Compensation of the temperature effect of the dark current in photodiodes dosimeters

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Introduction. Ionization chambers are the most commonly used device for radiotherapy treatment control, presenting some limitations compared to semiconductor-based systems, such as comparatively high cost, larger size and high voltage requirement for biasing. As an alternative or complement, some current-mode semiconductor devices have been studied for the same purpose, such as photodiodes and phototransistors [1,2]. The induced photocurrent current can be related with the radiation dose rate, and the absorbed dose is proportional to the integration of the current over the exposure time. Due to the exponential temperature dependence of the photodiode dark current, base line will be strongly affected in dosimetry. Consequently, a thermal compensation during dose reading should be required for an accurate dose measurement by photodiodes as affordable skin dosimeter. Our proposal consists in periodically measuring the forward voltage (V_γ) as a method of temperature estimation of the device. This value is employed for the thermal correction of the reverse dark current (I_S) which is the baseline of the radiation-induced photocurrent and the main contributor to its thermal drift.

Experimental setup. Six samples of the commercially available Si PIN photodiode BPW34S, divided in two groups of three devices, were used for the thermal modelling of forward biased DUT at constant current, and for the validation of the proposed model, respectively. Moreover, thermal dependence of the dark current under reverse biasing was measured in five samples. For temperature-controlled tests, samples were introduced in a climate chamber VCL4006. In a second step, the dosimetric characterization of the photodiodes was performed. Eight samples of the BPW34S were irradiated with a linear accelerator (LINAC) Siemens Artiste placed at the “Hospital Universitario Clínico San Cecilio” (Granada, Spain). The photon beam was produced with an electric potential of 6 MV. DUTs were located in the radiation isocentre (at 100 cm), and were irradiated with a field of 10x10 cm^2. The irradiation cycle of 90 minutes of duration is composed by a six-step decreasing average dose rate staircase from 4.87 to 0.81 cGy/s, a six-step increasing average dose rate staircase from 0.81 to 4.87 cGy/s, and a last step of 0.81 cGy/s. Between each step, a period without irradiation of 2 minutes was applied.

System design. To measure the internal temperature of the photodiode, a sink current source with a LM334 (Texas Instruments, Dallas, TX, USA) has been added to the reader unit. The working principle for thermal compensation is as follows: after dose measurement, the photodiode used as sensor is disconnected from both bias voltage source and current to voltage converter and connected between ground and sink current source. Then, the forward biased photodiode has a direct voltage drop proportional to temperature, typical of p-n junctions.

Results and conclusions. Excellent linear and exponential fittings with the temperature have been obtained for V_γ and I_S respectively, that provided accurate device temperature estimation and I_S thermal drift correction of 0.3°C. Once our compensation method is applied, resulting in a maximum relative error of 0.4%, thus a significant reduction of the baseline thermal drift is achieved. Therefore, the algorithm presented in this work is suitable for model and reduce the thermal dependence in measured induced photocurrent of photodiodes.

References

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