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Light induced fading associated with the application of OSL to personal dosimetry

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HIGHLIGHTS

- The light fading is one of the most important dosimetric characteristics of Al_2O_3:C.
- Optical decay of the OSL signal was studied when exposed to light in different ways.
- A loss in the OSL signal was found in all tested ways.

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ABSTRACT

Al_2O_3:C is the best material example that presents OSL response and adequate dosimetric behaviour for OSL dosimetry. It was the first commercial material manufactured for use in personal monitoring based on an OSL reader system from Landauer. The purpose of this paper was to report the results of optical fading experiments for the nanoDot commercial OSL detectors (Al_2O_3:C), provided by Landauer Inc. Five groups of different experimental conditions were formed with all detectors, exposing them to fluorescent and semiconductor light sources and to sun light. The loss of OSL signal when the detectors are kept open, was verified, which was already expected, but a loss in the OSL signal even when the detectors are exposed to light and covered with the manufacturer plastic protection are also revealed. The results show also that the use of Mylar filters can delay the OSL fading of the detectors.

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1. Introduction

Personal dosimetry and dose limits are extremely important as part of the evaluations in occupational exposure to ionizing radiations, in order to avoid possible over exposures (ICRP, 2008). The optically stimulated luminescence (OSL) technique has been utilized as an option for personal dosimetry due to a variety of factors, as the availability of commercial personal monitoring systems based on the OSL of Al_2O_3:C, which presents excellent dosimetric characteristics for OSL dosimetry. It was the first commercial material introduced for personal monitoring based on an OSL reader system from Landauer (McKeever et al., 2004).

With regard to personal dosimetry, the OSL technique has advantages over the thermoluminescence (TL) technique, since it allows repetition of the read-out of samples, it is a fast and simple method to obtain results, and thermal treatments are not necessary.

However, the light induced fading is among the most important dosimetric characteristics of Al_2O_3:C, due to its high sensitivity to light. The occurrence of light induced fading in Al_2O_3:C has already been reported by Akselrod et al. (1990), Moscovitch et al. (1993) and Gronchi et al. (2008). Due to the light induced fading, the detectors must have the sensitive elements covered in personal dosimetry application, and light leaks are not allowed, even if light exposure of the sample may result in loss of dose information.

Benevides et al. (2010, 2011) reported a loss in the OSL signal when the Landauer InLight OSL detectors (Landauer, 2006) were exposed to fluorescent, incandescent and sun lighting conditions, even when they are kept assembled and inside of the standard commercially available plastic badge.

Previous studies (Pinto et al., 2010; Antonio et al., 2011) have shown the possibility of the application of Landauer nanoDot OSL

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detectors in the monitoring of extremities of workers exposed to beta radiation at Nuclear Medicine services, when they are covered with Mylar filters instead of the manufacturer's plastic cover.

If the light sensitivity of this dosimetric material affects the measured dose, even when the commercial detectors are assembled, it is very important to study this behaviour for Al_2O_3:C involving different light sources.

The main purpose of this work was to study the optical decay of the OSL signal of the nanoDot detectors of Al_2O_3:C (Landauer) when exposed to light in different ways and to report the results of optical fading experiments.

2. Materials and methods

All OSL measurements were obtained using the MicroStar portable reader, software and single nanoDot detectors, from Landauer. The nanoDot detector has a sensitive diameter of 5 mm, 0.2 mm thick plastic disk infused with aluminum oxide doped with carbon (Al_2O_3:C). This disk is encased in a 10 mm × 10 mm × 2 mm light-tight plastic holder (Ding and Malcolm, 2013).

The detectors were kept in the dark, exposed to sun light, and to fluorescent and semiconductor light sources. The OSL sensitive elements were exposed to light sources directly (open detectors, Fig. 1a), covered with the manufacturer's plastic cover (assembled detectors, Fig. 1b) and covered with aluminized Mylar filters of different superficial densities.

A Delta OHM radiometer, model D09721, with a LUX LP 9021PHOT sensor, was always utilized to determine the different light levels, and the temperature was measured using a TP870A sensor. All detectors were irradiated with a dose of 6 mGy of beta radiation (^{90}Sr + ^{90}Y) of the secondary standard system of the Calibration Laboratory of IPEN, Buchler GmbH & Co, Germany, with radiation sources calibrated by the primary standard laboratory of Physikalisch – Technische Bundesanstalt (PTB), Germany. The detectors were irradiated with the sensitive elements directly exposed and kept in the dark during the irradiations.

The nanoDot detectors were divided into five groups, labelled 1 to 5.

Immediately after the irradiation, each detector was evaluated to determine the baseline response, which was compared to the OSL response after the experiment period.

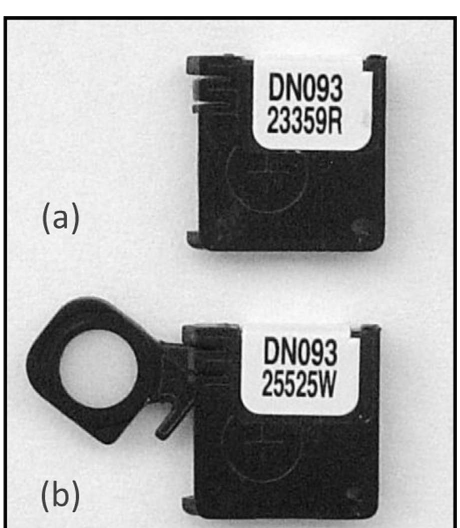

Fig. 1. Assembled (a) and open (b) nanoDot.

