DOSIMETRIC EVALUATION OF $CaSO_4$:Dy, LiF:Mg,Ti AND MICROLiF;Mg,Ti TL RESPONSE USING SOLID WATER PHANTOM FOR ELECTRON BEAMS DOSIMETRY

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Abstract: This study aimed to compare the performance of the thermoluminescent dosimeters (TLDs) of $CaSO_4$:Dy with LiF:Mg,Ti and microLiF:Mg,Ti for clinical electron beams dosimetry (6 and 9 MeV) using solid water phantom. The dose-response curves were obtained for irradiations with ^{60}Co gamma radiation source and clinical electron beams.

Key words: thermoluminescent dosimetry, radiotherapy, radiological protection, electron beams.

1. INTRODUCTION

Ionizing radiation is used for diagnostic and therapeutic purposes in medicine. This encompasses a wide range of different radiation doses and most applications make use of photons either in the form of X rays (diagnostic radiology, radiotherapy) or gamma rays (nuclear medicine, radiotherapy). This is followed by beta rays or electrons produced by linear accelerators or betatrons [1].

The two main objectives of dosimetry in a clinical environment are basically the radiological protection and its quality assurance in order to promote the protection of patients under treatment and the clinical staff. It is essential ensure reference levels of radiation to patients in medical procedures in order to estimate the risks associated with exposure. In radiotherapy, the main objective of dosimetry is to calculate the maximum dose to the target volume, as required, minimizing the dose received by healthy surrounding tissues [1,2].

The TL dosimetry technique was improved and stands as a major method in routine clinical dosimetry [3, 4, 5, 6]. Studies in the United States investigated the treatments planning using ionizing radiation and found that about 90% of academic institutions and 50% of hospitals used this method for *in vivo* dosimetry [5].

This study aims to compare the thermoluminescent (TL) response of calcium sulphate doped with dysprosium ($CaSO_4$:Dy) dosimeters produced by IPEN with the TL response of lithium fluoride dosimeters doped with magnesium and titanium (LiF:Mg,Ti and microLiF:Mg,Ti (TLD-100)) produced by Harshaw Chemical Company in clinical electron beams dosimetry (6 and 9 MeV) using solid water phantom (RMI-457). The dose-response curves were obtained for irradiation with cobalt-60 gamma radiation source and clinical electron beams of the Clinac model 2100C accelerator from Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HC-FMUSP). The TL sensitivity and reproducibility of each material were also determined to the different types of radiation.

2. MATERIALS AND METHODS

2.1 Dosimetric TL materials

In this study were used the following dosimetric materials: 200 $CaSO_4$:Dy TLDs produced by IPEN; 200 LiF:Mg,Ti (TLD-100) produced by *Harshaw Chemical Company* and 105 microLiF:Mg,Ti (TLD-100) produced by *Harshaw Chemical Company*.

2.2 Irradiation systems

- Linear accelerator *VARIAN* model Clinac 2100C of Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HC-FMUSP);
- ^{60}Co gamma source from Laboratory of Dosimetric Materials/IPEN (0,656GBq on 09/12/2008).

2.3 Equipments

- Solid water Phantom (RMI-457) 30x30cm^2 (Fig. 1);
- Furnace *Vulcan* model 3-550 PD;
- Surgical heater *Fanem* modelo 315-IEA 11200;
- TL Reader *Harshaw* model 3500.

Fig. 1: Solid water phantom positioned on the irradiation table and gantry irradiation with output beam perpendicular to the phantom.

2.4 Dose- response curves to ^{60}Co gamma irradiation

The pre-irradiation heat treatments used were:

- $CaSO_4$:Dy - 300ºC/3 h;
- LiF:Mg,Ti and LiF:Mg,Ti microdosimeters - 400ºC/1 h + 100ºC/2 h.

The dose-response curves to ^{60}Co gamma radiation were obtained in air and under electronic equilibrium conditions (PMMA plates). The dosimeters were selected and divided in the groups according to their sensitivities (± 5%). The dosimeters irradiated in the solid water phantom were positioned at a depth of maximum dose. The specifications followed for irradiation parameters were that recommended by the Technical Reports Series No. 398 (TRS-398) from International Atomic Energy Agency (IAEA): field size - 10 x 10 cm^2; TLDs-source distance - 100 cm [7]. The depths of maximum dose for irradiation of TLDs are presented in Table 1.

