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VERIFICATION OF ANGULAR DEPENDENCE IN MOSFET DETECTOR

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ABSTRACT

In vivo dosimetry is an essential tool for quality assurance programs, being a procedure commonly performed with thermoluminescent dosimeters (TLDs) or diodes. However, a type of dosimeter that has increasing popularity in recent years is the metal-oxide-semiconductor field effect transistor (MOSFET) detector. MOSFET dosimeters fulfill all the necessary characteristics to realize in vivo dosimetry since it has a small size, good precision and feasibility of measurement, as well as easy handling. Nevertheless, its true differential is to allow reading of the dose in real time, enabling immediate intervention in the correction of physical parameters deviations and anticipation of small anatomical changes in a patient during treatment. In order for MOSFET dosimeter to be better accepted in clinical routine, information reporting performance should be available frequently. For this reason, this work proposes to verify reproducibility and angular dependence of a standard sensitivity MOSFET dosimeter (TN-502RD-H) for Cs-137 and Co-60 sources. Experimental data were satisfactory and MOSFET dosimeter presented a reproducibility of 3.3% and 2.7% (1 SD) for Cs-137 and Co-60 sources, respectively. In addition, an angular dependence of up to 6.1% and 16.3% for both radioactive sources, respectively. It is conclusive that MOSFET dosimeter TN-502RD-H has satisfactory reproducibility and a considerable angular dependence, mainly for the Co-60 source. This means that although precise measurements, special attention must be taken for applications in certain anatomical regions in a patient.

1. INTRODUCTION

Cancer, malignant tumor or malignant neoplasm are names given to a same group of diseases that have as common characteristic the disordered cell growth. According to the World Health Organization (WHO), more than 8.8 million people came to death due to cancer in 2015, making it the second leading cause of death worldwide [1]. National Cancer Institute (INCA), a Brazilian reference in the treatment of tumors, reports that there are four main types of cancer treatment that can be used jointly or not: surgery, bone marrow transplantation, chemotherapy and radiotherapy [2].

Radiation therapy is the treatment where ionizing radiation is used to destroy tumor cells or inhibit their development [3]. An ideal radiotherapy treatment seeks to deliver the highest possible dose to tumor cells with less damage to surrounding healthy cells. Based on this principle, increasingly advanced techniques and devices have been developed in the radiotherapy field, which represents an immeasurable gain for whole society. On the other hand, for increasingly elaborate procedures to be implemented, tools must be developed to ensure proper administration of dose to the patient, being one of the roles assigned to quality assurance programs in radiotherapy.

In vivo dosimetry is an indispensable tool for quality assurance programs, especially in Total Body Irradiation (TBI) treatments and dose estimation in critical structures due to uncertainties in patient positioning or in absence of accurate dose calculation systems. For this purpose, the most commonly used dosimeters are thermoluminescent dosimeters (TLDs) and diodes [4]. However, a type of dosimeter that is increasingly being used is metal-oxide-semiconductor field effect transistor (MOSFET). MOSFET detectors meet the necessary characteristics to realize in vivo dosimetry since it has a small size, good precision, and measures feasibility, as well as easy handling. When compared to TLD, MOSFET dosimeter has advantages such as the possibility of real-time dose administration and easy data acquisition. A dosimetry by TLD tends to be a lengthy and laborious process since a post-irradiation step is required for data extraction [5]. Furthermore, when comparing MOSFET dosimeter to semiconductor detectors, the main advantage is its small size, the MOSFET being 100 times smaller than a diode [6]. All these features make of MOSFET dosimeter a viable tool for applications such as in vivo dosimetry, dosimetry of small field and brachytherapy. In addition, online dose reading allows an anticipation of small anatomical changes in the patient, besides making possible a correction in the characterization of physical parameters used during irradiation [4] [5] [7].

MOSFET dosimeter operation is based on the variation of threshold voltage obtained when a particle ionizes its sensitive volume of silicon dioxide (SiO_2), producing pairs of electron-hole charge. The sensitive volume of SiO_2 for a standard sensitivity MOSFET dosimeter is 0,04 mm² area extending through a very thin layer of 0.5 μm thickness [8].

It is important to note that threshold voltage varies linearly with administered dose, and a direct conversion of voltage in dose is always possible performed when calibrated [9]. In addition, the dual MOSFET composing the system of the integrated circuit of the device makes its response independent of room temperature [5].

