Characterization of Optically Stimulated Luminescence Response of LiF:Mg,Ti and microLiF:Mg,Ti Dosimeters for Beta Radiation

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Abstract

Optically Stimulated Luminescence (OSL) is the transient luminescence observed during illumination of crystalline insulators or semiconductors that were previously excited, typically by exposure to ionizing radiation. The phenomenon has been known for a long time and has been suggested for radiation detection first in the mid-twentieth century. Developments over the past two or three decade in OSL and TL dosimetry have led to the application of these techniques in many radiation dosimetry fields, including personal, environmental, retrospective, space, neutron and medical dosimetry [1]. This work aims to study the application of OSL technique using dosimeters of lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti and microLiF:Mg,Ti) produced by *Harshaw Chemical Company* for application in beta dosimetry. The dose-response curves for doses ranging from 0.5 to 15 Gy, thermal fading to a storage period up to 48 hours (under environment free of light) and the reproducibility of the OSL response of the dosimeters for beta radiation of an ^{90}Sr-^{90}Y source were evaluated.

Keywords: Optically Stimulated Luminescence, LiF:Mg,Ti, microLiF:Mg,Ti, beta dosimetry.

1- Introduction

The first use of Optically Stimulated Luminescence [2,3,4], OSL, as a dosimeter was to measure luminescence from quartz for dating sediments and artifacts from archeological samples exposed to background radiation for thousands of years. The use of synthetic materials for OSL has greatly improved the sensitivity of the method; it has now been used for about 10 years as a method for monitoring occupational radiation dose [5]. OSL dosimeters have been a replacement for personnel dose monitoring with film badges. The OSL material has now been fabricated into a dosimeter that can be used for *in vivo* dosimetry of radiation therapy patients [5].

The phenomenological description of the OSL and thermoluminescence, TL, process are the same. Pure crystalline dieletric materials either contain or have added trace amounts of contaminants that form crystal-lattice imperfections. These imperfections act as traps for electrons or holes and also can act as luminescence centers, which emit light when electrons or holes recombine near them [5]. After irradiation, free electrons and holes are generated that can be trapped. When the crystal is heated or optically stimulated, electrons can be ejected out of traps and recombine with holes at the F+ center. The recombination energy is transferred to a luminescence center where light is emitted [5].

In radiodiagnosis OSL has been used with great success in imaging systems. *In vivo* dosimetry is desired for cancer patients to ensure that the patient is not overexposed or that the exposure occurred in the desired region [5,6]. The high sensitivity means that the dosimeters can be very small, which gives them the property of high spatial resolution, meaning that they have the potential for measurement of dose in regions of severe dose gradients.

This work aims to study the application of OSL technique using dosimeters of LiF:Mg,Ti and microLiF:Mg,Ti produced by *Harshaw Chemical Company* for application in beta dosimetry. The dose-response curves for doses ranging from 0.5 to 15 Gy, thermal fading to a storage period up to 48 h (under environment free of light) and the reproducibility of the OSL response of the dosimeters for beta radiation of an ^{90}Sr-^{90}Y source were evaluated.

2- Materials and methods

To establish a consistent set of dosimeters was used fifty dosimeters of each type: LiF:Mg,Ti and microLiF:Mg,Ti (TLD-100). These dosimeters were produced by *Harshaw Chemical Company* (EUA). The dimensions of the two types of TLD-100 and the specifications of the OSL reader and of the beta radiation source are shown in table 1.

Table 1: TL dosimetric materials, specifications of OSL reader and beta radiation source.

Material	Composition	Dimensions
TLD type		
TLD-100	LiF:Mg,Ti	3.15 mm x 3.15 mm x 0.9 mm
Micro TLD-100	LiF:Mg,Ti	1 mm x 1 mm x 1 mm
OSL reader	**Model**	**Source**
RisØ	TL/OSL DA-20	^{90}Sr-^{90}Y*

*The beta radiation source is accommodated inside the OSL reader.

Initially, the dosimeters were submitted to the pre-irradiation heat treatment that consisted of 1 hour at 400ºC in a microwave furnace and 2 hours at 100ºC in a surgical heater (table 2).

