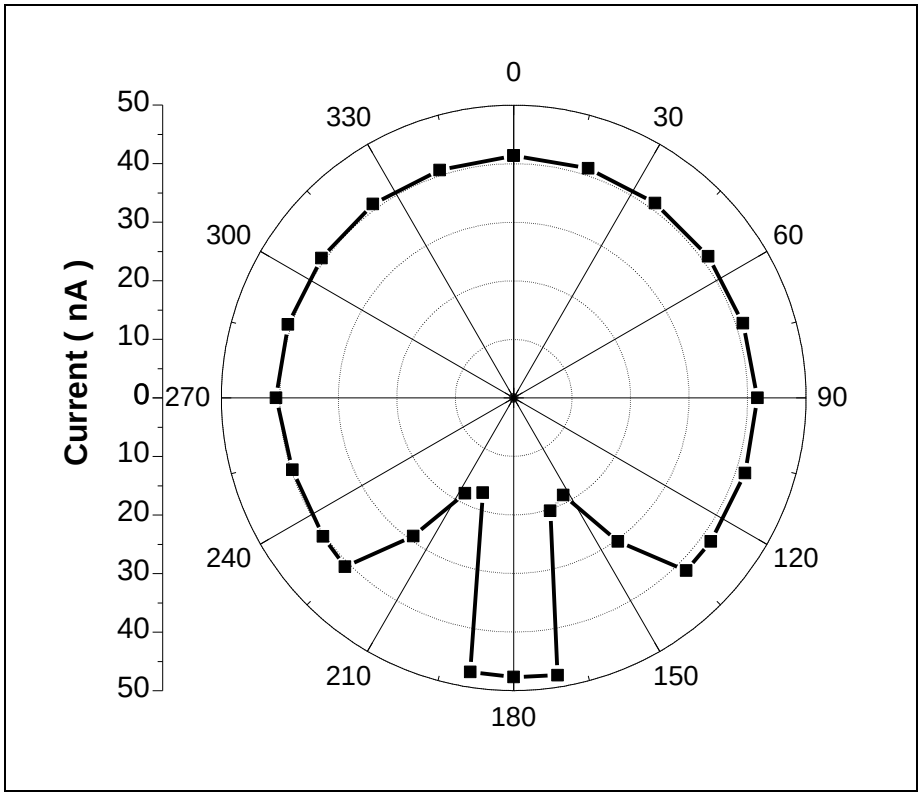

Figure 6. The distribution of dose rate around Co-60 source in Panoramic facility.

4. CONCLUSIONS

The results obtained with the SFH00206 diode, operating in the photovoltaic mode, have shown stable current signals during gamma irradiation at Co-60 Panoramic facility. The device dosimetric response, given by the accumulated charge in the diode as a function of the absorbed dose, was linear for doses up to 100 Gy. The current registered by the diode was in excellent agreement with dose rate calibrated.

The dosimeter presented fast response and easy handling, than those obtained by chemical Fricke dosimeter. This system will provide information for certification absorbed doses by secondary laboratory inside Panoramic Irradiator so improving information for Facility Qualification and irradiation processes validation.

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