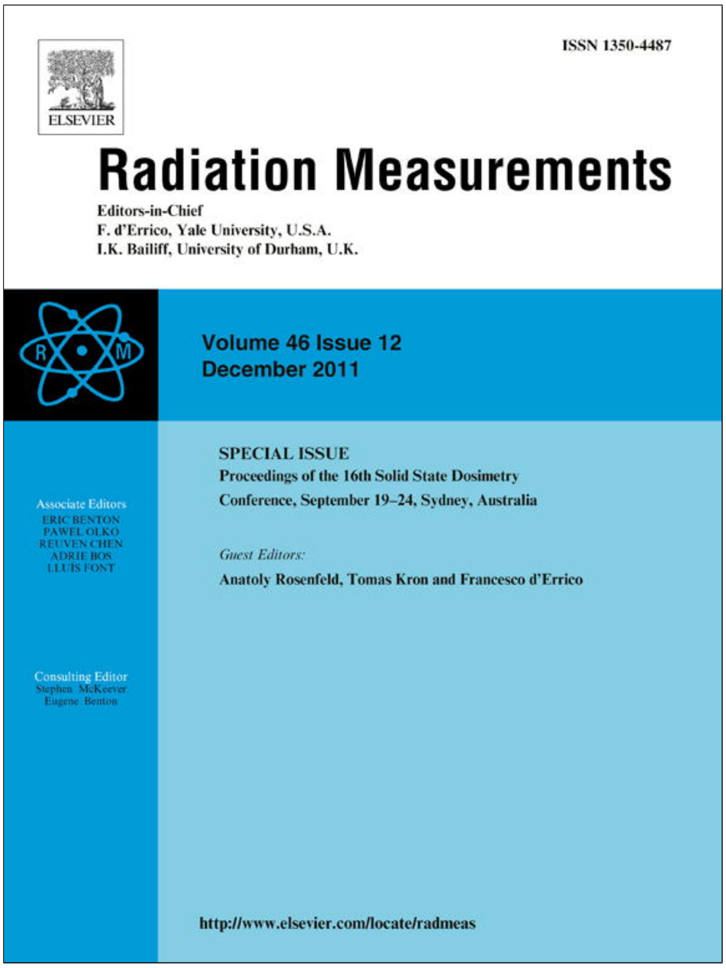

ISSN 1350-4487

ELSEVIER

Radiation Measurements

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Volume 46 Issue 12
December 2011

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Radiation Measurements 46 (2011) 1979–1981

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Study of LiF:Mg,Ti and $CaSO_4$:Dy dosimeters TL response to electron beams of 6 MeV applied to radiotherapy using PMMA and solid water phantoms

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ARTICLE INFO

Article history:
Received 4 September 2010
Received in revised form
10 May 2011
Accepted 13 May 2011

Keywords:
Thermoluminescence dosimetry
Electrons beam
Lithium fluoride
Calcium Sulfate

ABSTRACT

The performance of $CaSO_4$:Dy and LiF:Mg,Ti dosimeters to electron beams applied to radiotherapy was investigated. The TL response of these dosimeters was studied for 6 MeV electron beams using PMMA and Solid Water (SW) phantoms. The dosimeters were previously separated in groups according to their TL individual sensitivities to ^{60}Co gamma-radiation in air under electronic equilibrium conditions. After that, they were irradiated with 6 MeV electron doses of 0.1, 0.5, 1, 5 and 10 Gy using a linear accelerator Clinac 2100C *Varian* of Hospital Israelita Albert Einstein – HIAE. The electron beam irradiations were performed using a 10×10 cm^2 field size, 100 cm source-phantom surface distance and the dosimeters were positioned at the depth of maximum dose (1.2 cm). The TL readings were carried out between 24 and 32 h after irradiation using a *Harshaw* 3500 TL reader. The TL dose–response of both type of dosimeters and phantoms presented linear behavior on the electron dose range from 0.1 to 5 Gy $CaSO_4$:Dy dosimeter is 21 times more sensitive than LiF:Mg,Ti, dosimeter commonly used in clinical dosimetry. The obtained results indicate that the performance of $CaSO_4$:Dy dosimeters is similar to LiF:Mg,Ti dosimeters and this material can be an alternative dosimetric material to be used to clinical electron beams dosimetry.

