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Use of a homemade diode dosimetry system for transit dose measurements in a ^{60}Co Gamma Chamber facility

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1. Introduction

Low-dose (100 Gy) radiation processing applications have underscored the need for accurate absorbed-dose measurements, as transit dose incurred during source or product movement can significantly skew predicted values. Although the transit-dose contribution is typically neglected in routine high-dose processes spanning tens of kGy [1], its impact becomes critical in low-dose applications. Standard evaluation methods rely on ionization chambers and electronic portal imaging devices, which are unsuitable for radiation processing [2, 3]. To address this limitation, this work evaluates the transit dose of a small-scale gamma irradiator using a custom in-house dosimetry system based on a PIN photodiode operating in short-circuit mode. By measuring the radiation-induced current in real time, the system enables precise assessment of transit time through signal-profile analysis - a capability unavailable in passive dosimeters. Experimental results are validated against reference data obtained from Fricke dosimeters, as certified by the manufacturer.

2. Methodology

The experimental setup is based on an unbiased PIN photodiode (SFH206k, Osram) operating in either online (current) or offline (charge) mode, with its detailed performance characteristics described elsewhere [4]. Irradiations are conducted using a ^{60}Co Gamma Chamber (model GC-5000, manufactured by BRIT), installed at the Radiation Technology Center (CETER) of IPEN/CNEN. Dose rates ranged from 0.9105 kGy/h to 9.105 kGy/h, achieved with appropriate lead attenuators, as illustrated in Figure 1.

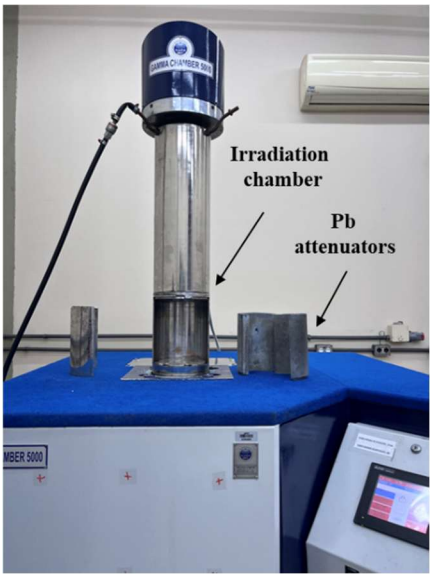

Figure 1: ^{60}Co Gamma chamber model GC-5000 and the lead attenuators used for transit dose measurements at dose rates from 0.9105 kGy/h up to 9.105 kGy/h.

Output current readings are acquired using a Keithley 6517B electrometer. The dose-response of the diode - determined by integrating the current signal to obtain charge as a function of absorbed dose - is evaluated between 2.5 and 30 Gy in a ^{60}Co Gammacell 220 (Nordion), which was previously calibrated against reference standard alanine dosimeters with a ± 3% uncertainty (LDAD-CNEA certification). From this, the linearity and charge sensitivity are investigated. To determine the transit time of the GC-5000 Gamma Chamber, the variation in current intensity was analyzed as a function of exposure time across five consecutive on/off irradiation cycles to enhance accuracy. Finally, the corresponding transit dose for each cycle was calculated offline utilizing the established dose-response curve.

3. Results and Discussion

Figure 2 shows the output current signals recorded sequentially over five diode-movement cycles at a dose rate of 9.105 kGy/h, with each irradiation cycle lasting 15 s. An average transit time of (10.214 ± 0.02) s was determined by analyzing the rise and fall times across the entire signal set. For clarity, an expanded view of these parameters within a single current signal is presented in Figure 3. Based on the linear dose-response, a charge sensitivity of (0.7854 ± 0.0021) μC/Gy, and the average charge delivered by the diode during movement, the transit dose was calculated as (12.2 ± 0.5) Gy. Following the same procedure, transit doses were evaluated at lower dose rates by introducing three cylindrical lead tubes of varying thicknesses into the sample chamber (Figure 1), attenuating the gamma-ray intensity by 50%, 70%, and 90%, respectively. Table I summarizes the corresponding transit doses obtained for the Gamma Chamber GC-5000 under the different dose-rate conditions. These parameters measured with the SFH206k diode are in excellent agreement with the manufacturer-supplied specifications, falling well within the combined experimental calibration uncertainty of the Gammacell (3%) and statistical uncertainties. It is important to note that, according to the manufacturer, the minimum exposure time of a material in the 60Co facility is 6 s. For this reason, as also shown in Table I, the minimum possible irradiation doses in the Gamma Chamber GC-5000 are 27 Gy at a dose rate of 9.105 kGy/h, and, at the lower limit, 2.8 Gy for a dose rate of 0.9105 kGy/h.

