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COMPARATIVE EVALUATION OF THE PERFORMANCE OF THIN DIODES USED AS ON-LINE DOSIMETERS IN RADIATION PROCESSING APPLICATIONS

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ABSTRACT

In this work, we report a comparison between the performance of two samples of commercial PIN photodiodes (SFH206K from Osram® and S2506-04 from Hamamatsu®) mainly addressing the variation of their current sensitivities with accumulated dose ranging from 0-15 kGy. All the results so far obtained have revealed that the radiation induced currents are linearly dependent on dose rates from 3.65 to 55.64 Gy/h. The current sensitivity of both unirradiated diodes (0.178 nA.h/Gy.mm^3) slightly decreases with accumulated dose, namely 0.32%/kGy (SFH206K) and 1.4%/kGy (S2506-04). Although the SFH206K device compares favorably with the S2506-04, both diodes can be considered as a low budge alternative, good enough for on-line dosimetry applications in the field of radiation processing.

1. INTRODUCTION

Silicon diodes have been widely used as relative dosimeters for clinical photon and electron beams in radiodiagnostic and radiotherapy applications [1-9]. Several authors [1,2,4,6] have reported that the sensitivities of these diodes, attainable through the slope of either dose rate or dose response curves, exhibit a non-negligible dependence on the accumulated dose due to the onset of radiation damage effects. Such effects are mainly responsible for the production of traps and generation-recombination centers in the silicon bulk, which manifest themselves in both the dark current growth and the decay of the sensitivity with accumulated doses. These drawbacks are the most severe constraints for using silicon diodes in harsh radiation environment such as found in radiation processing applications. Nevertheless, our previous studies carried out with a PIN diode (SFH206K from Osram®) integrated in a dosimetry system developed for routine gamma process control have demonstrated that the decrease in the current sensitivity can be mitigated by using thin devices provided that no external voltage is applied [10].

On this assumption, the performance of another low-cost commercial thin diode (S2506-04 from Hamamatsu®) has been investigated mainly addressing the linearity and stability of its dose rate response with the accumulated dose. In this work, the degree of stability is assessed by the current sensitivity, which is a key parameter to predict the lifespan of the diode to be used as dosimeter in compliance with the requirements of ISO/ASTM 51702 [11] and ISO/ASTM 52628 [12]. In order to check whether the performance of the diode S2506-04 are comparable with that of the diode SFH206K, the experimental data gathered with the latter and previously published elsewhere [10] is presented herein as a reference.

2. MATERIALS AND METHODS

The diodes used in this work are both manufactured with a PIN structure and were chosen in the market of commercial photodiodes specially designed for detection of low energy photons. These devices are expected to feature suitable characteristics to allow them to be operated unbiased and in current mode, namely, to be rather thin with negligible entrance dead layer and to have very low leakage current and small capacitance at 0V. The diodes SFH206K and S2506-04 meet these requirements as can be seen in Table 1, where their dimensions and electrical characteristics are presented.

Table 1: Dimensions and electrical characteristics of the diodes

Diode	Area (mm^2)	Thickness (mm)	Dark Current @ 0.01V (pA)	Capacitance @ 0V (pF)
SFH206K - Osram	7.0	0.230	40	72
S2506-04 - Hamamatsu	7.7	0.300	80	60

The dose rate responses have been investigated with the diodes operating in short-circuit current mode without external applied voltage. Each of them is housed in a polymethilmetacrylate light-tight probe with the back electrode (n+) grounded and the signal electrode (p+) connected to the input of a Keithley 6517B electrometer.

The irradiations have been performed with gamma rays from a Co-60 Panoramic Irradiator (FIS 60-04, Yoshizawa Kiko Ltd), with dose rates extending from 3.65 to 55.64 Gy/h. Dose-rate calibrations were previously obtained with standard reference alanine dosimeters with an expanded uncertainty of 1.7% (k=2) traceable to the secondary standard laboratory at the International Atomic Energy Agency (IAEA).

