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Study of Optically Stimulated Luminescence of LiF:Mg,Ti for beta and gamma dosimetry

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HIGHLIGHTS

- Study of Optically Stimulated Luminescence of LiF:Mg,Ti and microLiF:Mg,Ti.
- OSL response of TLD-100 dosimeters to beta and gamma radiation.
- Analysis of repeatability and lowest levels of detection of detectors LiF:Mg,Ti.

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ABSTRACT

Modern advances in radiation medicine – radiodiagnosis, radiotherapy and interventional radiography – each present dosimetry challenges for the medical physicist that did not exist previously. In all of these areas a constant balance has to be made between the treatment necessary to destroy the tumor and the unnecessary exposure of healthy tissue. Innovative applications of OSL dosimetry are now appearing in each of these areas to help the medical physicist and oncologist design the most effective, and least deleterious, treatment for their patients. High sensitivity, precise delivery of light, fast readout times, simpler readers and easier automation are the main advantages of OSL in comparison with TLD.

This work aimed to study the application of OSL technique using lithium fluoride dosimeters doped with magnesium and titanium (LiF:Mg,Ti) for application in beta and gamma dosimetry.

1. Introduction

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 excitation puts the crystal in a metastable state, characterized by electrons and holes, separately trapped at defects in the crystal lattice. Dosimetric techniques based on luminescence are related to the deposition of energy by ionizing radiation, and the resulting accumulation of charge carriers (electrons or holes) in energy states that are stable at the temperature of irradiation, commonly called traps. A radiative recombination of charges occurs, with emission of light, when the charge carriers are released from their traps due to an additional energy input. The light intensity is commensurate with the energy deposited by the ionizing radiation in the material (Yukihara and McKeever, 2011; Bøtter-Jensen et al., 2003; Akselrod et al., 2007; Jursinic, 2007; McKeever, 2011; Yoshimura and Yukihara, 2006).

In radiation therapy the combined advances in medical imaging, radiation delivery techniques and treatment planning have provided us with an increasing ability to characterize tumors and conform the dose distributions to complex shapes, allowing an escalation of the dose to the target while sparing healthy tissues and critical organs or structures (Yukihara and McKeever, 2011). In intensity modulated radiation therapy (IMRT), for example, the patient is irradiated from multiple directions with megavoltage X-ray beams of non-uniform intensities determined by a three-dimensional treatment planning algorithm (Yukihara and McKeever, 2011). The precision and accuracy of modern radiation therapy techniques relies on robust and comprehensive quality assurance and quality control.

The outcome of treatment depends upon tumor doses that do not vary by more than ±5% about the optimum (American Association of Physicists in Medicine, 1983). In radiotherapy dosimetry the uncertainty associated with the measurement is

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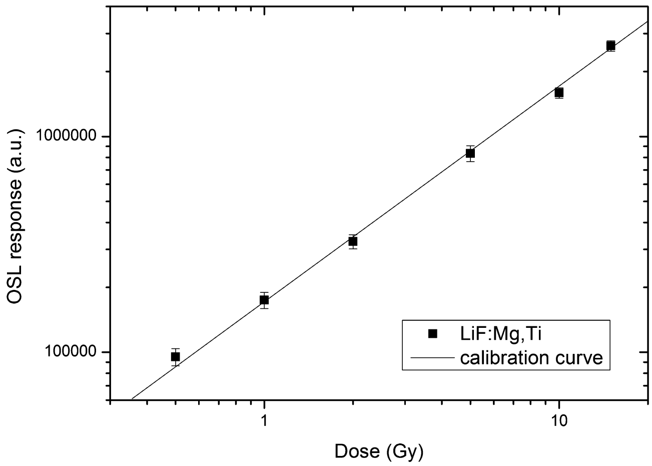

Fig. 1. OSL dose–response curve of LiF:Mg,Ti to gamma radiation of an ^{60}Co source (the calibration curve was obtained in Origin 7.5 (slope = 1)).

often expressed in terms of accuracy and precision (Podgorsak, 2005). The precision of dosimetry measurements specifies the repeatability of the measurements under similar conditions (Podgorsak, 2005). The sum of the uncertainties associated with radiotherapy dosimetry as intrinsic uncertainty of the dosimeter, the uncertainty associated with the OSL reader, error in the positioning of dosimeters during irradiation, uncertainty associated with the radiation beam should be up to 5% (American Association of Physicists in Medicine, 1983).

