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OSL and PTOSL of dosimetric materials: Observation of the luminescence after exposure to ^{90}Sr+^{90}Y source and LEDs in ultraviolet range

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ABSTRACT

The study of luminescence phenomena by crystal-based radiation detectors is suitable for radiation dosimetry, once the light emitted by them enables the quantification of their deposited radiation energy. The light emission can be promoted when a material is illuminated with a certain wavelength and time interval, as in the optically stimulated luminescence (OSL) and photo-transferred OSL (PTOSL) processes. The objective of this work is to evaluate the OSL and PTOSL responses of commercial dosimeters (LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy) in order to study their luminescence and the possibility of use in radiation dosimetry with the PTOSL technique. OSL and PTOSL responses of LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy dosimeters, commercially sold as TLD-100, TLD-200, TLD-400 e TLD-900, respectively, by Thermo Fischer Scientific, were studied. The samples were irradiated with the ^{90}Sr+^{90}Y source of the TL/OSL reader system Risø, and the measurements were taken using the same system and blue LEDs. For the PTOSL signal, the dosimeters were irradiated, thermally treated and illuminated with LEDs with wavelengths between 265 nm and 420 nm. The most intense OSL signal occurred for TLD-100. Comparing the OSL and PTOSL results, it is possible to observe clearly the photo-transferred effect for TLD-100. For TLD-200 and TLD-400, no effects were noted. In the case of TLD-900, it presented a PTOSL signal in a small-scale when analyzing the curve integral.

1. Introduction

The OSL process is a technique that has been showing effectiveness and efficiency in studies of the luminescence response of materials and in the dosimetry of radiation beams in various fields of applications, such as personal (Lee and Lee, 2001; Nascimento and Hornos, 2010), environmental (Kobayashi et al., 2005; Woda et al., 2012), dating and retrospective dosimetry (Bøtter-Jensen and Murray, 1999; Afouxenidis et al., 2007; McKeever and Sholom, 2019) and medicine (Akselrod et al., 2007; Yukihara et al., 2010).

The photo-transferred optically stimulated luminescence (PTOSL) is another process that involves emission of luminescence of a pre-irradiated material. The PTOSL signal is technically like an OSL signal emitted from a dosimetric material after its irradiation and illumination. For a measurement of a PTOSL signal, it is necessary to occur photo-transfer of charges from one electron trap (deeper trap) to another (shallow trap) of the material (Bulur and Göksu, 1999; Gronchi and Caldas, 2013; Kalita and Chitambo, 2019; Chitambo et al., 2023).

In a material submitted to a beam radiation, the traps associated to the higher OSL signal intensity are emptied during a measurement procedure, as in reading of the OSL response of the material, which does not cause the emptying of the deep traps (stable traps). When this material is illuminated with a light of adequate energy and wavelength, the charges that still occupy the deep traps are liberated in a way of light signal or transferred to the shallow traps (unstable traps). This transfer of charges causes the emission of a PTOSL signal, which can be a great tool for the study of the properties that occur in the structure of the materials, as for example at the deep traps. The results of this studies, as well as the PTOSL signal obtained can be employed in radiation dosimetry (Bøtter-Jensen et al., 2003; Pradhan et al., 2008; Yukihara et al., 2022; 2023).

Several materials have been object of study about their OSL responses and proved to be effective in the area of radiation dosimetry, including for applications involving different radiation beams, among them materials that are produced as LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy and commercialized, respectively, as TLD-100, TLD-200, TLD-400 and TLD-900 (Sunta, 1984; Allen and McKeever, 1990; Oster et al., 2010; Kry et al., 2019; Stella et al., 2019; Kato et al., 2022).

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Gronchi and Caldas (2013) studied the PTOSL response of the Al_2O_3:C InLight detectors (Landauer) with the objective to apply them in the area of the ultraviolet radiation dosimetry. The photo-transferred response was studied after the exposing of the detectors to gamma radiation (^{60}Co), optical treatment, since InLight detectors cannot be heat treated because they have a plastic cover, and the illumination with UV light. As a result, the PTOSL technique proved to be effective for the detection and dosimetry of UV radiation, as fulfillment of the objective of this study.

This work aims to evaluate the luminescence responses of commercial dosimeters (LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy) by means of OSL and PTOSL phenomena, in order to study the intensity of their luminescent signal after exposing them to the ^{90}Sr+^{90}Y radiation (OSL signal) and illuminating them with LEDs in ultraviolet wavelength (PTOSL), to verify if there is presence of PTOSL response in these materials, and to analyze the possibility of their use in radiation dosimetry with the PTOSL technique.

