Characterization of OSL response of LiF:Mg,Ti and microLiF:Mg, Ti to ^{60}Co gamma source

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Abstract
OSL dosimetry has been investigated for medical dosimetry applications due to its characteristics for applications in external beam radiation therapy. The ability to register the absorbed dose accumulated in the detector over extended periods of time, the high sensitivity, small detector size and real time measures of the OSL detectors make this technique suitable to be used as personal dosimetry technique. In the OSL technique no heating is required to the dose measurement, so there are no changes in the physical characteristics of the material and non-destructive readout, in other words, repetitive measures for the same material can be carried out. In this work the gamma dose assessment using LiF:Mg,Ti and microLiF:Mg,Ti dosimeters from Harshaw was evaluated using OSL technique. The dosimeters were previously selected according to its TL sensitivity to ^{60}Co gamma radiation. The dosimeters were heat-treated using a furnace Vulcan model 3-550 PD and were irradiated in air at electronic equilibrium conditions using a ^{60}Co gamma source with doses ranging from 0.1 up to 12 Gy. The OSL and TL measures were performed using an OSL reader Risø. The studied parameters were reproducibility, dose response and lower detection limit.

Key Words: Lithium Fluoride, Optically Stimulated Luminescence, ^{60}Co gamma source.

1. Introduction

The dosimetry of ionizing radiation is essential for the radiological protection programs for quality assurance and licensing of equipment. In radiotherapy treatments is necessary to be sure that the patient is receiving the correct prescribed dose and the main objective of dosimetry in radiotherapy is to determinate with greater precision the absorbed dose to the tumor [1].

The optically stimulated dosimeters (DOSLs) have not been much exploited in medicine yet, but Yukihara and McKeever 920080 mention that research involving optically stimulated luminescence (OSL) technique is increasing gradually in recent years. Properties as high sensitivity and the all-optical nature of the process are the two properties exploited most in medical dosimetry application [2]. The OSL is a signal emitted by an insulating or semiconducting material when exposed to light, after being irradiated. The intensity of the OSL signal is proportional to the dose of radiation absorbed by the detector [3]. The process is similar to the thermoluminescence, but differs in the stimulation: instead of thermal stimulation, in OSL defects in the detector are stimulated by optical means [4].

The OSL response of LiF:Mg,Ti (TLD-100) dosimeters to alpha and beta particles to application to mixed-field radiation dosimetry was investigated by *Oster et al* by measuring the excitation and emission spectra of OSL and comparing with thermoluminescent (TL) characteristics [5]. This paper aims to measure the OSL and TL response using an OSL reader Risø and study the reproducibility, dose response and lower detection limit of the LiF:Mg,Ti and microLiF:Mg,Ti to OSL technique.

2. Materials and Methods

Before irradiation the dosimeters were heat-treated 400ºC/1h using a furnace VULCAN model 3-550 PD plus 100ºC/2h using a furnace FANEN model 315-IEA 11200. Forty dosimeters of each type, LiF:Mg,Ti and microLiF:Mg,Ti, were irradiated in air under electronic equilibrium conditions with a ^{60}Co gamma source (656.4MBq) to be selected according to their sensitivity. After the TL readings the individual and average TL responses of the dosimeters were obtained, they were separated into 16 groups of 5 detectors each according to their sensitivity (8 groups of microLiF:Mg,Ti and 8 groups of LiF:Mg,Ti). One group was used to be the reference of background measures (0Gy).

Table 1 summarizes the heat-treatment of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters and the parameters used to gamma irradiation, to the selection of dosimeters and doses measures.

Table 1 – Parameters of gamma irradiation of LiF Dosimeters: heat-treatment, characteristics of dosimeters and gamma sources properties.

Material	**TLD- 100– LiF:Mg,Ti - microLiF:Mg,Ti**
Heat-Treatment	1h/400ºC + 2h/100ºC
Detectors Dimensions	LiF:Mg,Ti: 3.15 x 3.15 x 1.00 mm microLiF:Mg,Ti: 1.00 x 1.00 x 1.00 mm
Gamma Sources – dosimeters selection	^{60}Co – gamma source of GMR/IPEN* (656.4MBq)
dose response measures	^{60}Co – Panoramic Irradiator of CTR/IPEN** (12.46TBq)
Dose-rate (40 cm source-detector distance) –	19.1 Gy/h (February/2012) (12.46TBq)
Transit Dose (40 cm source-detector distance) –	0.0517 Gy (February/2012) (12.46TBq)
Absorbed Doses	0.1, 0.5, 1.0, 3.0, 5.0, 10, 12 Gy

