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Technical Notes

Characterization of commercial MOSFET detectors and their feasibility for in-vivo HDR brachytherapy

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ABSTRACT

Aim: The present study was to investigate the use of MOSFET as an vivo dosimeter for the application of Ir-192 HDR brachytherapy treatments.
Material and methods: MOSFET was characterized for dose linearity in the range of 50–1000 cGy, depth dose dependence from 2 to 7 cm, angular dependence. Signal fading was checked for two weeks.
Result and discussion: Dose linearity was found to be within 2% in the dose range (50–1000 cGy). The response varied within 8.07% for detector-source distance of 2–7 cm. The response of MOSFET with the epoxy side facing the source (0 degree) is the highest and the lowest response was observed at 90 and 270 degrees. Signal was stable during the study period.
Conclusion: The detector showed high dose linearity and insignificant fading. But due to angular and depth dependence, care should be taken and corrections must be applied for clinical dosimetry.

Introduction

Recent advancement in radiotherapy has increased the complexity of treatment planning and delivery of radiation. Quality Assurance (QA), which is an integral part of radiotherapy, has now become more stringent to cater to the demand of such complex treatments. A persistent QA program is capable of identifying the possible wear and tear or failures of the treatment unit, however it does not verify the actual dose delivered to the patient. In-vivo dosimetry is the recommended and direct method for monitoring the dose delivered to the patient [1,2]. Desired characteristics of an in-vivo dosimeter are miniature size, accuracy and feasibility for measurement. Thermoluminescence dosimeters (TLDs) using LiF were preferred as in-vivo dosimeter since the past few decades as its effective atomic number is close to the human body and can be prepared as small sachet, rod and discs. Many authors have explored the use of TLDs as an in vivo dosimeter for prostrate brachytherapy implants [3,4]. However TLD is a passive dosimetry method and has a significant gap between the irradiation and dose measurement. It also shows depth dependent sensitivity [5]. Moreover system maintenance and TLD preparation are a tedious process. Introduction of diodes and MOSFET in radiotherapy as an online in-vivo dosimeter has gained popularity in the recent years. They were particularly well suited for relative dosimetry and if calibrated individually could be conveniently used for in-vivo dosimetry [6–11]. There are various studies reported in literature on the feasibility of MOSFET as an in vivo dosimeter. Many authors have reported the performance characteristics of low sensitivity TN502RD and high sensitivity TN1002RD MOSFETs for entrance and exit in-vivo dose measurements, respectively, in external beam radiotherapy and TN-RD-16 MOSFETs for electron treatments [9–13]. The authors also reported the angular dependence of MOSFET in free-air as well as in soft-tissue equivalent material for dental photon energy [14]. Use of MOSFET for in-vivo dosimetry is extensively studied and well established in external beam photon and electron therapy.

However it is suggested that there is no ideal detector for all brachytherapy measurements because of the stringent requirements needed and demands expected of the dosimeters [15]. All the currently used detectors exhibit varying degrees of artifacts such as volume-averaging, self-attenuation, angular anisotropy, energy dependence, and a nonlinear dose response. Therefore dosimeter selection for brachytherapy is crucial and is dictated by the radioactive source in question, spatial location of the measurement points with respect to the source, practical insertion(s) of the detectors, and the disease site. Only detector designs that can be easily placed within the intraluminal catheters or special applicators inserted into patients can be considered.

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There are few studies that investigated the feasibility of different MOSFETs for HDR [16–18] and LDR [19] in-vivo dosimetry. All these studies have concluded that MOSFET detectors are easy to measure, reproducible and reliable. The present study was carried out to investigate the characteristics of commercially available MOSFETs (TN502-RD) and their feasibility as an in-vivo dosimeter for Ir-192 HDR brachytherapy treatments.

Materials and Methods

MOSFET

The MOSFET system (TN502RD, Thomson and Neilson) consists of a reader in which 4 bias supply boxes can be connected at a time. It is a software-controlled system (v 2.2) with semiconductor transistors with dimensions of 0.2 mm by 0.2 mm by 1 mm. For our experiments, we have used the standard sensitivity bias voltage supply (1 mV/cGy). The details of the MOSFET system are also available in the link provided [20]. Although all four MOSFETs were calibrated, the characteristics of three MOSFET dosimeters were studied in detail in the present work.

Phantoms

Two different phantoms were used for the present study.

(a) **Virtual water phantom:** The virtual water (Standard Imaging™) phantom was used for the study [21]. This phantom has sheets of varying thickness from 0.2 cm to 5 cm and 30 cm × 30 cm in lateral dimensions. The MOSFET was placed in an in-house fabricated holder. It was made using a slab of Virtual water Phantom 1 cm thick and contains a 1 mm depth grove of 15 cm length. For all the experiments except in angular response we have ensured that the epoxy side always faced the source. This setup enabled accurate positioning and position reproducibility of the detector.

