Metrologia
Florianópolis - SC 2019

Fading estimation of SOL-GEL α-Al_2O_3 detectors

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Abstract. The OSL and the TL techniques are used in several fields of radiation dosimetry. The dosimeters are affected by a signal loss in the time between the irradiation and readout (fading). This undesirable characteristic can cause an underestimation of the irradiation dose. The fading estimation of SOL-GEL α-Al_2O_3 with several different concentrations of impurities is reported. The thermal fading and the light-induced fading of the SOL-GEL α-Al_2O_3 detectors were estimated. Furthermore, the exponential equations used to interpolate the experimental results were presented.

Keywords. SOL-GEL α-Al_2O_3, OSL, TL, fading.

1. Introduction

The thermoluminescence (TL) and optically stimulated luminescence (OSL) techniques are used in personal, environmental and clinical dosimetry. Other important applications are geological and archeological dating. The application of the TL and OSL dosimeters in the radiation dosimetry is based on the fact that for some materials the light emitted as a result of heat (TL) or light (OSL) stimulation, is proportional to the absorbed dose to which the material was exposed [1,2]. One of the most important problems of radiation dosimetry is the loss of the dosimeter stored signal in the time between the irradiation and readout. This characteristic is known as thermal fading [3,4]. Fading is the decrease in the dosimeter response due to loss of some of the trapped charges between the irradiation and the measurement. It can be caused by heat, even at room temperature (thermal fading) or by unwanted exposure to light (light induced fading) [5]. Some detectors are sensitive to light, so if they are exposed to sunlight or to laboratory light, a light-induced fading of the luminescent signal may occur [6]. The loss of signal in the dosimeter causes an underestimation of the radiation dose.

The low cost SOL-GEL α-Al_2O_3 detectors with several different concentrations of impurities were produced at the Centro de Desenvolvimento da Tecnologia Nuclear (CDTN/CNEN) in Belo Horizonte, Brazil. For the production of these detectors, aluminum nitrate dissolved in alcohol was utilized as an alumina precursor. To this solution were added the following dopants: Fe, Mg, Ca, Cr, Ni and Mo, as well as C [7]. These detectors showed suitable OSL and TL dosimetric characteristics, such as good reproducibility, good linearity of response, a glow curve with a 230 °C TL peak, and high phosphor sensitivity [7,8].

The determination of the signal fading of the SOL-GEL α-Al_2O_3 detectors remained a subject of further research. The material producers focused generally on the material production conditions, and

on the dosimetric characteristics of these detectors, but they found that the fading of these detectors increases with exposure to light [7]. Although the fading study of Al_2O_3:C synthesized with other methods have already been studied [6,9,10], a detailed analysis of the fading estimation of aluminum oxide synthesized with the sol-gel method with several different concentrations of impurities has not been published yet. The aim of this work was the estimation of thermal fading and the light-induced fading of the SOL-GEL α-Al_2O_3 detectors. The fitting parameters for the exponential equations used to interpolate the experimental results are presented.

2. Materials and Methods

An analysis using inductively coupled plasma mass spectrometry (ICP-MS, ELAN DRC/PerkinElmer), the material SOL-GEL α-Al_2O_3 revealed the following impurities: Fe (99.8 ± 9.9) ppm, Mg (0.9 ± 0.10) ppm, Ca (310 ± 30.6) ppm, Cr (31.5 ± 3.2) ppm, (Ni 25.0 ± 2.5) ppm, Mo (5.0 ± 0.3) ppm, and using a combustion method (LECO CS 230), C (895.5 ± 44.8) ppm [7].

The SOL-GEL α-Al_2O_3 detectors have (4.59 ± 0.01) mm in diameter, (1.119 ± 0.010) mm in thickness, and (51.8 ± 0.4) mg of mass.

