

Commercial TL and OSL Al₂O₃:C detectors for use in beta occupational monitoring

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Abstract. Thermoluminescence (TL) and optically stimulated luminescence (OSL) have been applied in different areas of science, and these results have been related and discussed in several papers. In this work, the Al₂O₃:C material, studied in relation to its TL signal, and nowadays also applied as an OSL material, was characterized in relation to its properties. Al₂O₃:C commercial samples (TLD-500) were exposed to the beta secondary standard sources (⁹⁰Sr+⁹⁰Y, ⁸⁵Kr and ¹⁴⁷Pm) to verify their response for use in beta radiation dosimetry. The tests performed demonstrated that the detectors present potential use as TL and OSL beta dosimeters, because they presented good results and high sensitivity to beta radiation.

1. Introduction

Luminescent techniques as thermoluminescence (TL) e optically stimulated luminescence (OSL) in radiation dosimetry have been discussed by different authors in relation to their applications, including a comparison between their advantages and disadvantages [1-2]. Although the OSL technique is nowadays so utilized as the TL technique, the first one presents some advantages in relation to the TL technique as: it requires no heating of the samples, the detectors may be evaluated several times, and OSL is a relatively cheaper method than TL [3].

The Al₂O₃:C material, initially developed as TL dosimeter, is a detector which has become the main studied OSL material, because it presents good TL response, excellent OSL dosimetric characteristics [4], and high sensitivity [5]. This kind of material has already been studied in several radiation beams, through the TL and OSL phenomena, showing good behaviour [6-7].

Al₂O₃:C dosimeters, commercialized as TL materials [8], were previously studied [9] in relation to their TL characteristics. The objective of this work was to characterize and to evaluate the performance of Al₂O₃:C Rexion commercial detectors, using both TL and OSL techniques, in standard beta radiation beams, to verify their application for beta radiation occupational monitoring.

2. Materials and Methods

Carbon doped luminum oxide (Al₂O₃:C) pellets (5.0 mm in diameter and 1.0 mm in thickness) were studied in this work, acquired as commercial dosimeters from Rexion TLD Systems.

At the Calibration Laboratory of IPEN (LCI) there are two beta radiation secondary standard systems: BSS1, Buchler GmbH, & Co., Germany, and BSS2, Isotrak, Germany. In Table I, the main characteristics of these sources are shown. The sources have calibration certificates issued by the primary standard laboratory Physikalisch – Technische Bundesanstalt (PTB), Germany. During the irradiations, the samples were positioned in a polymethylmetacrilate (PMMA) support, kept in dark and covered by a Mylar foil (superficial density of 0.71 mg/cm²) to avoid the TL and OSL signal fading.

Table I. Characteristics of the beta standard sources used for the irradiation of the Al₂O₃:C dosimeters.

Beta Secondary Standard System	Radiation Source	Field Flattening Filter	Absorbed Dose Rate (μGy/s)	Calibration Distance (cm)	Reference Date
BSS1	⁹⁰ Sr+ ⁹⁰ Y	No	518.4 ± 5.180	11	04.02.81
BSS2	⁹⁰ Sr+ ⁹⁰ Y	No	16.46 ± 0.220	30	12.01.05
	⁸⁵ Kr	Yes	39.70 ± 0.500	30	30.11.04
	¹⁴⁷ Pm	Yes	2.350 ± 0.050	20	19.11.04

The TL and OSL response of the samples were determined using the Risø, model TL/OSL-DA-200 reader system. In the case of TL, a sample heating rate of 10°C/s and a final temperature of 400°C were used. For the OSL measurements, blue LEDs with optical power of 90% were used; in this case, a stimulation time of 50 s was adopted. A filter basket Hoya U-340 was used in front of the photomultiplier. For the measurements with both techniques, a black mask with a central orifice of 5.0 mm in diameter was used between the photomultiplier and the filter. This accessory was important to avoid the saturation of the photomultiplier. After each cycle of irradiation and measurement, the Al₂O₃:C samples were thermally treated at 400°C during 1 h, for posterior reutilization.

3. Results

The TL and OSL responses of the Al₂O₃:C detectors were verified by means of their main characteristics.