2. Materials and methods

This work aimed the analysis of the luminescent response of the following commercial dosimetric materials: LiF:Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy, commercially sold by Thermo Fischer Scientific as TLD-100, TLD-200, TLD-400 e TLD-900, respectively. These materials were manufactured with 3.2 × 3.2 × 0.89 mm^3 of dimensions. LiF:Mg,Ti, CaF_2:Dy and CaF_2:Mn are still commercialized by Thermo for several applications: TLD-100 for research and clinical use; TLD-200 for environmental use, and TLD-400 for environmental and high dose dosimetry (Thermo Fischer Scientific, 2016).

The experiments were performed exposing the dosimeters to beta radiation, irradiating them with a^{90}Sr+^{90}Y source, with an absorbed dose rate of 0.1 Gy/s in June 10, 2010, of the TL/OSL reader system Risø, model TL/OSL-DA-20.

An important characteristic to verify the dosimetric conditions for a material to be used as radiation dosimeter is the minimum detectable dose (MDD). This value represents the minimum absorbed dose limit that a sample can indicate through its measurement. In this work, this dose was obtained according to the procedure described in the literature: relating the study of variation in the signal of the samples after thermal treatment (0R signal) and three times the standard deviation of the response of the samples under this same condition (after thermal treatment), and multiplying them by the calibration factor, which is the absorbed dose provided to the samples divided by the measurement obtained in terms of counts) (Pagonis et al., 2006).

The measurements were performed using the TL/OSL reader system Risø, and all the results from the measurements obtained during the experimental procedures were analyzed in terms of number of counts, reached from the integral of the area below of the OSL and PTOSL decay curves. For the measurements of OSL and PTOSL signal with the reader system Risø, the following parameters were adopted: light of blue LEDs as stimulus for signal emission, LED power of 90% and stimulation time of 100 s.

All OSL measurements were taken immediately after irradiation, since both steps were performed on the same equipment. The PTOSL measurements were obtained after three steps: 1) irradiation of the dosimeters, 2) post-irradiation thermal treatment, 3) illumination with light-emitting diodes (LEDs), and 4) PTOSL signal analysis. The LEDs used in this work consist in LED Saber devices manufactured by BioLambda (Fig. 1).

The sample lighting procedure was performed using the lighting/irradiation system, BioLambda, with two LED Saber devices, which have one unit of light-emitting diode in each device: one at a wavelength of 265 nm and the other at 365 nm. Along with LED Saber, a BlackBox controller system is used (which automatically recognizes the wavelength of the LED in application), where the adopted parameters of LED power, radiant exposure, irradiance and lighting time can be adjusted via touch. BlackBox is also responsible for turning the LEDs on and off.

Fig. 1. LED Saber device during an experimental procedure, with illumination of dosimeters.

The illumination steps with the LEDs were performed using certain chosen irradiance and radiant exposure values, depending of the wavelength of the LEDs.

The experiments that compose the studies of this work were carried out with 10 samples for the TLD-100, TLD-200 and TLD-400, and 15 samples for the TLD-900.

For their reuse, the samples after the measurements of the OSL and PTOSL signals were thermal treated at 400 °C/1 h.

3. Results

In order to promote a better understanding about the results, all the experiments and measurements performed in this work were divided into two main studies: initial study of OSL response and study of PTOSL response.

3.1. Study of OSL response

Initially, the commercial dosimeters were studied in relation to their dosimetric responses, by means of the following tests: behavior of the OSL decay curve, OSL response reproducibility, dosimeter response after heat treatment for reuse (called “0 radiation signal – 0R signal”), and minimum detectable dose (MDD).

3.1.1. OSL decay curves

Among the dosimetric characteristics of the tested materials, the behavior of the OSL signal decay curve as a function of illumination time of the sample was the first characteristic studied of the dosimeters.

For this initial study, the absorbed doses provided to the commercial dosimeters, during irradiation with the ^{90}Sr+^{90}Y source, were: 0.75 Gy for TLD-100 and TLD-900, 20 Gy for TLD-200 and 50 Gy for TLD-400. These doses were adopted based on tests previously carried out, with different absorbed doses, to check the post-irradiation signal.