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To evaluate the doses responses the irradiation parameters for each group of 5 dosimeters were: 40 cm source-detector distance and doses ranging from 0.1 up to 12 Gy, in air under electronic equilibrium conditions using a ^{60}Co gamma source (12.46TBq). Each value quoted in this paper is the average of measurements of five dosimeters of the same sensitivity group and the error bars represent the standard deviation of the mean (1σ).The reproducibility and the lower detection limit (LDL) were calculated with the respective equations:

$$\text{Reproducibility}\,(\%) = \frac{\sigma}{\sqrt{\text{n}} \cdot \overline{R}} \cdot 100\,,$$

$$LDL = \overline{R}(0) + 3 \cdot \sigma\,,$$

where: σ is the standard deviation, n is the number of dosimeters, $\overline{R}$ is the mean of the response, OSL or TL, of the dosimeters of each group and $\overline{R}(0)$ is the average response of non-irradiated dosimeters.

3. Results and Discussion

The Figure 1 shows the TL dose-response curves of LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to ^{60}Co gamma radiation. The OSL dose-response curves of the same dosimeters are presented in Figure 2 and 3. The Figure 3 shows the OSL dose-response curve to microLiF:Mg,Ti with all doses values studied.

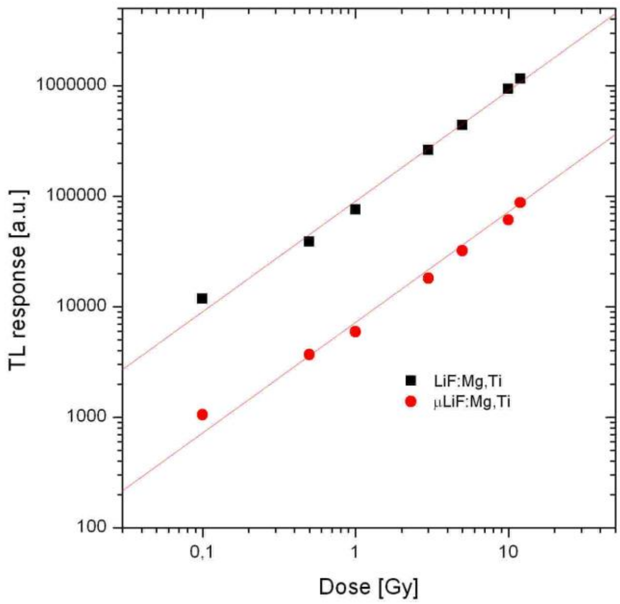

Fig. 1. TL Dose–response curves for the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters.

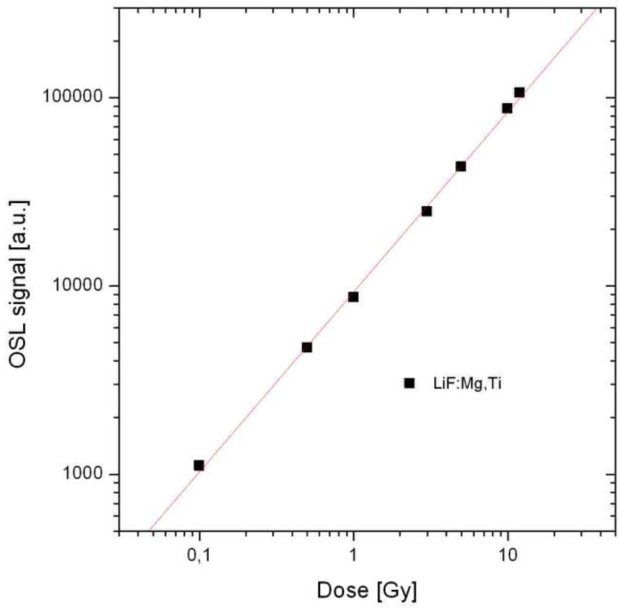

Fig. 2. OSL Dose–response curve for the LiF:Mg,Ti dosimeters.