Table 2: Equipments and parameters of pre-irradiation heat treatment.

Dosimeter	Equipment	Heating Temperature	Period
LiF:Mg,Ti and microLiF:Mg,Ti	Furnace Vulcan	400º C	1 hour
		+	+
	Surgical heater	100º C	2 hours

The dose-response curves were obtained to the cobalt-60 gamma radiation source from Laboratory of Dosimetric Materials/LMD-IPEN (A=0.656 GBq on 09/12/2008). The dosimeters were irradiated in air and positioned on PMMA plates to ensure the electronic equilibrium conditions. The dosimeters were previously selected according to their thermoluminescent responses for ^{60}Co gamma radiation with sensitivities better than ± 5%.

The irradiation and reading of dosimeters were performed using a beta source (^{90}Sr-^{90}Y, dose rate = 0.1 Gy/s) accommodated inside the RisØ TL/OSL DA-20 reader of the OSL Laboratory of Gerência de Metrologia das Radiações (GMR-IPEN). The LiF:Mg,Ti dosimeters were stimulated with the blue LED (NICHIA, type NSPB -500AS) with an emission peak of 470 nm and it was used the Hoya U-340 filter. Before the measurements, tests were performed for verifying the operation of the photomultiplier tube in order to check the interference from any external light.

The OSL dose-response curves were obtained for the following doses: 0.5, 1, 2, 5, 10 and 15 Gy. The OSL fading curves of the dosimeters were obtained by readings

1 min, 5 min, 10 min and 1 hour after irradiation. Each presented value represents the average of five OSL readings and the error bars the standard deviations of the mean (1σ) with a confidence level of 95%.

3- Results

Figures 1 and 2 presents the OSL dose-response curves of LiF:Mg,Ti and microLiF:Mg,Ti, respectively, to beta radiation of an ^{90}Sr-^{90}Y source. Figures 3 and 4 presents the OSL dose-response curves of LiF:Mg,Ti and microLiF:Mg,Ti to the beta radiation source for doses ranging from 0.5 to 15 Gy. Figures 5 and 6 presents the OSL fading curves of the LiF:Mg,Ti and microLiF:Mg,Ti.

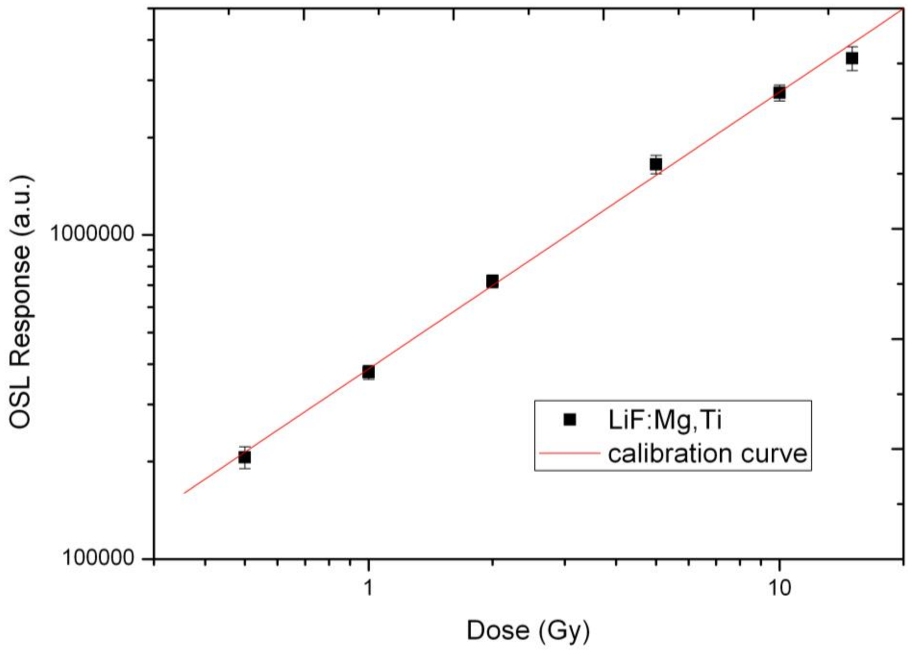

Fig. 1: OSL dose-response curve of LiF:Mg,Ti to beta radiation of an ^{90}Sr-^{90}Y source.