The OSL signal decay curves were verified for all analyzed samples: 10 samples of TLD-100, TLD-200 and TLD-400, and 15 samples of TLD-900. Fig. 2a-d shows OSL signal decay curves obtained for two samples of each of the materials studied: TLD-100, TLD-200, TLD-400 and TLD-900. The curves shown correspond to the samples that presented a minimum and maximum counting point in the first second of illumination.

The OSL signal decay curves showed a certain difference in intensity between each of the two samples, which represents the minimum and maximum starting point of signal decay, in terms of counting, in the case of TLD-100, TLD-200 and TLD-900; for TLD-400, the signal between samples was similar. Table 1 shows the OSL intensity obtained in relation to two factors: the decay initial value and the integral value below the curve, both in terms of counts.

According to Fig. 2(a–d), it can be seen that the signal is more intense in the case of the LiF:Mg,Ti material (TLD-100), that the decay is faster for TLD-100 and TLD-400, and is slower for TLD-200 and TLD-900, as well as noisier, since the signal is less intense in these cases than in the other two materials.

3.1.2. Reproducibility of OSL response and signal after thermal treatment ("0R signal")

Response stability of the material, or reproducibility study, is one of the main characteristics that makes a material suitable for use in radiation dosimetry.

This study was carried out for the four dosimetric materials, with five series of: 1) irradiation with absorbed doses of 0.75 Gy for TLD-100 and TLD-900, 20 Gy for TLD-200 and 50 Gy for TLD-400, using the ^{90}Sr+^{90}Y source; 2) OSL signal analysis; and 3) thermal treatment for reuse of the samples.

Table 1
Intensity of the OSL signal in relation to the decay initial value and the integral of the curve for the materials: LiF:Mg,Ti (TLD-100), CaF_2:Dy (TLD-200), CaF_2:Mn (TLD-400) and $CaSO_4$:Dy (TLD-900).

Material	Intensity of the OSL Signal (counts)		
	Kind of Analysis	From	To
LiF:Mg,Ti (TLD-100) (Fig. 2a)	*Decay Initial Values*	3.98×10^4 (sample 7)	5.33×10^4 (sample 5)
	Curve Integral	1.57×10^9	1.95×10^6
CaF_2:Dy (TLD-200) (Fig. 2b)	*Decay Initial Values*	1.09×10^3 (sample 10)	2.25×10^3 (sample 6)
	Curve Integral	7.36×10^4	17.54×10^4
CaF_2:Mn (TLD-400) (Fig. 2c)	*Decay Initial Values*	$1.08.10^4$ (sample 10)	1.33×10^4 (sample 3)
	Curve Integral	2.65×10^5	2.97×10^5
$CaSO_4$:Dy (TLD-900) (Fig. 2d)	*Decay Initial Values*	1.55×10^3 (sample 11)	2.92×10^3 (sample 2)
	Curve Integral	9.78×10^4	17.06×10^4

The temperature and time used for the thermal treatment adopted to erase any residual signal from the TLD-100 and TLD-900 samples was 400 °C/1 h, according to the previously published work (McKeever et al., 1995; Furetta, 2010). For the TLD-200 and TLD-400 dosimeters, it was decided to also carry out the same thermal treatment (400 °C/1 h), although studies presented in the literature show a treatment for reuse of 500 °C/1 h. This decision was also taken after testing the OSL signal for this temperature/time. All these samples had been stored and unused for several years, and for this reason there was preoccupation that treating them at a temperature of 500 °C could cause damage to the material. Therefore, it was decided to subject them to 400 °C/1 h, because this option was also described in previous works (Furetta, 2010; Topaksu et al., 2016). Therefore, the thermal treatment adopted after all OSL and PTOSL measurements of 4 materials (TLD-100, TLD-200, TLD-400 and TLD-900) was 400 °C/1 h.

After measurements of the OSL signal by means of the five reproducibility cycles, all analysis obtained for each sample were corrected for two values: 1) the intensity value of the OSL signal obtained after

