

Peripheral dose measurement with a MOSFET detector

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Abstract

The accuracy of a MOSFET dosimetry system with respect to peripheral therapeutic doses from high-energy X-rays has been evaluated. The results have been compared with ionisation chamber measurements in the same peripheral regions of the beam. For 6 MV and 18 MV X-ray beams, the MOSFET system in the high-sensitivity mode produces reproducibility of dose measurement with relative standard deviations within 1% of the maximal dose in the beam, if the measurement is made upto 15 cm away from the beam edge. The results have shown that the MOSFET device can adequately measure peripheral doses, which would be beneficial for in vivo dose assessments in radiotherapy.

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1. Introduction

In vivo dosimetry for radiotherapy patients often requires dose measurements not in the treatment area, but in the peripheral regions, so that doses to critical organs could be recorded and minimized, if possible. For many such measurements, one needs detectors with the ability to measure low doses accurately and tolerance to some variations in the spectral quality of the calibration beam. Detectors like radiochromic film are not sensitive enough to measure small doses accurately (Butson et al., 2003). Metal oxide semiconductor field effect transistor (MOSFET) featured the ability to integrate dose measurements and to provide immediate dose readout (Thomson et al., 1984). In combination with a very small sensing volume, this makes the MOSFET dosimetry system advantageous

over the other systems used in radiotherapy. Thus, MOSFET detectors are finding applications in radiotherapeutic in vivo dosimetry (Butson et al., 1996; Bloemen-van Gurp et al., 2003; Kron et al., 2002; Rosenfeld, 2002; Chuang et al., 2002; Quach et al., 2000). In this short note, we report the results of an investigation of the ability of a MOSFET dosimetry system to accurately measure doses in peripheral regions of high-energy X-ray beams; the accuracy of the technique was evaluated by comparing peripheral region dose measurement with the results of standard ionisation chamber measurements.

2. Materials and methods

The MOSFET-based ‘Clinical semiconductor dosimetry system’ (CSDS) evaluated for peripheral dose assessment is a commercial product manufactured by the Centre for medical radiation physics (CMRP), University of Wollongong, NSW Australia. It employs

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an integrating MOSFET with two p-MOSFET devices on the same chip, which are sourced from REM Oxford UK (Holmes–Siedle 2001). The system is capable of reading 10 MOSFETS online with results sent directly to a computer via a RS232 connection. A dual bias MOSFET probe can be used, which employs k-type and r-type MOSFETS with gate bias voltage of +12 and +5 V, respectively. The control software and internal microprocessor correct for any drift of the MOSFET threshold voltage due to slow border states induced by radiation and thermal effects (Savic et al., 1995; Rosenfeld et al., 2001). Results for peripheral dose assessment were obtained with the high-sensitivity sections of the probe (i.e. 5 V bias MOSFET). Measurements were made to analyse the accuracy of the devices for peripheral dose regions. This was performed in a solid water phantom moulded to fit the device at D_{\max} (1.5 cm) using a 6 MV X-ray beam under standard conditions. Doses were delivered to the MOSFET detector at the central axis and then in the peripheral regions of the beam ranging from 1 to 15 cm outside the geometric edge of the X-ray field. The doses measured in this way were then compared with the results of standard measurements made with a cylindrical thimble-type ionisation chamber placed in the same positions as the MOSFET detector. Experiments were also performed to evaluate the effects of low-dose assessment introduced by peripheral dose assessments as could be the case of in vivo dosimetry.

3. Results

Fig. 1 shows the measured percentage doses for both the MOSFET detectors and the thimble ionisation chamber for a 10×10 and 20×20 cm X-ray field in the peripheral regions of the beam up to 15 cm away

from the field edge. Results show a good agreement at both field sizes, which was also the case for all the measured fields with the sizes ranging from 5×5 cm to 30×30 cm. The measured dose is slightly higher for the MOSFET device as compared with the ionisation chamber result, but this difference is always less than 1% of the maximum dose under our experimental configurations. Similar results for 18 MV X-rays and the same experimental configurations are shown in Fig. 2. As the MOSFET detector is based on silicon, one could expect a higher-energy dependence of the dose and, as a result, additional inaccuracies in the assessment of doses in peripheral regions due to variations in the electron energy in those regions. This would result in higher readings and an overestimation of doses in peripheral regions. That was really the case, but the deviation from the results of the ionisation chamber measurements was relatively small, less than 1% of the maximal of all measured values. This is within normal uncertainties of in vivo measurements.