Advantages presented by this radiation detector when incorporated into radiotherapy are evident. However, for MOSFET dosimeter to be better accepted in clinical routine, information related to its performance should be made available frequently. For this reason, this work aims to verify reproducibility and angular dependence of MOSFET dosimeter for radioactive sources of Cesium-137 and Cobalt-60.

2. MATERIALS AND METHODS

2.1. MOSFET Dosimetry System

The mobileMOSFET System is a dosimetry system manufactured by Best Medical Canada. It basically consists of a Reader Module TN-RD-16, a license for the mobileMOSFET Monitoring Dose Verification Software TN-RD-75, a standard sensitivity dosimeter TN-502RD and cables for connection to PC-Reader and power supply. Moreover, there is the possibility of connecting Reader-PC through a Wireless Transceiver. With exception of TN-502RD dosimeter and wireless connection, all components supplied by the manufacturer were used during irradiation. The reader was connected directly to PC via 15 meters RS-232 cable that accompany dosimetry system.

The reading module of MOSFET dosimetry system is a device where the detector is connected for data collection. This reader is connected to a microcomputer that must have manufacturer's software installed. The reading module operates on the dual bias, which enables either a standard bias sensitivity setting or a high bias sensitivity setting. In summary, a reader configured in high bias sensitivity varies three times more its voltage than when configured in standard bias sensitivity, and is, therefore, more precise [10]. Nevertheless, there is a "cost" for this greater accuracy because if voltage consumption of dosimeter is three times higher in high bias sensitivity, it is a consequence that useful time of detector is anticipated.

In addition to choosing a bias sensitivity of reading module, there is also another selection to be made before an irradiation is performed: the sensitivity of the detector. MOSFET dosimeter recommended for higher dose applications, such as in radiotherapy, is TN-502RD standard sensitivity model. In addition to this model, a TN-1002RD is also available, which is a dosimeter three times more sensitive than standard sensitivity. However, its useful life is shorter and is recommended by the manufacturer to be applied at lower doses, such as those commonly given in diagnostic radiology.

MOSFET dosimeter used in this work was the TN-502RD-H, a standard sensitivity model that is reinforced for greater strength and durability when compared to the standard TN-502RD according to the manufacturer [11].

2.2. Irradiation System: Cesium-137 and Cobalt-60

In experiments performed with MOSFET detector, the energy deposition by source of Cs-137 is due to its emission of 0.662 MeV photons. In turn, a Co-60 source emitting 1.17 and 1.33 MeV photons.

Both the Cs-137 and Co-60 radioactive source irradiation systems are located in the Instruments Calibration Laboratory of Nuclear and Energy Research Institute (LCI/IPEN) [12]. For experiments using the Cs-137 source, the detector was placed on 100 cm SSD, suspended in the air for a time of 15 minutes, generating a fixed dose of 30 cGy.

Regarding the experiments with the Co-60 source, the detector was placed on a 100 cm SSD, suspended in the air for 16 minutes and 17 seconds, also generating a fixed dose in all irradiations.

2.3. Reproducibility

The reading module was set in high sensitivity bias during all experimental measurements in order to obtain the best possible accuracy. To verify reproducibility at each detector angle at the Cs-137 source, a single standard sensitivity MOSFET dosimeter (TN-502RD-H) was irradiated three times at a constant dose for each of the five different angles (0°, 45°, 90°, 135° and 180°).

Experimental measurements on the source of Co-60 were performed after measurements with Cs-137 with the same MOSFET dosimeter. Four irradiations were done in a constant dose for each of the five different angles (0 °, 45 °, 90 ° 135 ° and 180 °). This procedure was repeated three times, generating a total of 12 irradiations for each of the angles.

2.4. Angular Dependence

Angular dependence of the MOSFET dosimeter was evaluated by means of reproducibility measurements for each of the five angles in each of the radioactive sources. Average voltages were normalized to an angle corresponding to the epoxy side (180°) as this orientation showed a greater response than the Kapton side (0°).

3. RESULTS

Readings of TN-502RD-H MOSFET dosimeter with respect to reproducibility are shown in Tables 1 and 2 for five different angles. MOSFET dosimeter presented a reproducibility of 3.3% and 2.7% for Cs-137 and Co-60 sources, respectively, being satisfactory at all angles for both radioactive elements.