This work aimed to study the application of OSL technique using dosimeters of lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti) produced by *Harshaw Chemical Company* for application in beta and gamma dosimetry. The dosimeters were previously selected according to their thermoluminescent responses for ^{60}Co gamma radiation with sensitivities better than ±5%. The dose–response curves for doses ranging from 0.5 to 15 Gy and the repeatabilities of the OSL response of the dosimeters for beta and gamma radiation were evaluated. The lowest levels of detection were calculated for the LiF:Mg,Ti dosimeters to both type of radiation.

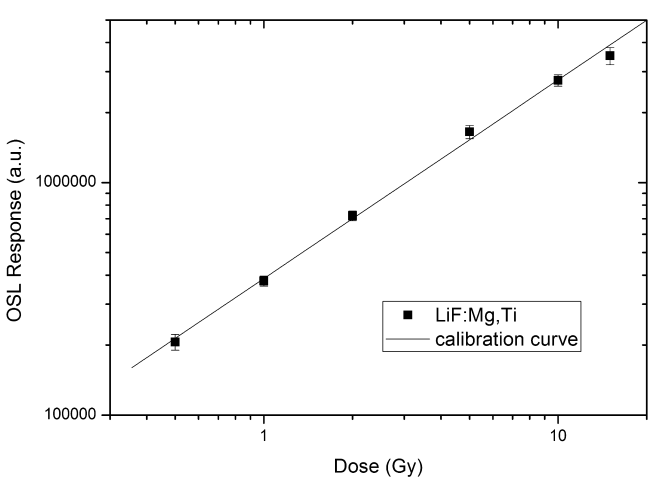

Fig. 2. OSL dose–response curve of LiF:Mg,Ti to beta radiation of an ^{90}Sr–^{90}Y source (the calibration curve was obtained in Origin 7.5 (slope = 1)).

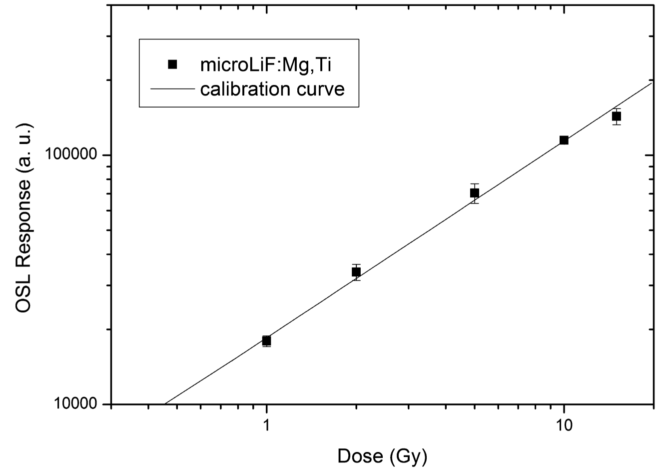

Fig. 3. OSL dose–response curve of microLiF:Mg,Ti to beta radiation of an ^{90}Sr–^{90}Y source (the calibration curve was obtained in Origin 7.5 (slope = 1)).

2. Materials and methods

Fifty TLD-100 dosimeters of each type: LiF:Mg,Ti and microLiF:Mg,Ti (TLD-100) produced by *Harshaw Chemical Company* (USA) were used to dose evaluation. The dimensions of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters are: 3.15 mm × 3.15 mm × 0.9 mm and 1 mm × 1 mm × 1 mm, respectively. The dose–response curves were obtained to ^{60}Co panoramic gamma radiation source (the activity of gamma source was 11.7 TBq on 07/08/2012). The dosimeters were irradiated in air and positioned between polymethylmethacrylate (PMMA) plates, having a build-up thickness of 3.0 mm. The dosimeters were previously selected according to their thermoluminescent (TL) responses for ^{60}Co gamma radiation with sensitivities better than ±5%. The beta irradiations and readings were performed using a ^{90}Sr–^{90}Y beta source (dose rate: 0.1 Gy/s) accommodated inside an automated RisØ TL/OSL DA-20 reader. The LiF:Mg,Ti dosimeters were stimulated with the blue LED (NICHIA, type NSPB-500AS), in a constant illumination intensity mode (CW), with an emission peak of 470 nm and it was used the Hoya U-340 filter. The OSL decay curves were obtained for the following doses: 0.5, 1, 2, 5, 10 and 15 Gy. Each presented value (Figs. 1–7) represents