The comparative evaluation of the online performance of both diodes is carried out by considering two relevant dosimetric parameters: the linearity between the current generated in the sensitive volume of the diodes as a function of the dose rate and how they resist to the radiation-induced damage. The latter is indirectly assessed through the variation of the current sensitivity, defined as the current per unit of dose rate, with the accumulated dose. As these parameters are interrelated, they are experimentally investigated through sequential measurements of the dose rate response of the same diode unirradiated (used as reference of 0 Gy) and preirradiated up to 15 kGy, fractioned in three steps of 5 kGy. The corresponding currents versus dose rate plots are used to comparatively analyze the influence of the accumulated dose on the linearity and the current sensitivity parameters on both diodes.

The combined uncertainties of the current measurements are calculated taking into account the contributions from the diode reading, the resolution and stability of the electrometer and the nominal dose-rate uncertainty. The expanded uncertainty is calculated using a coverage factor k=2, with a level of confidence of 95%.

3. RESULTS

The dose rate responses of the two diodes gathered prior of irradiation (0 Gy) and after accumulating 15 kGy fractioned in 5 kGy are shown in Fig.1 (SFH206K) and Fig. 2 (S2506-04). For comparative purposes, the data on currents attained with the diodes are given per unit of volume (nA/mm^3).

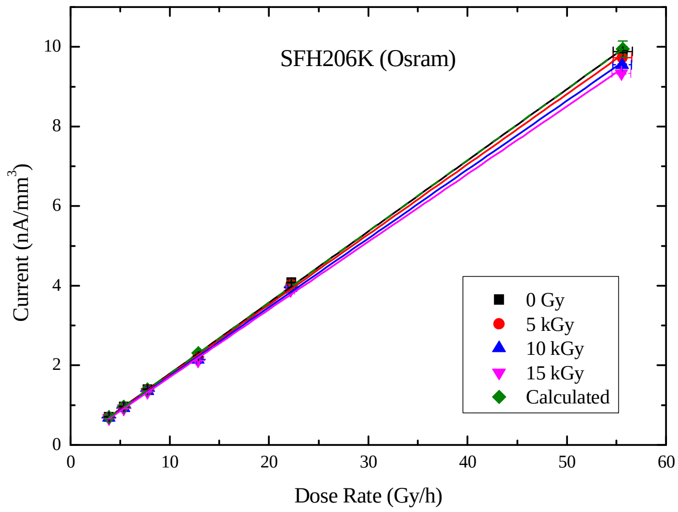

Figure 1: Dose rate responses of the SFH206K diode unirradiated (0 Gy) and preirradiated to 5kGy, 10 kGy and 15 kGy. For comparison, the calculated dose rate response is also presented.

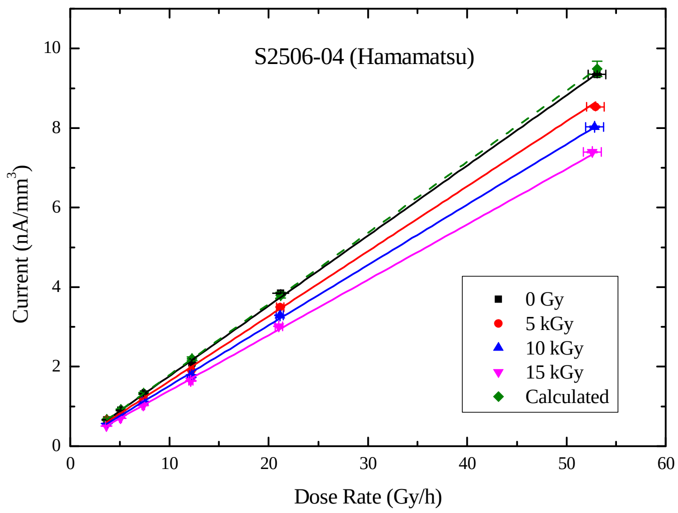

Figure 2: Dose rate responses of the S2506-04 diode unirradiated (0 Gy) and preirradiated to 5kGy, 10 kGy and 15 kGy. For comparison, the calculated dose rate response is also presented.