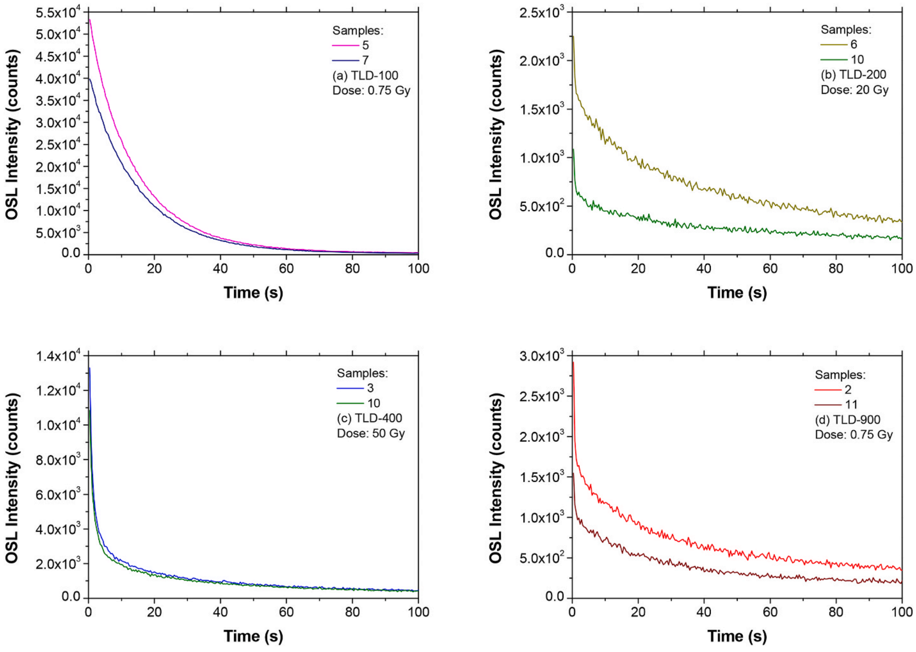

Fig. 2. OSL decay curves for samples of: (a) LiF:Mg,Ti (TLD-100), (b) CaF_2:Dy (TLD-200), (c) CaF_2:Mn (TLD-400), and (d) $CaSO_4$:Dy (TLD-900).

thermal treatment, which is known as the “0R signal”, and 2) the individual calibration factor of each one of them, which is the ratio between the absorbed dose delivered to the dosimeter and the number of counts obtained in the measurement.

The results obtained in the OSL response reproducibility study were: 2.5% (TLD-100), 3.3% (TLD-200), 2.5% (TLD-400) and 4.3% (TLD-900). All these reproducibility values (for the set of samples of each material, obtained from the average value of the five OSL signal measurements) were considered satisfactory, since the response of a dosimeter is considered reproducible if the coefficient of variation is equal or less than 5% (Furetta, 2010).

The OSL response of the dosimeters was also taken immediately after the thermal treatment of 400 °C/1 h, the “0R signal”. The importance of this study is based not only in the verification of the intrinsic signal of each pelles (to be able to use it in measurement corrections after irradiation), but also to observe whether the thermal treatment adopted is efficient and actually has the capacity to erase any residual OSL signal that may still be present in the material after measurement. Furthermore, the values obtained in the 0R study in terms of counts are used to determine other dosimetric characteristics of the material: as its minimum detectable dose (MDD).

To perform the 0R study, six series of signal measurements and thermal treatments were carried out. The coefficients of variation obtained were: 2.3% in a range of 6180.8 to 6697.0 counts (TLD-100), 3.5%, from 6442.3 to 7143.3 counts (TLD-200), 8,6%, from 8441.3 to 11,474.3 counts (TLD-400), and 6.0%, from 14,011.3 to 16,450.8 counts (TLD-900).

3.1.3. *Minimum detectable dose*

In addition to the behavior of the OSL decay curve, OSL response reproducibility and dosimeter response after heat treatment for reuse (called “0 radiation signal – 0R signal”), another dosimetric property was studied: the minimum detectable dose.

The results of the MDD obtained for the four materials studied were: 3.03 mGy (TLD-100), 1.56 Gy (TLD-200), 2.30 Gy (TLD-400) and 0.11 Gy (TLD-900).

3.2. *Study of PTOSL response*

After the study of the OSL response of the materials by means of their dosimetric characteristics described in items 3.1, the next step was studying the PTOSL response. In this case, all samples of each material continued to be used.

3.2.1. *OSL response after post-irradiation thermal treatment*

The previous data showed results of OSL response taken immediately after irradiation of the dosimeters. The next step was studying the OSL signal after irradiation and a post-irradiation thermal treatment (PITT), in order to know the response of the materials before the PTOSL measurements. Thus, the PITT is a thermal treatment between the steps of irradiation and measurement of the signal given to the pellets to empty the shallow traps of the structure of the material, by means of liberation of charges. In this way, the pellets of TLD-100, TLD-200, TLD-400 and TLD-900 were irradiated, subjected to the PITT, and then their OSL response was evaluated. This study is fundamental to know the response intensity that still remains post-PITT, in order to compare it with the PTOSL response.