3.1. Reproducibility of Response

The reproducibility of the TL and OSL response of Al₂O₃:C detectors was obtained using the beta radiation source of ⁹⁰Sr+⁹⁰Y from the BSS1 system, at a source-detector distance of 11 cm, and an absorbed dose of 10 mGy (in five cycles of irradiation, measurement and thermal treatment). In the case of TL response, the reproducibility obtained was 3.2% (final standard deviation of the mean value of five cycles using 10 samples), and the maximum standard deviation of all measurements was 3.9% (maximum deviation obtained from all deviations considering each sample and all the five cycles). For the OSL technique, the reproducibility obtained was 4.1%, and the maximum standard deviation was 4.8%.

3.2. TL Emission Curve and OSL Signal Decay

The TL emission curve and OSL signal decay (Figure 1) were obtained exposing the Al₂O₃:C samples to the ⁹⁰Sr+⁹⁰Y radiation source (BSS1 system), at a source-detector distance of 11 cm, and in a dose interval from 100 mGy to 400 mGy.

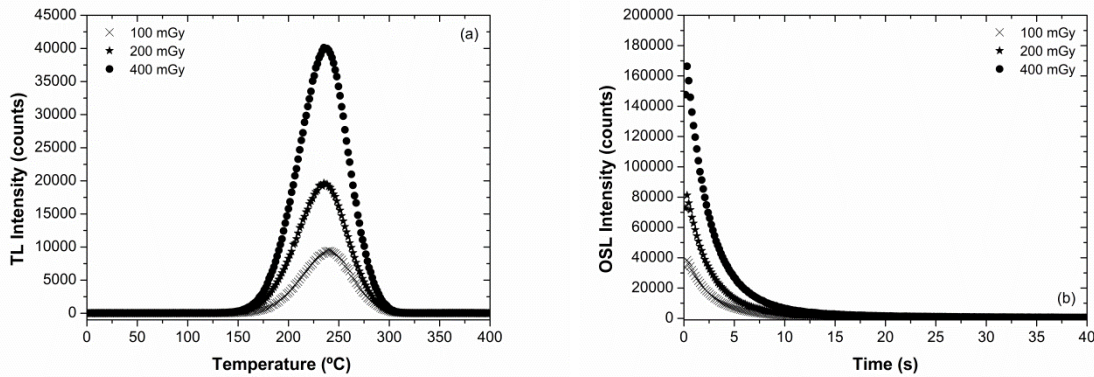


FIG. 1. TL and OSL signal of the Al₂O₃:C detectors: (a) TL emission curve; and (b) OSL signal decay.

Figure 1a shows the TL signal emission. A dosimetric peak can be observed at about 235°C, differently of that informed at the technical specifications of the material [8], which was 185°C, although they used a maximum temperature of 270°C during the measurements, and in this work 400°C was reached. The recommended maximum temperature was tested, but the dosimetric peak was not possible to observe. Therefore, a higher temperature (400°C) was used. Figure 1b presents the OSL signal decay after the detector irradiation with the same absorbed doses as in the case of the TL signal.

3.3. Dose-Response Curves

In this study, the detectors were irradiated with absorbed doses between 1 mGy and 400 mGy ($^{90}\text{Sr}+^{90}\text{Y}$, BSS1), and 0.01 mGy and 0.4 mGy ($^{90}\text{Sr}+^{90}\text{Y}$, BSS2), at the source-detector distance of 30 cm. The maximum standard deviations obtained were 6.1% (10 mGy, TL), and 7.1% (400 mGy, OSL). Figure 2 shows the TL and OSL dose-response curves obtained in this work. In both cases, linear behaviors can be observed in the interval from 1 mGy to 400 mGy, with correlation coefficients greater than 0.9997.

This study presented results comparable to those of other works. The linearity was already observed at the TL response of Rexon $\text{Al}_2\text{O}_3:\text{C}$ samples irradiated with beta radiation [9], but for high doses and in different parameters (heating rate of 5°C/s, and maximum temperature of 500°C). Other $\text{Al}_2\text{O}_3:\text{C}$ samples were studied by Akselrod et al. [6]: they observed linearity in the same dose interval as in this work for TL response (beta radiation), from 1 mGy to 400 mGy.