The study was realized at the Center for Radiation Metrology of IPEN. For the fading studies, the RISØ TL/OSL-DA20 system was used [11]. The detectors were irradiated using the RISØ $^{90}Sr/^{90}Y$ beta source with 0.5 Gy. To avoid the influence of light on the response, the measurements were taken in a dark room. The heating rate was 5 °C/s and the maximum temperature was 350°C for all TL measurements, and they were performed in a N_2 atmosphere. The emission from the samples was detected by a photomultiplier tube after passing through the Hoya U-340 UV filter with 7.5 mm thickness and 45 mm diameter (transmission band 250–390 nm FWHM). For OSL measurements, the constant light intensity (CW-OSL) mode was provided by 470 nm blue LEDs with a 60 s counting and 90 % of power.

For the study of the light-induced fading, the detectors were exposed to light of approximately 1800 lumens of fluorescent light. The exposure time intervals were 5 min, 10 min, 15 min and 20 min, and the first reading was taken just after irradiation.

For the study of thermal fading, the detectors were irradiated and stored at different time intervals. Three samples were used at a time. The emission curves were recorded, and the background signal was subtracted. The storage intervals were 24 h, one week (168 h) and one month (720 h). After these storage time intervals, the OSL and TL measurements were obtained of the detector response.

3. Results and Discussions

Figures 1 and 2 show the OSL decay curves and the TL glow curves of irradiated SOL-GEL α-Al_2O_3 detectors obtained for five light exposure time intervals.

Figure 3 shows the decrease of the OSL and the TL output of irradiated SOL-GEL α-Al_2O_3 detectors depending on the light exposure time. The data were normalized to the initial OSL and TL signal, acquired immediately after the irradiation (time = 0 min).

In both OSL and TL responses, the effect of the light-induced fading due to 1800 lumens in 1 min does not exceed 1%. This allows the detector to be taken out of the dosimeter holder, and placed in the dosimeter reader in the presence of light without any loss of signal under routine personal monitoring conditions.

Figure 4 shows the OSL and the TL responses of SOL-GEL α-Al_2O_3 detectors acquired immediately after the irradiation (time=0h) up to over one month (720 h) post-irradiation. The data were also normalized to the initial OSL and TL signals (time = 0 h).

A loss of 13% of the signal from 168 h (one week) after irradiation of the detectors in the case of the OSL response fading can be observed in Figure 4. In the case of the TL response fading, a 19% loss is

observed 24h after irradiation. It is recommended to perform the measurements with these detectors 1h after irradiation when the signal is more stable.

The time-dependent fading data of SOL-GEL α-Al_2O_3 detectors appear consistent with an exponential function of the form $y = A_1*\exp(-x/t_1) + y_0$, where *y* corresponds to the intensity of the OSL or TL signal, *x* is the time after irradiation, A_1, t_1 and y_0 are the amplitude, the decay constant of the function, and offset respectively. For the OSL response, the fitting parameters of the equation are as follows: $A_1 = (0.30 \pm 0.03)$; $t_1 = (327.\ 39 \pm 109.26)$ h e $y_0 = (0.69 \pm 0.03)$. For the TL response, the fitting parameters are: $A_1 = (0.29 \pm 0.07)$; $t_1 = (23.0 \pm 11.0)$ h e $y_0 = (0.709 \pm 0.024)$.