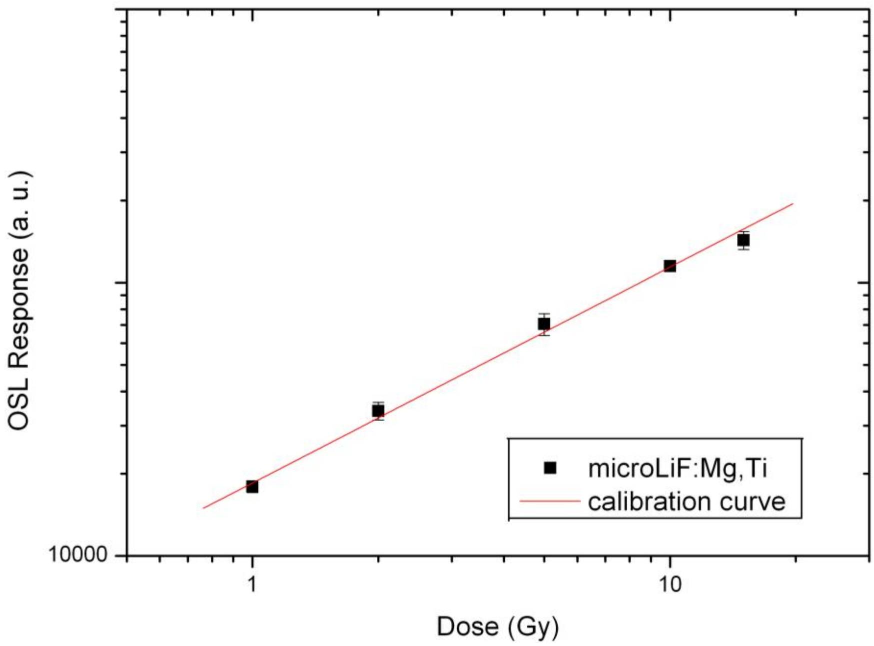

Fig 2: OSL dose-response curve of microLiF:Mg,Ti to beta radiation of an ^{90}Sr-^{90}Y source.

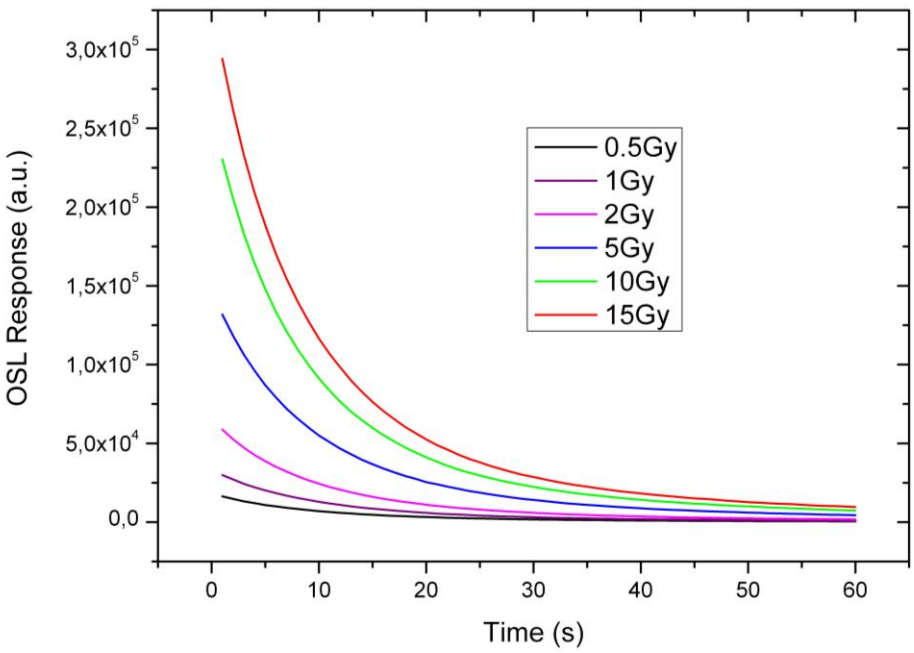

Fig. 3: OSL response curve of LiF:Mg,Ti according to the beta radiation doses of ^{90}Sr/^{90}Y.