Table 1: Reproducibility of TN-502RD-H MOSFET dosimeter for Cs-137 source

Irradiation No.	Angle Response (mV)				
	0°	45°	90°	135°	180°
1	97	97	100	98	104
2	95	100	101	101	101
3	99	96	98	105	104
Mean	96.67	97.73	99.46	101.45	103.01
SD	1.9	2.0	1.4	3.3	1.4

Table 2: Reproducibility of TN-502RD-H MOSFET dosimeter for Co-60 source

Irradiation No.	Angle Response (mV)				
	0°	45°	90°	135°	180°
1	60	65	69	69	69
2	55	65	70	70	69
3	56	65	70	67	66
4	56	66	68	67	68
Mean	56.65	65.13	69.15	68.36	67.99
SD	2.2	0.4	0.9	1.7	1.2
1	56	63	72	70	65
2	58	63	69	67	69
3	56	64	70	70	65
4	57	63	71	69	69

Mean	56.84	63.19	70.41	69.24	66.93
SD	0.9	0.5	1.2	1.2	2.3
1	56	61	65	68	67
2	54	66	72	67	67
3	55	62	69	68	67
4	57	66	67	68	67
Mean	55.45	63.90	68.38	67.83	66.96
SD	1.0	2.5	2.8	0.3	0.3
Overall Mean	56.31	64.07	69.31	68.48	67.29
Overall SD	1.5	1.6	1.9	1.3	1.5

Angular dependence data can be seen in Figures 1 and 2. The detector response was normalized to 180° angle (epoxy side). A difference of up to 6.1% in the response of the MOSFET dosimeter to the source of Cs-137 was found when its angle with respect to the beam is changed. The angular dependence found for the Co-60 source was higher than that found for the Cs-137 source, and a difference in response of up to 16.3% was found.

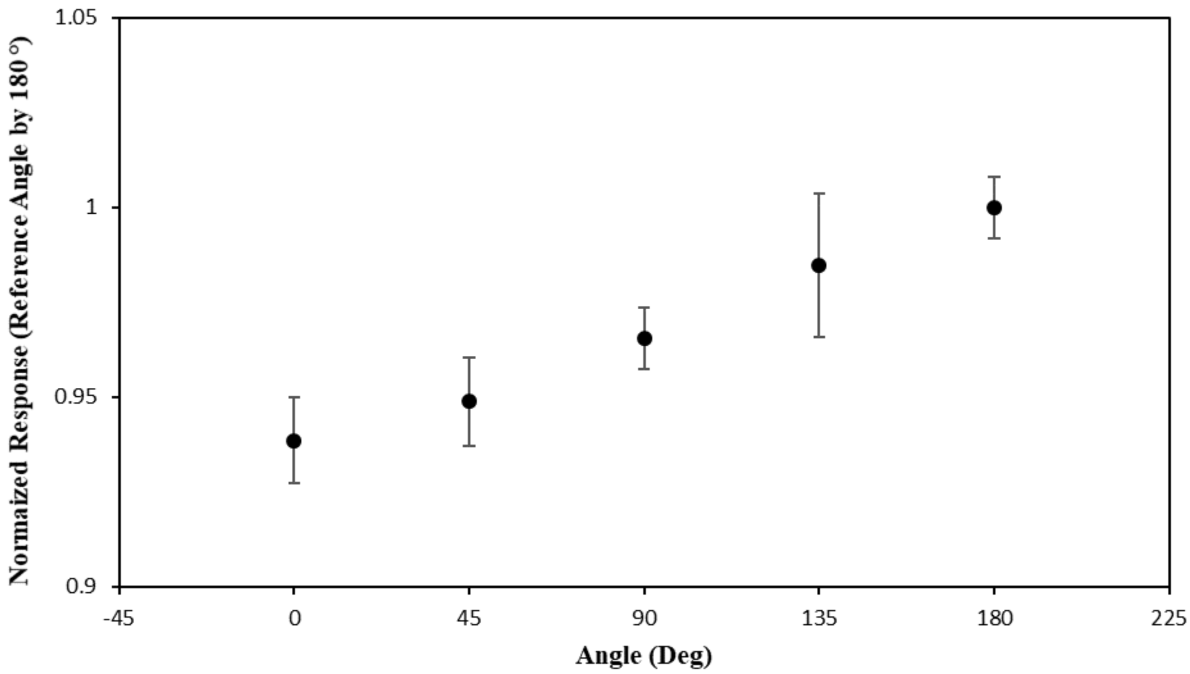

Figure 1: Normalized Angular Dependence of the TN-502RD-H MOSFET dosimeter for Cs-137 source