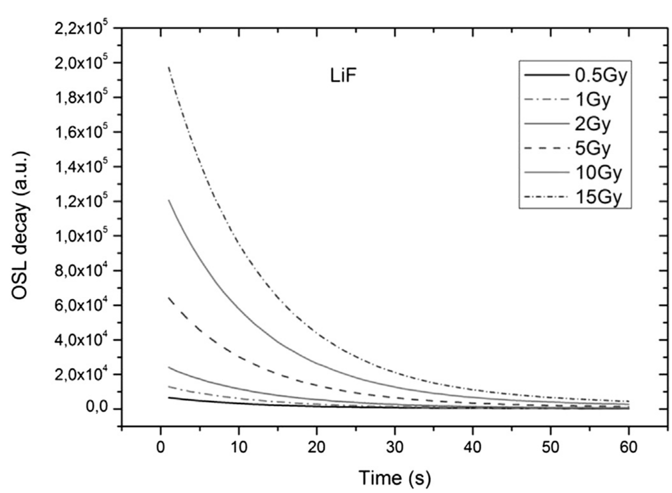

Fig. 4. OSL decay curves of LiF:Mg,Ti according to the gamma radiation doses of ^{60}Co.

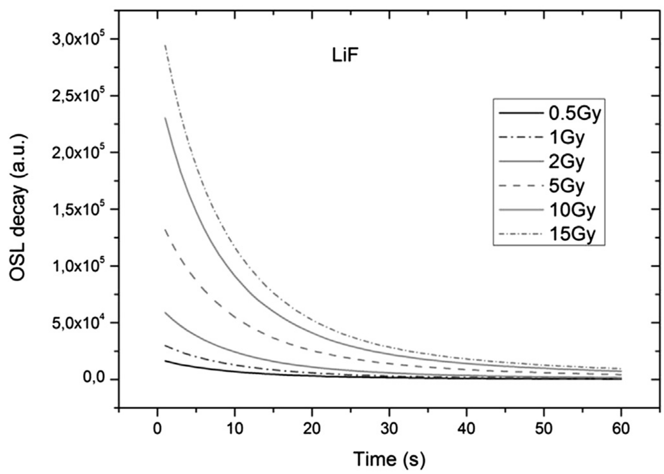

Fig. 5. OSL decay curves of LiF:Mg,Ti according to the beta radiation doses of $^{90}Sr/^{90}Y$.

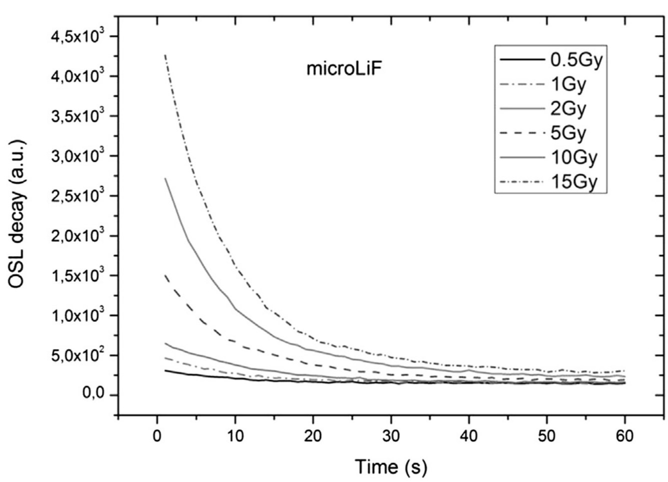

Fig. 6. OSL decay curves of microLiF:Mg,Ti according to the to the gamma radiation doses of ^{60}Co.