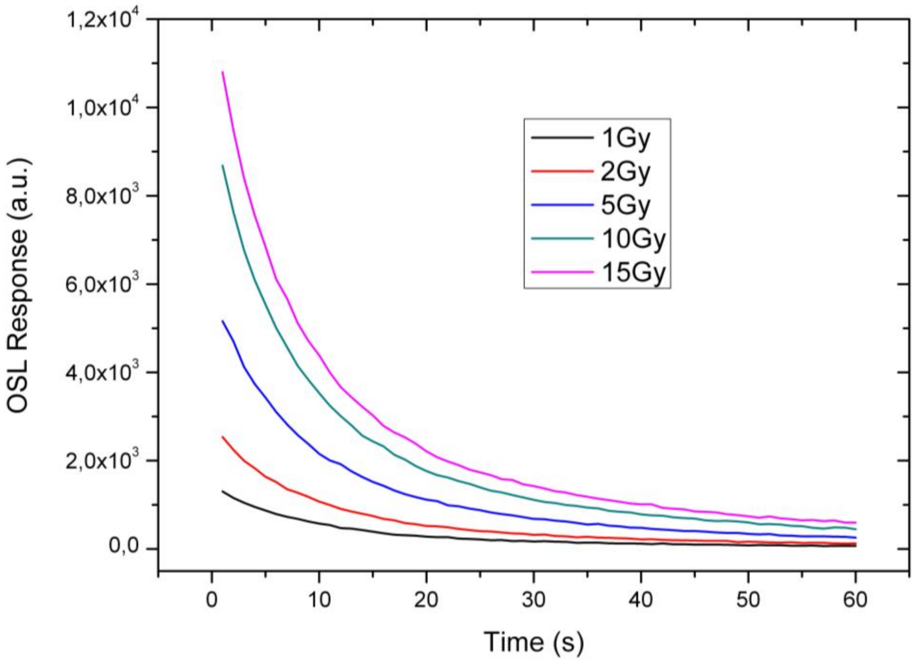

Fig. 4: OSL response curve of microLiF:Mg,Ti according to the beta radiation doses of $^{90}Sr/^{90}Y$.

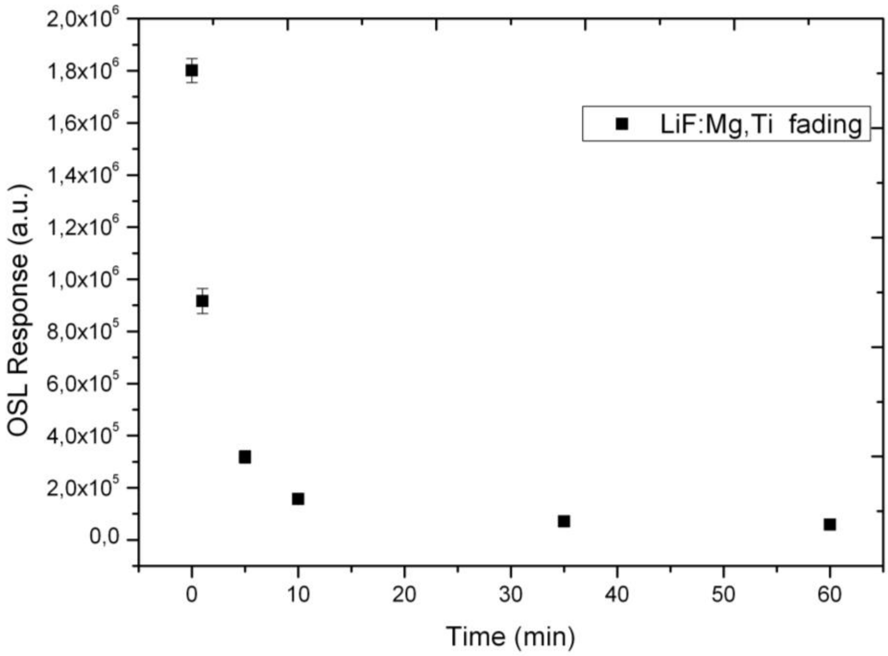

Fig. 5: OSL fading curve of the LiF:Mg,Ti for reading time up to 1 hour after irradiation.