In the case of the TLD-100 and TLD-900 materials, the PITT thermal treatment provided was 280 °C/15 min; this temperature/time was chosen because there is already a description in the literature about its use for these materials (Caldas, 1973). For the TLD-200 and TLD-400 samples, the PITT of 250 °C/15 min and 350 °C/15 min were used, respectively, based on previous measurements tests carried out.

In this stage of the experimental procedures, the samples were irradiated with the ^{90}Sr+^{90}Y source with higher absorbed doses than that for the OSL response after irradiation, since that the signal of the materials may be more intense because a part of it will be erased due to PITT; the absorbed doses were: 10 Gy (TLD-100), 75 Gy (TLD-200), 100 Gy (TLD-400) and 15 Gy (TLD-900). Therefore, the steps performed in this study were: 1) irradiation, 2) PITT, and 3) measurement of OSL signal immediately after PITT. Fig. 3a-d shows the OSL responses obtained in this study, for all materials.

In the case of TLD-100 material (Fig. 3a), it presented the highest signal decay peak when compared to the others (Fig. 3b–d); the beginning of the OSL signal decay occurred at 543 counts and 439 counts, for the samples 5 and 7, respectively. Comparing the integral values of the 10 pellets of TLD-100, the OSL signals after irradiation and PITT were well reproducible, showing a coefficient of variation of 1.1%. For the TLD-200 material (Fig. 3b), the decay of the OSL signal started at 490 counts (sample 6) and 441 counts (sample 10); for this material, the integral of the OSL signal decay curves of the 10 samples was also reproducible: 2.9%. In the case of TLD-400 (Fig. 3c), the signal decay peak value in terms of counts was 559 counts (sample 3) and 549 counts (sample 10); In this case, the integral values for the 10 samples also showed a very good coefficient of variation: 3.1%. For the TLD-900 samples (Fig. 3d), the OSL signal decay peak values were 803 counts for sample 2, and 558 counts for sample 11. Regarding the coefficient of variation obtained from the integral values for the 15 TLD-900 samples, it was the highest of the four materials, but still considered very good, as it is below 5%: 4.4%.

These results occurred as expected, after the post-irradiation thermal treatment, since the OSL signal intensities decreased for the 4 materials when they were thermally treated after their irradiation, which promoted the emission of part of the electrons during the heating of the samples.

3.2.2. *PTOSL decay curves*

The study of the photo-transferred OSL response (PTOSL) was carried out in 4 phases: 1) irradiation of the samples with ^{90}Sr+^{90}Y beta source, 2) post-irradiation thermal treatment, 3) illumination with LEDs, and 4) analysis of the PTOSL response, by means of the decay curves. Table 2 shows the parameters used in these steps for each of the materials.

During PTOSL response measurements, the same parameters of the previous studies were adopted, so that it was possible to compare the results: blue LEDs to stimulate signal emission, power of 90% and time of 100 s.

In Figs. 4–7, the PTOSL decay curves, or PTOSL response, obtained for four materials and for the two samples of each of them (the same ones presented in Figs. 2 and 3, for comparison) can be seen: TLD-100, TLD-200, TLD-400 and TLD-900.

The samples were irradiated with the ^{90}Sr+^{90}Y source with the same absorbed doses as in the previous study (item 3.2.1) for TLD-100, TLD-200, TLD-400 and TLD-900, respectively: 10 Gy (irradiation time = 133 s), 75 Gy (t = 997 s), 100 Gy (t = 1329 s) and 15 Gy (t = 199 s).

The LED wavelengths used for the lightning/illumination of the dosimeters were adopted as by Caldas (1973), for the cases of the TLD-100 and TLD-900 samples, and based on the TL emission spectra demonstrated by McKeever et al. (1995) for the 4 types of materials (LiF: Mg,Ti, CaF_2:Dy, CaF_2:Mn and $CaSO_4$:Dy) (Caldas, 1973; McKeever et al., 1995).