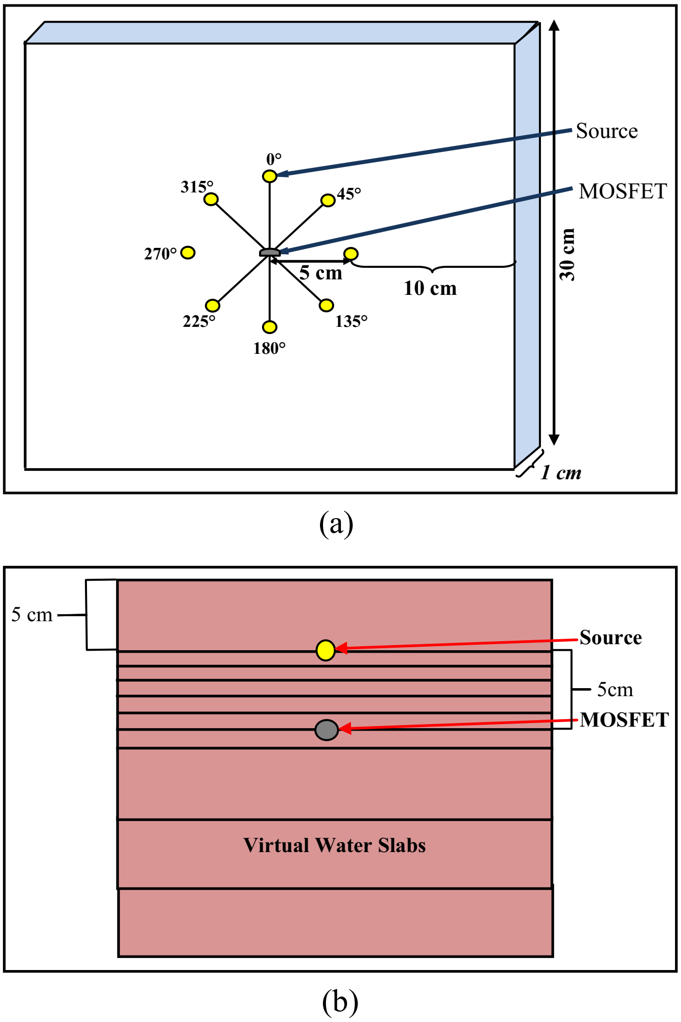
(b) **Phantom for angular dependence:** This phantom was fabricated using virtual water phantom sheets. It facilitated equidistant and accurate positioning of an implant tube at every 45° starting from 0° to 360° increasing in clockwise direction with the first position being vertically above the MOSFET at a radial distance of 5 cm and perpendicular to its axis. The cross sectional view is as shown in Fig. 1a. The phantom was sandwiched between a 10 cm layer of virtual water slabs from both sides to provide adequate scattering for measurements.

Calibration

Figure 1b represents the experimental setup for the MOSFET calibration. The MOSFET was placed in an adapter which was sandwiched between layers of virtual water phantom. A flexible implant catheter was placed in a customized groove vertically above the MOSFET as shown in Fig. 1b. Only the first dwell position of source was programmed. A slab of 5 cm was placed above the implant tube to provide scattering. The epoxy face of MOSFET always faced the source during calibration. Plans were generated in Oncentra Treatment Planning System (Version 4.1 SP 2, Elekta™) to deliver 100 cGy at 5 cm from the source.

Calibration factors were calculated using the following formula:

$$\mathrm{CF} = \mathrm{Prescribed\ dose\,(cGy)/MOSFETs\ Reading\,(mV)} \tag{1}$$



(a)

(b)

Figure 1. (a) Schematic diagram of phantom showing the angles used to study angular dependence. The phantom was sandwiched between two 5 cm thick virtual water slabs from both sides in order to provide adequate scattering for measurements. (b) Schematic diagram of virtual water phantom used for measurements of MOSFET characteristics.

Dose linearity

Different plans were generated to deliver a dose ranging from 50 cGy to 1000 cGy at a 3 cm distance. This experimental setup was similar to the calibration set up. Dose measured by MOSFET was plotted against the prescribed dose.

Angular dependence

The reference angle for all measurements was at 0° in which the epoxy layer of MOSFET was facing the source. Only the first dwell position of the source was programmed and three readings at eight angles with an increment of 45° (0°, 45°, 90°, 135°, 180°, 215°, 270° and 315°) were measured. These readings were normalized to the average reading at the reference angle.

Depth dependence

Depth dependence was investigated by varying the distance between the source and the MOSFET from 2 to 7 cm. For each depth, the after-loader was programmed to deliver 50 cGy to the point of measurement. Measured dose was compared with the TPS calculated