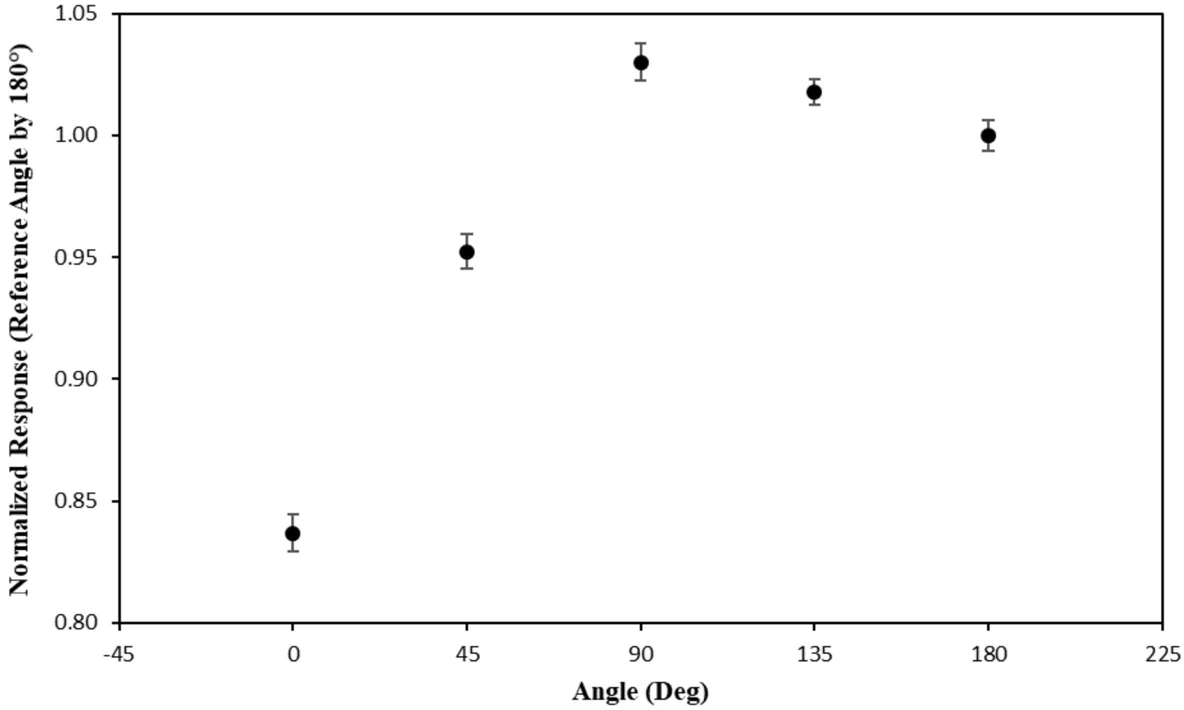

Figure 2: Normalized Angular Dependence of the TN-502RD-H MOSFET dosimeter for Co-60 source

4. DISCUSSION

Wang et al. model in Monte Carlo a high-sensitivity MOSFET dosimeter (TN-1002RD) for low and medium energy photon. Angular dependence found by both simulation and experimental measurements for Cs-137 source was 8%. A value close to that found in this study for standard sensitivity MOSFET dosimeter [13].

The TN-502RD-H model of MOSFET dosimeter used in this work presented a coherent response to those found by Gopiraj et al. and Scalchi et al. In other photon energies for a TN-502RD model of the device [4] [5].

In this work, reproducibility and angular dependence were verified for TN-502RD-H MOSFET dosimeter for a Cs-137 and Co-60 source. In addition, during the realization of the experiments was clear another feature of the device already mentioned in previous work: its easy manipulation and simple calibration when compared to other dosimeters, such as TLDs [4] [5] [6] [7].

5. CONCLUSIONS

It was possible to verify that the detector has a good reproducibility of measurement for both Cs-137 and Co-60 sources. Moreover, it was found to exist angular dependence of dosimeter in both energies, being much greater for the source of Co-60, that emits higher energies photons, demonstrating that much attention is needed for applications in certain configurations and anatomical regions in patient in radiotherapy treatment. All this information agrees with the literature and motivates the research group to continue seeking to contribute to the understanding of this device. As a next step, new experiments should be performed for more energies in order to analyze how the response of this detector varies with energy of incident photon.

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