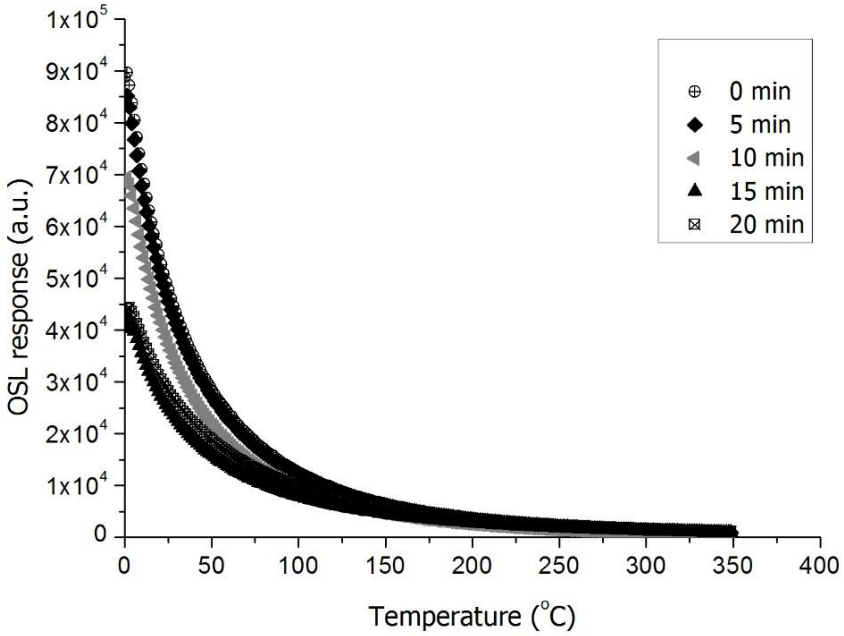

Figure 1. OSL decay curves of irradiated SOL-GEL α-Al_2O_3 detectors obtained for five light exposure time intervals (Initial dose of 0.5 Gy).

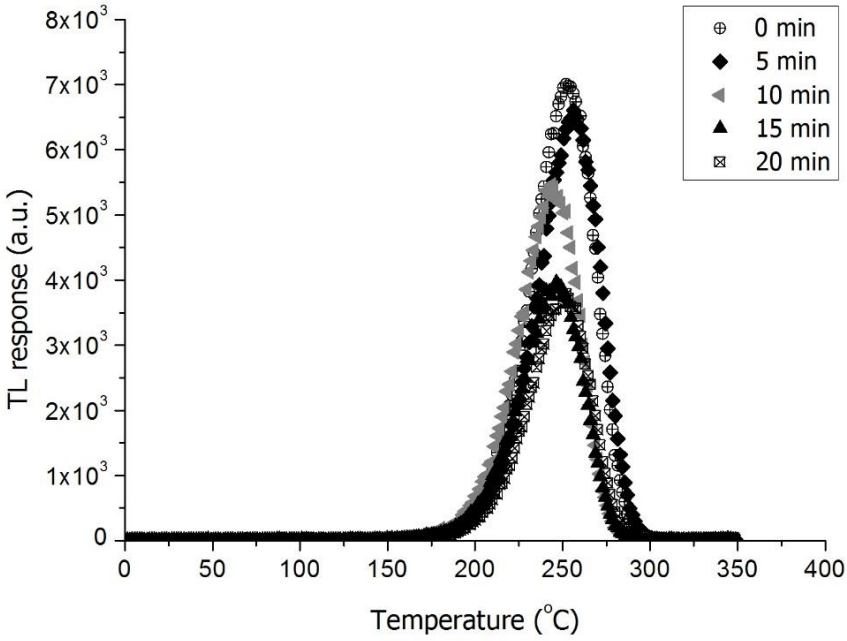

Figure 2. TL glow curves of irradiated SOL-GEL α-Al_2O_3 detectors obtained for five light exposure time intervals (Initial dose of 0.5 Gy).