1. Introduction

Ionizing radiation is used in Medicine for therapeutic purposes and diagnosis. In the radiotherapy dosimetry an efficient and accurate calibration of the radiation beam ensures knowledge of the radiation dose delivered to the patient, allowing thus an effective radiation treatment with a destruction of cancer cells producing the least possible harm to healthy tissue around the tumor. Clinical electron beams are used to treat superficial malignant tumors and this application requires a precise and accurate dosimetry of the electron beams to obtain the desirable absorbed dose delivered in the tumor. A variation of ±5% is decisive to the risk of recurrence or sequel (Nelson et al., 2010). The purpose of dosimetry in radiotherapy is to determine the absorbed dose by calibrating the radiation beam (Metcalfe et al., 2007). The high sensitivity of thermoluminescent materials enables the construction of resistant detectors in all shapes and sizes, which makes them a useful tool, particularly for measurements in region of sharp dose gradient. The small size and the large useful dose range are the advantages to using thermoluminescent dosimeters for this purpose. Furthermore, it is possible the direct measurement of doses under some conditions in which other forms of dosimetry is not possible (Cameron et al., 1968; Duch et al., 1998; Kron, 1999; Venables et al., 2004).

Measurements using tissue equivalent phantoms for dosimetry of clinical beams used in radiotherapy provide more relevant results than measurements in air (Mckeever, 1985). A research in the United States studied the planning of treatments of radiotherapy and pointed out that about 50% of hospitals and 90% of academics institutions used the method of thermoluminescence for *in vivo* dosimetry (Kron, 1999).

The LiF:Mg,Ti is the TL material most used and studied in radiotherapy due to near tissue-equivalence of the material, along with its overall reliability. This dosimeter was developed by *Harshaw Chemical Company Inc.* in collaboration with Cameron. *Harshaw* markets lithium fluoride (LiF) as TLD-100 and its isotropic variants TLD-600 and TLD-700 as a powder, discs, sticks and pellets (Oberhofer and Scharmann, 1979; Kron et al., 1994; McKeever et al., 1995). Other dosimeter, $CaSO_4$:Dy, is manufactured and marketed by the Dosimetric Materials Laboratory of the Radiation Metrology Centre/IPEN as powder and pellets and offers extensive range of linear response to radiation. This dosimeter has already been used

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doi:10.1016/j.radmeas.2011.05.033

Table 1
Average TL sensitivity of $CaSO_4$:Dy and LiF:Mg,Ti for PMMA and Solid Water phantoms.

	Average TL sensitivity [μC Gy^{-1}]	
	PMMA	SW
$CaSO_4$:Dy	15.63 (±0,21)	15.57 (±0,36)
LiF:Mg,Ti	0.7409 (±0,0051)	0.7368 (±0,0017)

in radiation protection dose measurement due to its high sensitivity and recent investigations have assessed its application related to radiotherapy (Campos, 1983; Campos and Lima, 1987; Nunes, 2008). This study aims to evaluate the TL response of $CaSO_4$:Dy and LiF:Mg,Ti dosimeters to 6 MeV clinical electron beams provided by a *Varian* Clinac 2100C using PMMA and Solid Water phantoms.

2. Materials and methods

Before irradiation the dosimeters were always heat-treated with the following conditions: $CaSO_4$:Dy – 300 °C/3 h using a furnace *VULCAN* model 3-550 PD; LiF:Mg,Ti – 400 °C/1 h using a furnace *VULCAN* model 3-550 PD plus 100 °C/2 h using a furnace *FANEN* model 315-IEA 11200. Three cycles of heat-treatment, irradiation in air under electronic equilibrium conditions with a ^{60}Co gamma source (Activity: 656.4 MBq) and TL reading were performed and the individuals and average TL responses of the dosimeters were obtained and they were separated into 10 groups of 5 detectors according to their sensitivity. The TL readings were performed using a TL reader *Harshaw* model QS 3500.

To perform the irradiations in the clinical electron beam (6 MeV) using a linear accelerator *Varian* Clinac 2100C the selected groups were positioned at the PMMA and Solid Water phantoms consisting of 30 × 30 cm^2 plates of different thickness at the depth of maximum dose, 1.2 cm. To ensure the adequate backscatter of the beam 5 cm of the simulator material was used.

The radiation field size applied was 10 × 10 cm^2 with a source-detector distance of 100 cm.