The PTOSL response is the OSL signal induced by an illumination/lighting event. During the photo-transfer phenomenon, electrons are liberated from the deep traps of the crystal, and then they are captured by the shallow traps also present in the material structure, previously emptied after the PITT thermal treatment. For this reason, it is possible to observe two essential points in the measurement and evaluation of the photo-transfer response, in the case, PTOSL response: 1) whether electron photo-transfer occurred, and 2) the observed PTOSL signal (in the case of Figs. 4–7) presents an intensity increase not seen in the curve obtained after PITT procedure (Fig. 3a–d of this work), because this factor indicates that the material has deep traps in its structure.

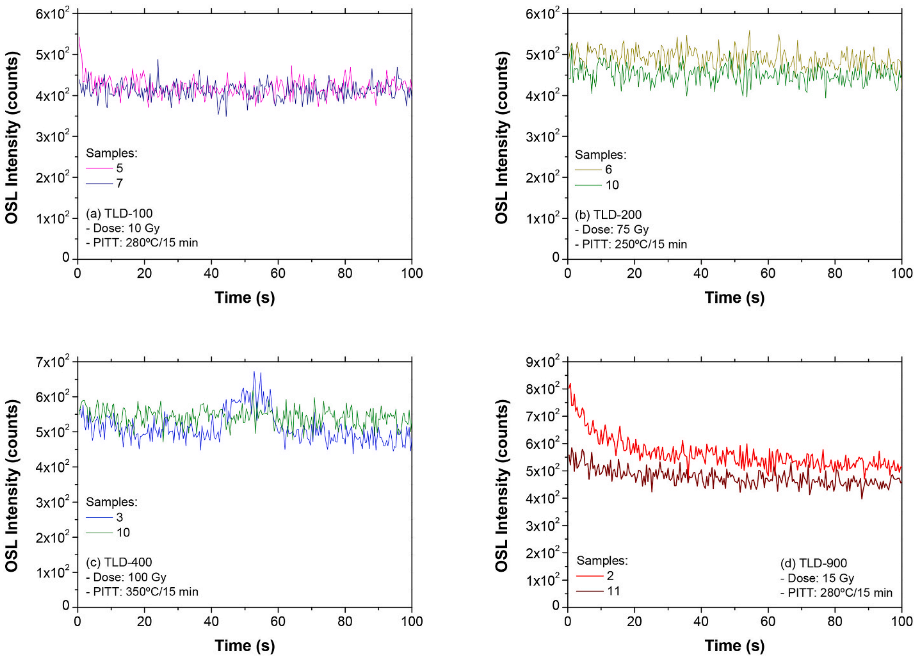

Fig. 3. OSL response obtained after irradiation (^{90}Sr+^{90}Y) and post-irradiation thermal treatment (PITT) for samples of: (a) LiF:Mg,Ti (TLD-100), (b) CaF_2:Dy (TLD-200), (c) CaF_2:Mn (TLD-400), and (d) $CaSO_4$:Dy (TLD-900).

Table 2
Irradiation parameters (^{90}Sr+^{90}Y source), post-irradiation thermal treatment (PITT) and lighting used in the study of the PTOSL response for the materials: LiF:Mg,Ti (TLD-100), CaF_2:Dy (TLD-200), CaF_2:Mn (TLD-400) and $CaSO_4$:Dy (TLD-900).

Material	Absorbed Dose	PITT	Lighting
LiF:Mg,Ti (TLD-100)	10 Gy	280 °C/15 min	265 nm/10 min
CaF_2:Dy (TLD-200)	75 Gy	250 °C/15 min	365 nm/10 min
CaF_2:Mn (TLD-400)	100 Gy	350 °C/15 min	365 nm/10 min
$CaSO_4$:Dy (TLD-900)	15 Gy	280 °C/15 min	365 nm/10 min

The PTOSL signal observed for LiF:Mg,Ti (TLD-100), in Fig. 4, clearly shows that there was a photo-transfer effect, when we compare it with Figs. 2a and 3a. For sample 5, the decay peak after irradiation started at 5.33 × 10^4 counts (Fig. 2a), after PITT the peak was at 543 counts (Fig. 3a), and after illumination it was at 5.66 × 10^4 counts. In the case of sample 7, the behavior was the same. This large increase in the signal after the illumination process indicates that there was re-trapping of electrons as explained in the previous paragraph, indicating that the photo-transfer occurred.

For the CaF_2:Dy (TLD-200) samples, it was not possible to observe the photo-transfer phenomenon, because there was no increase between the decay peak intensity value of the luminescent signal after PITT (Fig. 3b – sample 6: 4.90 × 10^2 counts/sample 10: 4.41 × 10^2 counts) and after illumination with LEDs (Fig. 5 – sample 6: 4.63 × 10^2 counts/sample 10: 4.43 × 10^2 counts).