The accuracy of the MOSFET detector depends on the dose applied to the detector, and it is lower for small doses. This may be a limiting factor in some assessments of peripheral doses, as doses typically given, for example, to eyes and scrota are small. Table 1 compares the accuracy and limits of measurement of the MOSFET detector at low doses, which are compared to standard ionisation chamber results along with lithium fluoride thermoluminescent dosimeter results. The ionisation chamber provides the highest level of accuracy for low doses, however, these types of chambers cannot be used in vivo due to their size and shape. Results for the MOSFET device show that the level of accuracy that can be achieved using 95% confidence interval half-widths range from approximately 10–2.5% when the absorbed dose ranges from 2 to 10 cGy. These values provided a lower uncertainty in measured dose

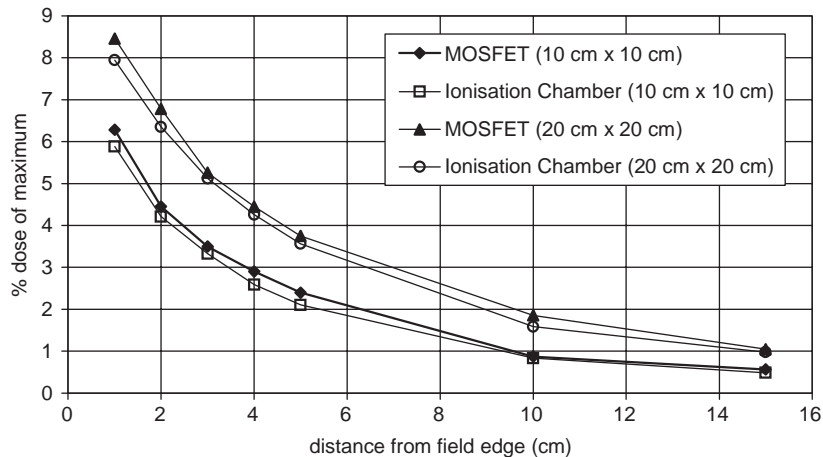


Fig. 1. Peripheral dose assessment with the CSDS MOSFET dosimetry system at 6 MV X-ray energy.

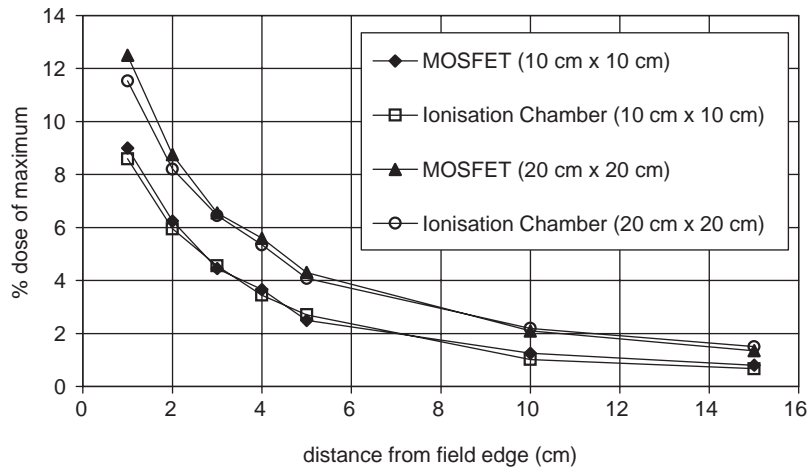


Fig. 2. Peripheral dose assessment with the CSDS MOSFET dosimetry system at 18 MV X-ray energy.

Table 1

Accuracy (%) of MOSFET dosimetry system and standard ionisation chambers (with 95% confidence interval half-widths and at quoted dose level cGy)

Dosimeter	2	4	6	8	10
Thimble ionisation chamber	1.6	0.8	0.4	0.4	0.3
UOW MOSFET system	9.8	6.3	3.5	3.1	2.3
LiF (Mg,Ti) TLDs	12.5	9.6	6.1	5.3	4.5

compared to that of LiF (Mg,Ti) thermoluminescent dosimeters over the same dose range.

In summary, the CSDS MOSFET can provide adequate measurements of high-energy X-ray doses in areas peripheral to the main beam. Results of such measurements in a solid water phantom compare favourably with the results of ionisation chamber. Thus, the MOSFET devices should adequately measure peripheral dose levels in vivo without major adverse effects from variations of the electron energy in peripheral regions of the beams.

4. Conclusions

The CSDS MOSFET dosimetry system provides an adequate dose assessment in peripheral regions of high-energy X-ray beams. Results are in a good agreement with ionisation chamber measurements in these regions. For low applied doses, which may be used in peripheral irradiations during radiotherapy, the MOSFET devices provide a slightly better accuracy than the LiF (Mg,Ti) thermoluminescence dosimeters at the same dose levels.

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