Table 1: Depths of maximum dose (cm) used for TLDs irradiations.

Electron clinical beam energy (MeV)	Depth of maximum dose (cm)
6	1.2
9	1.9

2.5 TL readings

The TL responses were evaluated and the dose-response curves of each dosimeter type and its individual sensitivities were obtained to 6 and 9 MeV to the radiation doses: 0.1, 0.5, 1.0; 5.0 and 10.0 Gy. Each presented value represents the average of 10 TL responses and the error bars the standard deviation of the mean (1σ).

3. RESULTS

Figures 2, 3 and 4 show the dose-response curves of the three types of TLDs to gamma radiation from ^{60}Co in air and under electronic equilibrium conditions. Figures 5 and 6 show the dose-response curves for clinical electrons beams (6 and 9 MeV), respectively.

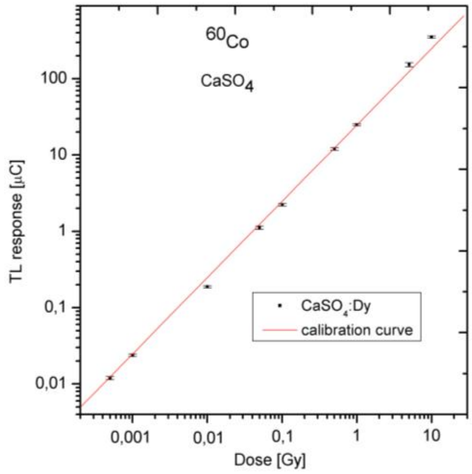

Fig. 2: Dose-response curve of $CaSO_4$:Dy for irradiation in ^{60}Co gamma radiation source in air and under electronic equilibrium conditions (PMMA plates).

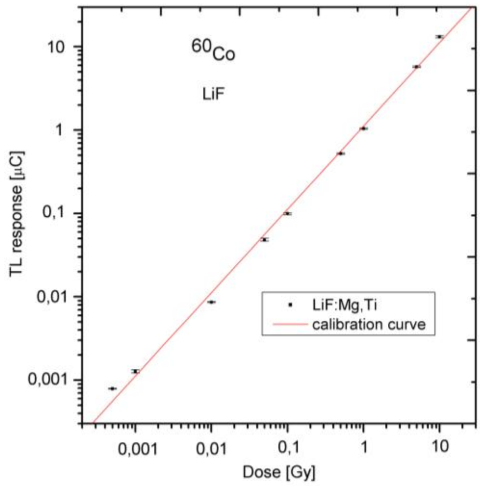

Fig. 3: Dose-response curve of LiF:Mg,Ti for irradiation in ^{60}Co gamma radiation source in air and under electronic equilibrium conditions (PMMA plates).

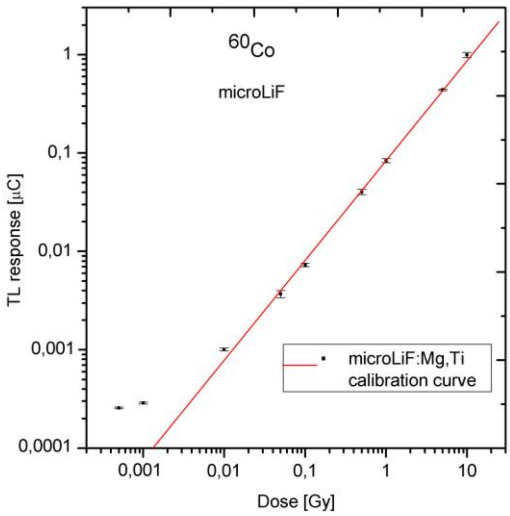

Fig. 4: Dose-response curve of microLiF:Mg,Ti for irradiation in ^{60}Co gamma radiation source in air and under electronic equilibrium conditions (PMMA plates).

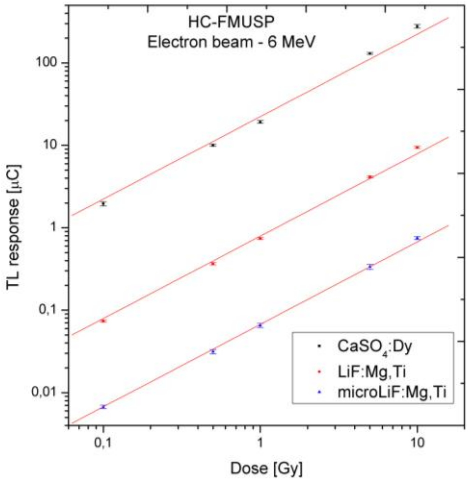

Fig. 5: Dose-response curves to 6 MeV electrons using solid water phantom.