The same situation can be observed for the CaF_2:Mn (TLD-400) samples. Comparing the signal obtained after PITT (Fig. 3c – sample 3: 5.59 × 10^2 counts/sample 10: 5.49 × 10^2 counts) with the signal verified after illumination with LED (Fig. 6 – sample 3: 5.82 × 10^2 counts/sample 10: 5.36 × 10^2 counts), it is noted that there was no increase in the response of the material when analyzing the intensity of the signal decay peak. However, there are two different questions in the case of this material. The first is that in Fig. 3c, sample 3 presents a type of signal peak in the middle of the curve, in a time correspondent of approximately 50 s of illumination. The second issue is that Fig. 6 presents a type of decay beginning, even if small, for sample 3. These two situations need to be verified by means of other future studies.

The data obtained for the $CaSO_4$:Dy (TLD-900) samples indicated that the photo-transfer phenomenon may have occurred. Comparing Fig. 3d (sample 2: 8.03 × 10^2 counts/sample 11: 5.58 × 10^2 counts) and Fig. 7 (sample 2: 9.96 × 10^2 counts/sample 11: 6.75 × 10^2 counts), a discrete signal increase in the second case can be observed.

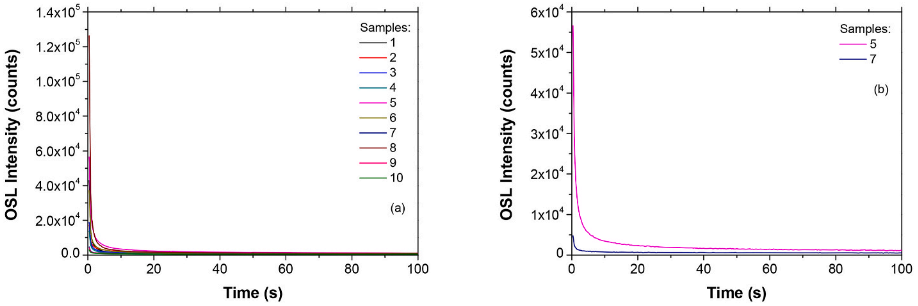

Fig. 4. Study of the PTOSL response of LiF:Mg,Ti (TLD-100) for all 10 dosimeters (a) and for two samples (5 and 7) (b), after irradiation (10 Gy, with a^{90}Sr+^{90}Y source), post-irradiation thermal treatment (PITT) at 280 °C/15 min and illumination at 265 nm/10 min.

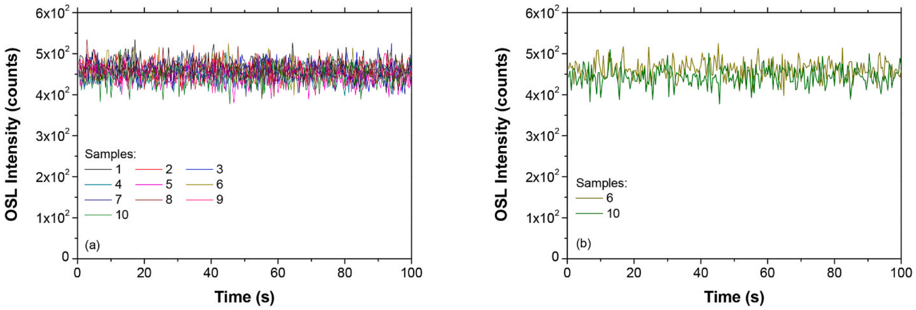

Fig. 5. Study of the PTOSL response of CaF_2:Dy (TLD-200) for all 10 dosimeters (a) and for two samples (6 and 10) (b), after irradiation (75 Gy, with a ^{90}Sr+^{90}Y source), post-irradiation thermal treatment (PITT) at 250 °C/15 min and illumination at 365 nm/10 min.