As can be seen in these figures, the radiation induced currents are linearly dependent on the dose rate within the range of 3.65 - 55.64 Gy/h, whichever the diode type and its accumulated dose history. Indeed, all dose rate response curves exhibit the same linear pattern alike those calculated through the equation deduced by Osvay and Tárczy [13] for the radiation induced current in a p-n junction. The agreement among calculated and experimental sets of data is found to be good but, as expected, is better for those obtained with unirradiated diodes. This result is consistent with the drop of the current sensitivity of both diodes with increasing accumulated doses as displayed in Table 2.

Table 2: Current Sensitivity (S_c) of SFH206K and S2506-04 diodes unirradiated and irradiated to 5, 10 and 15 kGy.

	SFH206K	**S2506-04**
Accumulated Dose (kGy)	**Current Sensitivity ($nA.h/Gy.mm^3$)**	**Current Sensitivity ($nA.h/Gy.mm^3$)**
0	0.178 ± 0.004	0.177 ± 0.004
5	0.176 ± 0.004	0.164 ± 0.004
10	0.173 ± 0.004	0.152 ± 0.003
15	0.171 ± 0.004	0.140 ± 0.003
Calculated	0.179 ± 0.004	0.179 ± 0.004

This behavior is also observed in Fig.3, where current sensitivities of the preirradiated diodes, normalized to those attained prior the irradiation, are plotted as a function of the accumulated dose.

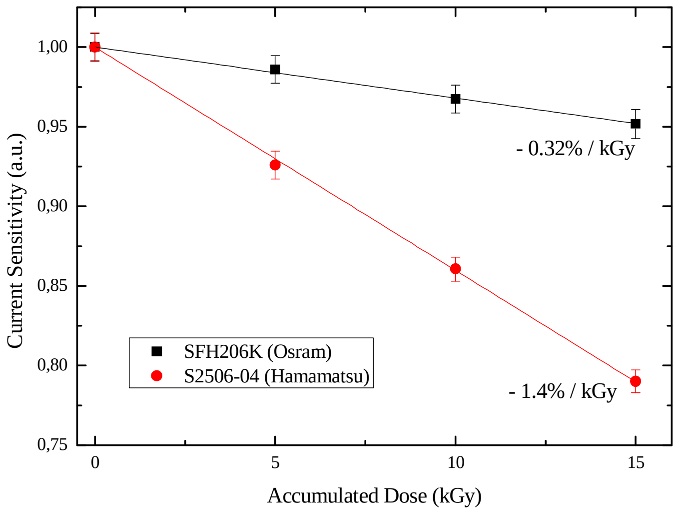

Figure 3: Current sensitivity of preirradiated SFH206K and S2506-04 diodes normalized to that gathered before the irradiation, as a function of the accumulated dose.

The corresponding plots shows that the decrease of the current sensitivity of the SFH206K with the accumulated dose is less pronounced that found with the S2506-04 diode. It also can be drawn from Fig. 3 that the sensitivity decrease of the two diodes are evaluated at 0.32%/kGy for SFH206K and 1.4%/kGy for S2506-04 in the accumulated dose range herein investigated.

4. CONCLUSIONS

A comparative evaluation of the dose rate response of commercial thin diodes (SFH206K and S2506-04) has been performed in this work mainly addressing the variation of their current sensitivities with accumulated dose ranging from 0-15 kGy. All the results so far obtained have revealed that the radiation induced currents are linearly dependent on dose rates from 3.65 to 55.64 Gy/h. The current sensitivity of both unirradiated diodes (0.178 $nA.h/Gy.mm^3$) slightly decreases with accumulated dose, namely 0.32%/kGy (SFH206K) and 1.4%/kGy (S2506-04). Although the SFH206K device compares favorably with the S2506-04, both diodes can be considered as a low budge alternative, good enough for on-line dosimetry applications in the field of radiation processing.

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