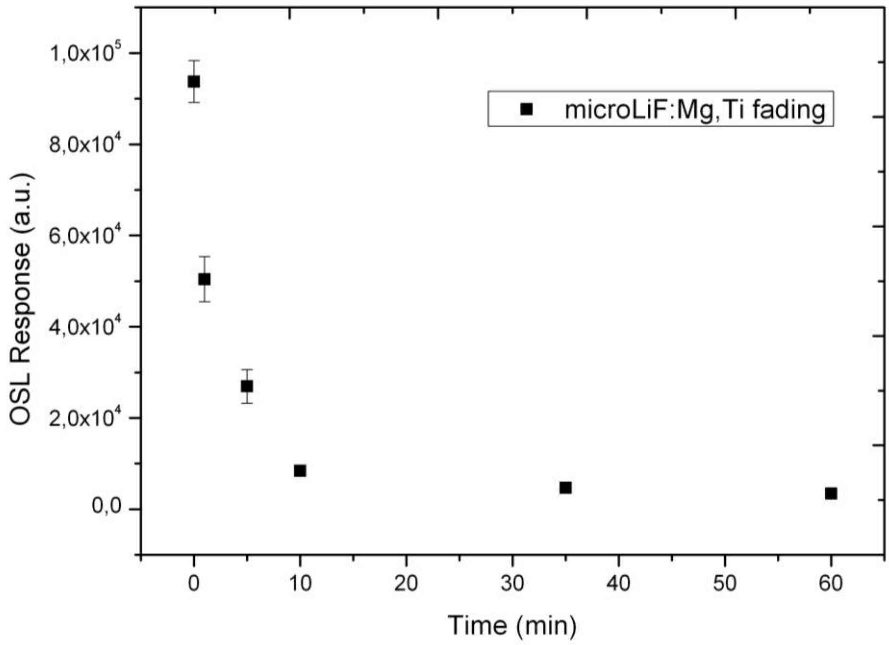

Fig. 6: OSL fading curve of the microLiF:Mg,Ti for reading time for up to 1 hour.

The OSL response reproducibilities of the LiF;Mg,Ti dosimeters were calculated according to the beta radiation doses (table 3).

Table 3: OSL response reproducibility (± %) of the LiF;Mg,Ti and microLiF:Mg,Ti dosimeters.

	LiF:Mg,Ti	**microLiF:Mg,Ti**
Dose (Gy)	**Reproducibility (± %)**	
0.5	0.69	4.04
1	1.11	4.52
2	0.84	4.21
5	3.41	4.57
10	1.20	2.70
15	1.48	4.89

4- Conclusion

According to the analysis of Fig. 1 and 2 can be observed a linear behavior to the dose range from 0.5 to 10 Gy to beta radiation of $^{90}Sr/^{90}Y$, for doses higher than 15 Gy can be noted a beginning of supralinearity behaviour. Further studies will be made to better analyze the supralinear behaviour of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters.

The results of Fig. 3 and 4 showed that the OSL signal is proportional to the absorbed radiation dose, i.e., it increases with the number of electrons and holes trapped. For the analysis of Fig. 5 and 6 can be concluded that the fading occurs within the first 10 minutes after irradiation. After a period of 1 hour the signal remains substantially constant over a period longer than 48 hours [7] (maximum time measured in this study). The fading is an effect that may be related to other parameters such as material type, reading profile and treatment process [8]. In this study can be observed a decrease of the OSL signal 11.46 and 11.13 times between the reading time (immediately after the irradiation) and the period of 72 hours after irradiation for LiF:Mg,Ti and microLiF:Mg,Ti, respectively.

The OSL response reproducibility of the both dosimeters type studied is better than ± 4.89%, lower than 5% required for radiation therapy.

Taking into account the initial results of reproducibility and OSL dose-response curves the LiF;Mg,Ti and microLiF:Mg,Ti dosimeters may be used for application to beta dosimetry.

5- Acknowledgements

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