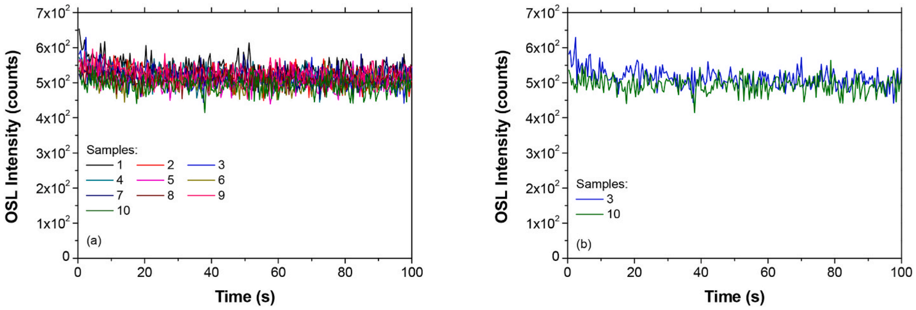

Fig. 6. Study of the PTOSL response of CaF_2:Mn (TLD-400) for all 10 dosimeters (a) and for two samples (3 and 10) (b), after irradiation (100 Gy, with a ^{90}Sr+^{90}Y source), post-irradiation thermal treatment (PITT) at 350 °C/15 min and illumination at 365 nm/10 min.

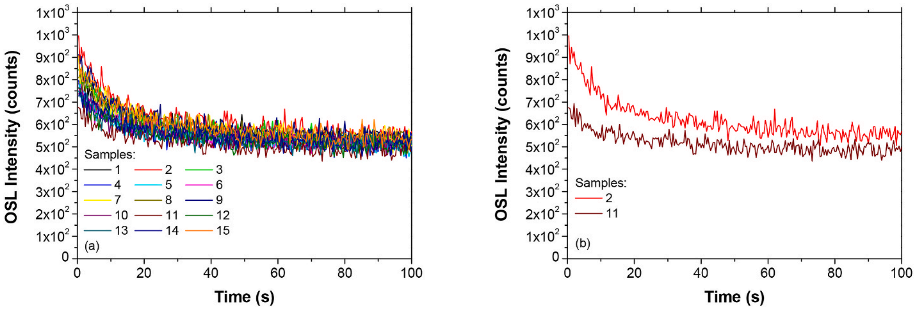

Fig. 7. Study of the PTOSL response of $CaSO_4$:Dy (TLD-900) for all 15 dosimeters (a) and for two samples (2 and 11) (b), after irradiation (15 Gy, with a ^{90}Sr+^{90}Y source), post-irradiation thermal treatment (PITT) at 280 °C/15 min and illumination at 365 nm/10 min.

4. Conclusions

The presentation of the experimental procedure of this work was divided into two parts: study of OSL response, and study of the PTTL response, for better comprehension and comparison of the results.

The OSL response reproducibility study showed results of the coefficient of variation less than 5%, for LiF:Mg,Ti (TLD-100), CaF_2:Dy (TLD-200), CaF_2:Mn (TLD-400) and $CaSO_4$:Dy (TLD-900) materials, which are within of the data previously presented in the literature. This response stability of a material indicates that it can be used with efficiency as a radiation dosimeter. For all studies, the TLD-100 samples presented the more intense signal.

The OSL response after the thermal treatment called PITT was also performed in terms of comparison with the response after irradiation and after illumination. For the last, the PTOSL signal was taken after irradiation + PITT + illumination with LEDs, in order to observe the occurrence of photo-transfer of the charges in the material.

In the case of TLD-100, it was possible to see, clearly, a noticeable and intense photo-transfer effect, since after lighting the samples the PTOSL intensity corresponded to the same order of magnitude of the OSL signal intensity obtained after irradiation.

For the TLD-200 and TLD-400, it was not possible to observe any photo-transfer effect. For TLD-900 there was a small increase of the signal when a comparison is done between the OSL response after PITT and PTOSL response.

In order to continue studying the PTOSL of the TLD-200, TLD-400 and TLD-900 samples, an alternative to increase the signal is to perform other studies, as example, to verify the PTTL response with variation in wavelength and variation in lighting time, and to perform these experiments providing a higher absorbed dose to the materials, as 150 Gy for TLD-200, 200 Gy for TLD-400 and 50 Gy for $CaSO_4$:Dy.

CRediT authorship contribution statement

Patrícia L. Antonio: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Iury S. Silveira:** Methodology, Software. **Linda V.E. Caldas:** Writing – review & editing, Visualization, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Patricia de Lara Antonio reports financial support was provided by State of Sao Paulo Research Foundation. Patricia de Lara Antonio reports financial support was provided by National Council for Scientific and Technological Development. Linda Viola Ehlin Caldas reports financial support was provided by State of Sao Paulo Research Foundation. Linda Viola Ehlin Caldas reports financial support was provided by National Council for Scientific and Technological Development. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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