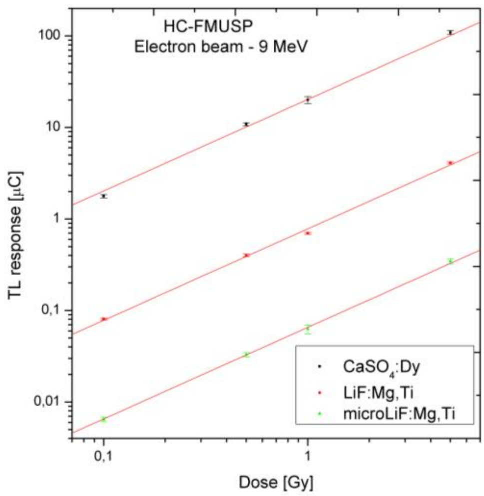

Fig. 6: Dose-response curves to 9 MeV electrons using solid water phantom.

The dose-response curves of the studied materials ($CaSO_4$:Dy; LiF;Mg,Ti and microLiF:Mg,Ti) present linear behavior for absorbed doses up to 10 Gy. Figure 7 presents the average sensitivity of the three types of TLDs to 6 and 9 MeV clinical electrons beams using solid water phantom.

Analyzing the TL sensitivities can be observed that the $CaSO_4$:Dy dosimeters present TL sensitivity approximately 30 and 400 times higher than LiF:Mg,Ti and microLiF:Mg,Ti dosimeters, respectively.

Table 2 presents the average reproducibility of the TL response of the three types of dosimeters, according to electron beam energy.

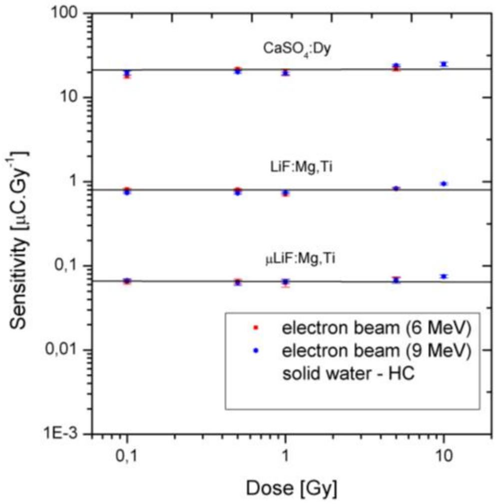

Fig. 7: Average sensitivity of the TLDs to 6 and 9 MeV electrons using solid water phantom.

Table 2: Average reproducibility of the TL response of dosimeters.

Hospital	Beam	Reproducibilities (%)		
	Electron	$CaSO_4$:Dy	LiF:Mg,Ti	μLiF:Mg,Ti
HC-FMUSP	6 MeV	1.22	0.723	1.85
	9 MeV	1.51	0.644	2.41

4. CONCLUSION

It may be noted that the TL response of the microLiF:Mg,Ti dosimeters are not adjusted in the calibration curve for the lower doses. This may be due to the lower detection limit of this type of dosimeter.

The dose-response curves obtained presents linear behavior in the 6 and 9 MeV electrons dose range from 0.1 to 10 Gy.

The average sensitivity calculated for each dose shows little variation, especially for the two varieties of LiF:Mg,Ti. The TLD of $CaSO_4$:Dy shows a greater variation in mean sensitivity, a result that was expected because the thermoluminescence is an effect dependent on the mass and area of the dosimeter and also by a sensitivity higher than the other dosimeters. By analyzing the sensitivities can also conclude that the three types of TLDs showed no energy dependence in the energy range studied.

The TL response reproducibility is better than ± 2.41% for both 6 and 9 MeV electron beams in accordance with the references found in literature [6, 8].

The $CaSO_4$:Dy pellets, developed and produced in commercial scale by the Laboratory of Dosimetric Materials/IPEN can represent a cheaper alternative to the imported chips TLD-100 to be applied in clinical photon beams dosimetry and its main advantage is the high TL sensitivity.

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