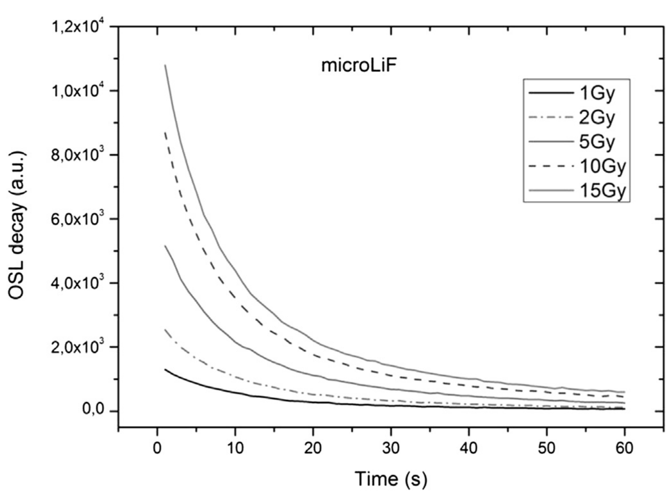

Fig. 7. OSL decay curves of microLiF:Mg,Ti according to the beta radiation doses of $^{90}Sr-^{90}Y$.

Table 1
OSL response repeatability (±%) of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to gamma and beta radiation.

Dose (Gy)	Repeatability (±%)			
	Gamma radiation		Beta radiation	
	LiF:Mg,Ti	microLiF:Mg,Ti	LiF:Mg,Ti	microLiF:Mg,Ti
0.5	0.91	0.33	0.51	4.82
1	0.86	0.52	1.56	2.57
2	0.75	0.71	1.32	1.84
5	0.84	0.92	0.98	2.95
10	0.55	0.87	1.55	0.97
15	0.54	1.51	1.22	1.70

the average of ten OSL readings and the error bars the standard deviations of the mean (1σ) with a confidence level of 95%.

3. Results

Figs. 1 and 2 presents the OSL dose–response curves of LiF:Mg,Ti to gamma (^{60}Co) and beta ($^{90}Sr-^{90}Y$) radiation sources, respectively. Fig. 3 present the OSL dose–response curve of microLiF:Mg,Ti to beta radiation ($^{90}Sr-^{90}Y$ source). Figs. 4 and 5 presents the OSL decay curves of LiF:Mg,Ti to the gamma and beta radiation, respectively. Figs. 6 and 7 presents the OSL decay curves of microLiF:Mg,Ti to the gamma and beta radiation, respectively. In Figs. 4–7 can be noted that the OSL signal obtained with blue light stimulation is intense and proportional to dose (the OSL readout time was 60 s).

The lowest levels of detection (LLD) found for LiF:Mg,Ti dosimeters are 60.08 mGy and 31.55 mGy, respectively, for gamma and beta radiation and for microLiF:Mg,Ti dosimeters is 607.7 mGy for beta radiation.

The repeatability of the OSL responses were calculated according to the gamma and beta radiation doses (Table 1). The results found are lower than 3% (that is the sum of all main uncertainties, which are within recommended in the literature) (American Association of Physicists in Medicine, 1983; Podgorsak, 2005), except the OSL response repeatability for microLiF:Mg,Ti to beta radiation dose of 0.5 Gy that is 4.82% (this result can be explained considering that the dose is of the same order of the LLD).

4. Conclusion

According to Figs. 1–3 can be observed a linear behavior of the LiF:Mg,Ti (Figs. 1 and 2) and microLiF:Mg,Ti (Fig. 3) OSL responses in the dose range studied from 0.5 to 15 Gy to gamma and beta irradiation, respectively. The analysis of Figs. 4–7 shows that LiF:Mg,Ti and microLiF:Mg,Ti dosimeters are more sensitive for beta radiation than gamma radiation (the lowest level of detection for LiF:Mg,Ti is approximately twice higher for beta radiation). The OSL response repeatabilities of both dosimeters type studied is better than ±3%, lower than 5% required for radiation therapy. These preliminary studies indicate that OSL method associated with LiF:Mg,Ti and microLiF:Mg,Ti dosimeters may be used for radiation therapy since the doses of treatment are higher than for personal dosimetry.

Acknowledgments

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