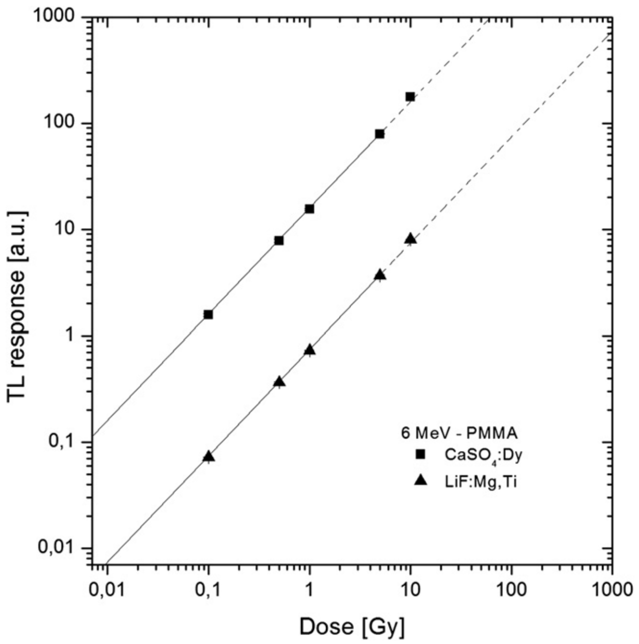

Fig. 1. Dose–response curve of $CaSO_4$:Dy and LiF:Mg,Ti TL dosimeters for 6 MeV electron beam using PMMA phantom.

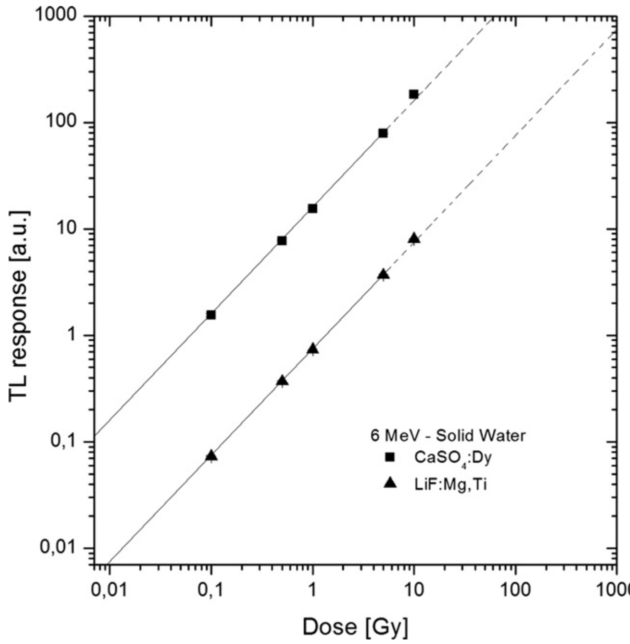

Fig. 2. Dose–response curve of $CaSO_4$:Dy and LiF:Mg,Ti TL dosimeters for 6 MeV electron beams using SW phantom.

The TL responses were carried out between 24 and 32 h after the irradiation and each presented value is the average of 5 TL readings of $CaSO_4$:Dy and LiF:Mg,Ti dosimeters of the same group and the error bars the standard deviation of the mean (1σ).

3. Results

The average TL sensitivity and dose–response curves of $CaSO_4$:Dy and LiF:Mg,Ti dosimeters to each different used phantom, PMMA and Solid Water, at the depth maximum dose and