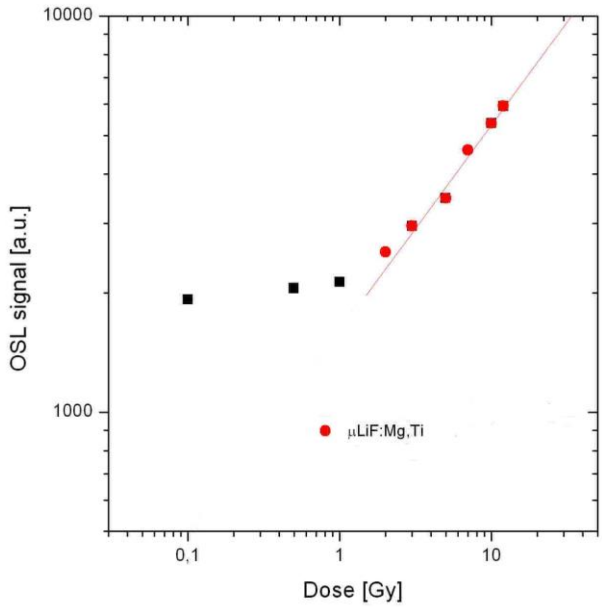

Fig. 3. OSL Dose–response curve for the microLiF:Mg,Ti TL dosimeters.

The TL dose-response curves to ^{60}Co gamma radiation of both dosimeters present linear behaviour in the dose range from 0.1 to 12 Gy.

The OSL dose-response curve to the microLiF:Mg,Ti dosimeters is linear from their LDL, 2Gy, to 12 Gy.

The Tables 1 and 2 present the LDL and the reproducibility of the dosimeters studied to ^{60}Co gamma radiation using the TL and OSL technique, respectively.

Table 1: LDL and reproducibility of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to ^{60}Co using TL technique.

TL	Dose [Gy]	0	0,1	0,5	1	3	5	10	12
microLiF:Mg,Ti	**LDL**	0.1 Gy							
	reproducibility [%]	±1.94	±1.36	±0.80	±1.83	±1.22	±1.20	±1.97	±2.17
LiF:Mg,Ti	**LDL**	0.1 Gy							
	reproducibility [%]	±1.59	±0.85	±1.35	±1.94	±1.77	±1.31	±2.02	±1.56

Table 2: LDL and reproducibility of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to ^{60}Co using OSL technique.

OSL	Dose [Gy]	0	0.1	0.5	1	3	5	10	12
microLiF:Mg,Ti	**LDL**	2 Gy							
	Reproducibility [%]	±2.08	±1.97	±1.59	±0.75	±1.16	±0.85	±1.38	±2.40
LiF:Mg,Ti	**LDL**	0.1Gy							
	reproducibility [%]	±1.27	±0.72	±0.55	±1.22	±0.48	±1.61	±0.42	±1.04

Analyzing the Tables 1 and 2, we can conclude that the LDL of microLiF:Mg,Ti for OSL is approximately 10 times higher than the LiF:Mg,Ti and the reproducibility of the two types of dosimeters and to all doses is in accordance with the references in the literature, 5% [2]. To microLiF:Mg,Ti, the reproducibility ranged from ±0.80% to ±2.17% and from ±0.85% to ±2.4% to TL and OSL technique, respectively. To LiF:Mg,Ti, it ranged from ±0.85% to ±2.02% and from ±0.42% to ±1.61% to TL and OSL technique, respectively.

4. Conclusions

The OSL dose-response curve is linear to the dose range studied to LiF:Mg,Ti and linear from 3 Gy to 12 Gy to the microLiF:Mg,Ti dosimeters. The microLiF:Mg,Ti dosimeters are more sensitive to the TL than OSL technique and, its LDL is higher than to LiF:Mg,Ti to the OSL technique. As expected, the sensitivity of the microLiF:Mg,Ti is lower than LiF:Mg,Ti considering thar the TL and OSL responses related to the mass of the detector. All values of reproducibility are in accordance with the literature, ±5%, to the two types of dosimeters. Considering the preliminary results, LiF:Mg,Ti dosimeters can be indicate to be used in the OSL measures for application to the gamma dosimetry.

Acknowledgments

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References

[1] METCALFE, P.; KRON, T.; HOBAN, P. The Physics of Radiotherapy X-rays from Linear Accelerators. Madison, WI: Med. Phys, 2007.

[2] E.G.Yukihara, S.W.S.McKeever. Optically Stimulated Luminescence - Fundamentals and Applications.1st Ed. Oklahoma, USA. (2011).

[3] BOTTER-JENSEN, L.; McKEEVER, S. W. S.; WINTLE, A. G. Optically stimulated luminescence dosimetry. Amsterdam: Elsevier, 2003.

[4] YUKIHARA, E.G.; McKEEVER, S.W.S. Optically stimulated luminescence (OSL) dosimetry in medicine, Phys. Med. Biol., v.53, p.R351-R379, 2008.

[5] L.OSTER, Y.S.HOROWITZ, L.PODPALOV. OSL and TL in TLD-100 following alpha and beta irradiation: Application to mixed-field radiation dosimetry, Rad.Measurements. 45, p.1130-1133, 2010.