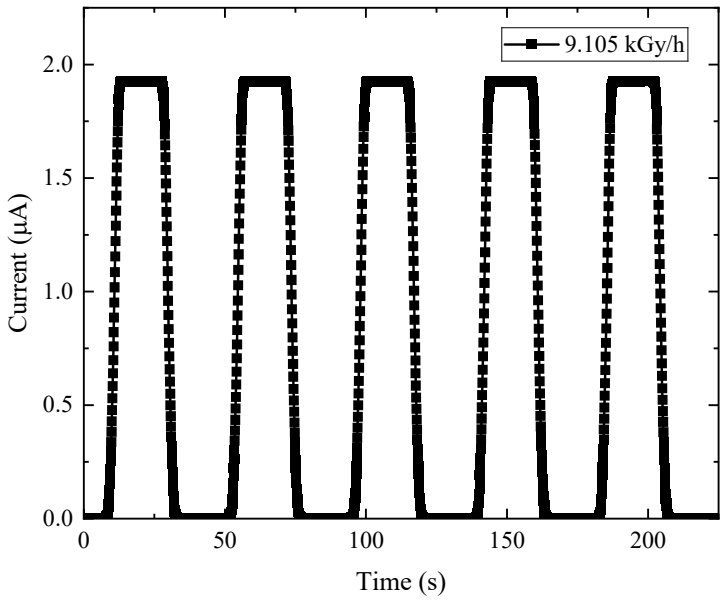

Figure 2: Five output current signals continuously recorded during the diode movement by switching the source on and off at a 9.105 kGy/h dose rate.

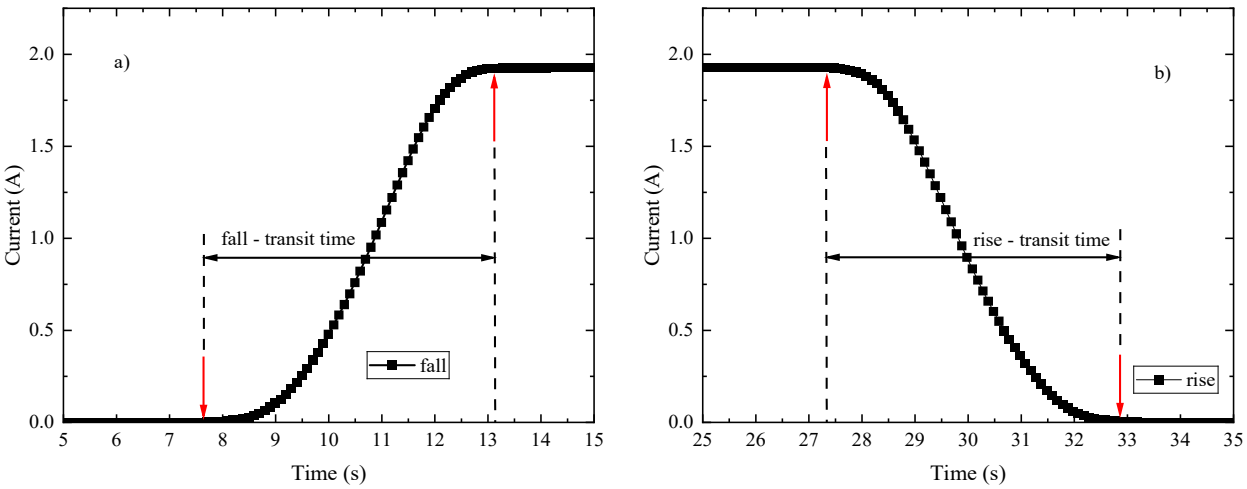

Figure 3: The expanded view of one current signal delivered by the diode during its (a) fall, and (b) rise movement.

Table I: Transit dose and minimum dose of the Gamma Chamber GC-5000 for the different dose rates. The transit dose value provided by the manufacturer was measured using Fricke dosimeters.

Dose rate (kGy/h)	**Photocurrent (μA)**	**Transit dose (Gy) This work**	**Minimum dose (Gy) This work**	**Transit dose (Gy) Manufacturer**
9.1050	1.919	12.2 ± 0.5	27.4 ± 0.4	12.83 ± 0.26
4.5525	0.877	5.10 ± 0.20	12.69 ± 0.20	not provided
2.7315	0.600	3.82 ± 0.15	8.37 ± 0.15	not provided
0.9105	0.214	1.34 ± 0.06	2.86 ± 0.06	not provided

4. Conclusions

This study presents a simple, rapid method for measuring the transit dose of a small-scale ^{60}Co gamma irradiator, based on real-time monitoring of the output current of a PIN photodiode operating in short-circuit mode as it moves toward the radioactive source. Analysis of the current signal profile yields precise data on the dose rate at each irradiation position, the transit time, and the corresponding transit dose. The online assessment of these parameters - a capability unachievable with passive dosimeters - is a key advantage for radiation processing dosimetry. Furthermore, the accuracy of the experimental results, validated against reference Fricke dosimeters, corroborates the suitability and reliability of the proposed methodology for transit dose measurements in industrial and research applications.

Acknowledgements

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