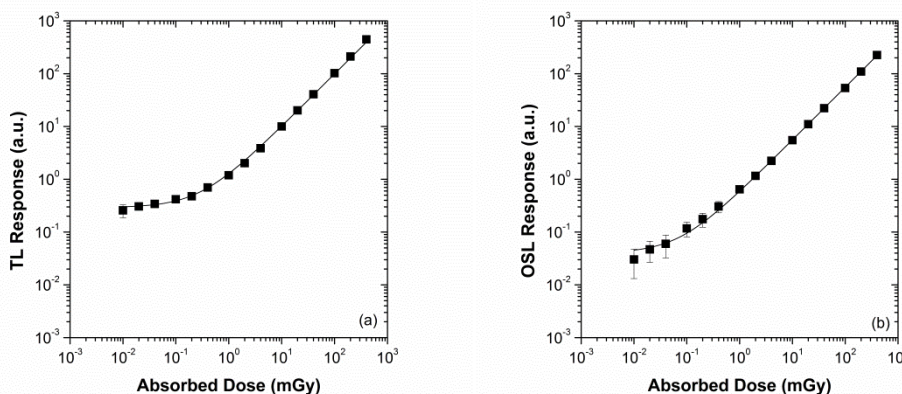


FIG. 2. Dose-response curves: (a) TL and (b) OSL.

3.4. Dependence of the TL and OSL Response with the Radiation Energy

The $\text{Al}_2\text{O}_3:\text{C}$ detectors were exposed to the beta sources of the BSS2 system at the calibration distances of 30 cm ($^{90}\text{Sr}+^{90}\text{Y}$ and ^{85}Kr sources), and 20 cm (^{147}Pm source). The maximum standard deviation obtained at the TL measurements was 5.4% ($^{90}\text{Sr}+^{90}\text{Y}$ source), and at the OSL readings it was 6.0% (^{147}Pm). In Table II the results obtained for the energy dependence study can be observed.

These results show the high energy dependence of both TL and OSL responses in beta radiation, which is very similar for both techniques. In the case of the OSL technique, the results presented similar behavior but slightly higher than those of another work [7], where the energy dependence of Landauer $\text{Al}_2\text{O}_3:\text{C}$ detectors was studied using the same sources ($^{90}\text{Sr}+^{90}\text{Y}$, ^{85}Kr , ^{147}Pm , BSS2).

3.5. Minimum Detectable Dose

The values of the minimum detectable dose (also called lower detection limit) using the TL and OSL techniques were obtained irradiating the $\text{Al}_2\text{O}_3:\text{C}$ detectors with the $^{90}\text{Sr}+^{90}\text{Y}$ sources of the BSS1 and BSS2 systems, without any field flattening filters. In this characterization test, the detectors were

irradiated in the same conditions described in item 3.3. The minimum detectable doses were determined graphically. For both cases (TL and OSL response), the result obtained was 0.04 mGy.

Table II. Energy dependence study of the Al₂O₃:C detectors.

Radiation Source	Field Flattening Filter	Absorbed Dose (mGy)	Beta Mean Energy (MeV)	Normalized Response to ⁹⁰ Sr+ ⁹⁰ Y	
				TL	OSL
⁹⁰ Sr+ ⁹⁰ Y	No	10	0.80	1.0000 ± 0.0482	1.0000 ± 0.0214
⁸⁵ Kr	Yes	10	0.14	0.1929 ± 0.0092	0.1713 ± 0.0110
¹⁴⁷ Pm	Yes	615	0.06	0.0120 ± 0.0004	0.0125 ± 0.0001

Conclusions

The characterization tests performed show that the Rexon Al₂O₃:C (TLD-500) samples can be used as TL and OSL detectors. They present good reproducibility of the TL and OSL responses. The dose-response curves show a linear behavior of the TL and OSL responses in the dose interval from 1 mGy to 400 mGy. The minimum detectable doses obtained show the usefulness of this material for low doses. Despite the high dependence of the TL and OSL response with beta radiation energy, the TL and OSL responses presented high sensitivity to beta radiation. Therefore, Al₂O₃:C detectors present potential use for beta radiation dosimetry, and for occupational monitoring, especially when the beta source is known.

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