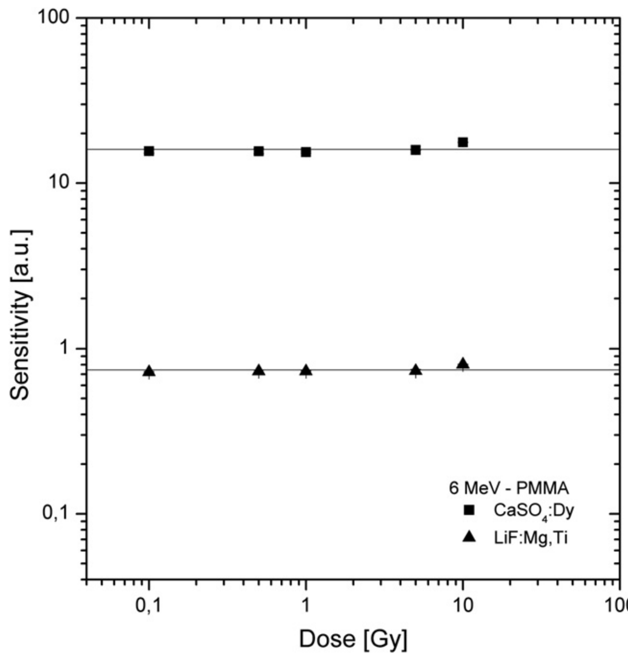

Fig. 3. Average TL sensitivity of $CaSO_4$:Dy and LiF:Mg,Ti TL dosimeters for 6 MeV electron beams using PMMA phantom.

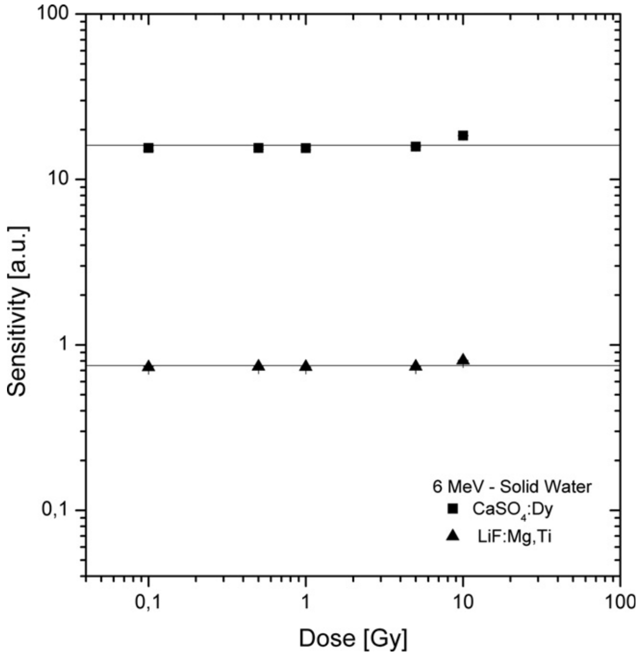

Fig. 4. Average TL sensitivity of $CaSO_4$:Dy and LiF:Mg,Ti TL dosimeters for 6 MeV electron beams using Solid Water phantom.

6 MeV electron beam to the absorbed dose range studied (0.1–10 Gy) are shown in Table 1 and Figs. 1 and 2 respectively.

No significant difference can be observed in the TL response as a function of phantom material.

Figs. 3 and 4 present the average sensitivity of $CaSO_4$:Dy and LiF:Mg,Ti dosimeters for PMMA and Solid Water phantoms and doses from 0.1 to 10 Gy.

For both studied phantom materials and TL dosimeters the dose–response curves show a linear behavior in the electron dose range from 0.1 to 5 Gy. For doses above 5 Gy can be observed a non-linear behavior with a supra-linear tendency, as confirmed in Figs. 3 and 4. TL sensitivity of $CaSO_4$:Dy dosimeters is higher than LiF:Mg,Ti and it ranged, for $CaSO_4$:Dy, from 15.41 to 17.68 $\mu C\ Gy^{-1}$ to PMMA and from 15.49 to 18.43 $\mu C\ Gy^{-1}$ to Solid Water phantoms. For LiF:Mg,Ti, its ranged from 0.7227 to 0.8037 $\mu C\ Gy^{-1}$ to PMMA and from 0.7331 to 0.8051 $\mu C\ Gy^{-1}$ to Solid Water phantoms.

4. Conclusions

The $CaSO_4$:Dy and LiF:Mg,Ti dose–response TL curves presented linear behavior in the electron dose range from 0.1 to 5 Gy, exhibiting supra-linear tendency for doses higher than 5 Gy for both phantom materials, PMMA and Solid Water. $CaSO_4$:Dy dosimeter is 21 times more sensitive than LiF:Mg,Ti.

$CaSO_4$:Dy TL dosimeter produced at the Instituto de Pesquisas Energéticas e Nucleares/IPEN can be an alternative dosimeter at depth of maximum dose in a 6 MeV electron beam.

Acknowledgments

The authors are thankful to CNPq and FAPESP for the financial support and to the radiation therapy staff of the Hospital Israelita Albert Einstein for the electrons irradiations.

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