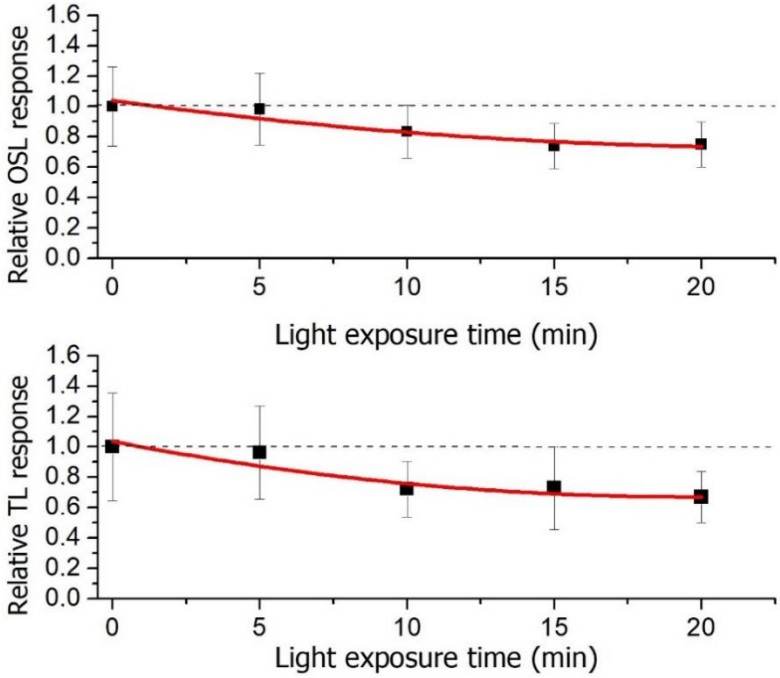

Figure 3. OSL and TL light induced fading in the response of SOL-GEL α-Al_2O_3 detectors.

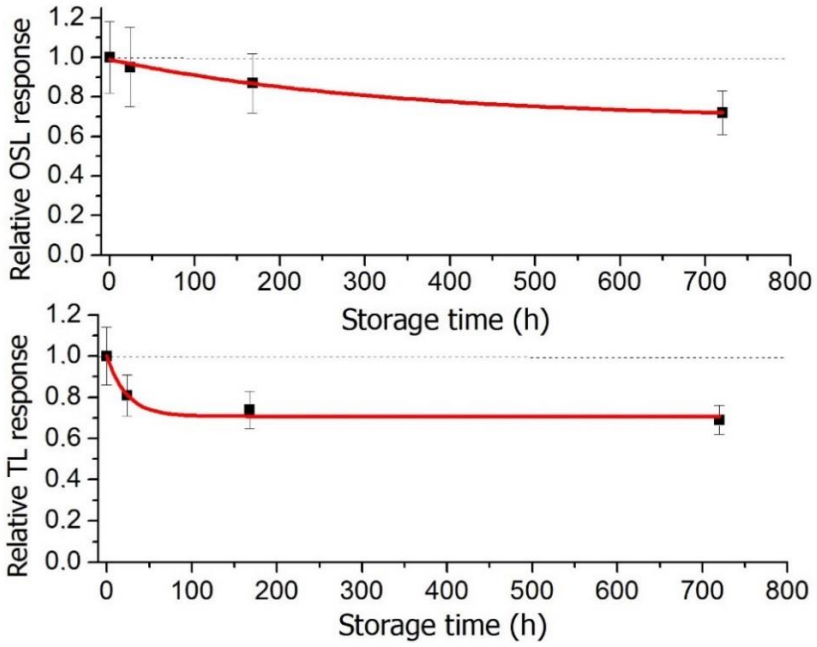

Figure 4. OSL and TL measurements of SOL-GEL α-Al_2O_3 detectors acquired immediately after the irradiation (time=0h) up to over one month (720 h) post-irradiation. The data were normalized to the initial OSL and TL signals (time = 0 h).

4. Conclusions

A detailed analysis of the fading estimation of aluminium oxide synthesized with the sol-gel method with several different concentrations of impurities was presented for the first time. The effect of the light-induced fading due to 1800 lumens in 1 min does not exceed 1% in these detectors for both OSL and TL responses for exposure time intervals of 5 min, 10 min, 15 min and 20 min. An OSL signal loss of 13% was observed one week after the detectors were irradiated using the RISØ $^{90}Sr/^{90}Y$ beta source with 0.5 Gy. A TL signal loss of 19% was observed in an hour after the detectors were irradiated under the same conditions as for the OSL technique. After these time intervals, the TL and OSL signals are more stable, and therefore it is recommended to make measurements with these detectors after this intervals. The exponential equation that can be used to estimate the response fading of the detectors was obtained.

Acknowledgments

The α-Al_2O_3 detectors were gently offered by Dr. Hudson Ferreira from the Centro de Desenvolvimento da Tecnologia Nuclear (CDTN/CNEN), Brazil, to whom the authors are very grateful. The authors thank the partial financial support of the Brazilian funding agencies CNPq (Processes: 142297/2015-1 fellowship of I.O. Polo, and 301335/2016-8) and CAPES (Project: 554/2018).

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