Group 1 was the control group and composed by three assembled detectors kept in the dark throughout the period of the experiment. Measurements were taken between 0.5 and 48 h.

Groups 2, 3 and 4 were composed by six detectors each one, three of them were kept assembled and three were open.

In group 2, the OSL nanoDot detectors were positioned on a laboratory bench and exposed to 280 lux of environmental light composed by 8 fluorescent lamps, Philips, model TLT 40 W/75 RS. The measurements were taken between 0.5 and 48 h.

Group 3 experiment was carried out exposing the detectors to 3.0×10^4 lux from semiconductor light sources inside a box. The semiconductor light source box was made at IPEN to be the OSL detector treatment box. It is composed by commercial ribbons with white LED diodes SMD 3528 (60 LED/m), colour temperature range of 6000 K, positioned both on the top as on the bottom of a steel box with dimensions of 15.5 cm × 49.8 cm × 14.5 cm. The detectors were positioned at the box centre, from 7.75 cm of the LEDs, and the box has forced ventilation in order to avoid temperature increase. The measurements were taken between 0.5 and 48 h.

Group 4 nanoDot detectors was part of the sunlight exposure study, that was realized during springtime, in São Paulo (23°S and 46°W and 750 m a.s.l.), in a clear sky day. The detectors were positioned on the ground where the temperature was measured as 28 °C. The sunlight intensity exposure was 1.0×10^5 lux. Measurements were taken between 0.5 and 2 h.

Group 5 was composed by 8 open nanoDot detectors, divided into two subgroups (5a and 5b). Immediately after the irradiation, one detector of each subgroup was covered with Mylar filters with superficial densities of 1.72 mg cm^{-2}, 3.53 mg cm^{-2} and 5.61 mg cm^{-2}. Subgroup 5a detectors were exposed to fluorescent light of 260 lux in the laboratory bench (the luminance level decreased with fluorescent lamps' natural use), and the detectors of subgroup 5b were exposed to 1.5×10^4 lux, inside a closed box with 1 fluorescent lamp (Sylvania, model F 16 W/78). The nanoDot samples were positioned at 9 cm from the lamp.

All readings were normalized to the initial measurement values.

The optical treatment of OSL nanoDot detectors was realized in a closed box (2.4×10^4 lux, fluorescent light source) during 24 h prior to each re-use.

3. Results and discussions

3.1. Control group – group 1

The results of group 1 (control group) show a loss of at most 2–4% of the OSL response in the first 2 h after irradiation, corroborating the results obtained by other authors (Jursinic, 2007). After this period, the response remained approximately constant up to the last reading, performed 48 h after irradiation.

3.2. Detectors exposed to environmental fluorescent light – group 2

The open detectors exposed to environmental fluorescent light (280 lux) presented a loss of about 20% in 30 min and 95% of the OSL signal in 24 h (Fig. 2). This result was expected, and similar results were found by Gronchi et al. (2008), which obtained a loss of 35% in 30 min of exposure of the OSL sensitive elements to light in comparable conditions.

The loss in the OSL signal of the assembled detectors was 2% in 48 h (Fig. 3). This result is equivalent to group 1 loss, and it does not indicate light leaks in the assembled nanoDots. Benevides et al. (2011) found no statistically significant fading due to light leaks in the detector element holder, studying another sealed OSL detector (InLight, Landauer) with a different geometry.

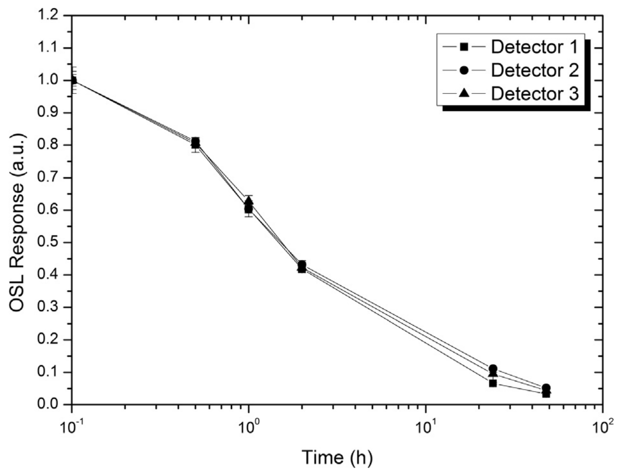

Fig. 2. Fading of open detectors exposed to environmental fluorescent light (280 lux).

3.3. Detectors exposed to semiconductor light inside a box – group 3

Figs. 4 and 5 show the results for the open and assembled detectors, respectively, exposed to semiconductor light (3.0×10^4 lux). The open detectors were almost reset in 30 min. Gronchi et al. (2008) obtained similar results exposing the OSL dot detectors (Landauer) to 2.6×10^4 lux of fluorescent light. The assembled detectors loss in the OSL signal was 16% in 48 h, which is significative.

3.4. Detectors exposed to sun light – group 4

The open detectors exposed to sun light (1.0×10^5 lux) were reset in 1 h (Fig. 6). Gronchi et al. tested OSL dot detectors (Landauer) in similar conditions and obtained null values in about 30 min of exposure to sun light. The assembled detectors loss in the OSL signal was 14% in 2 h (Fig. 7). This result indicates a significant loss. Benevides et al. (2010) exposed assembled InLight detectors (Landauer) to sun light for 45 days and obtained a significant loss of 55%.

3.5. Detectors covered with Mylar filters exposed to fluorescent light – group 5

Figs. 8 and 9 show that the use of optical filters delayed the decay of the OSL response of Al_2O_3:C detectors. The detectors

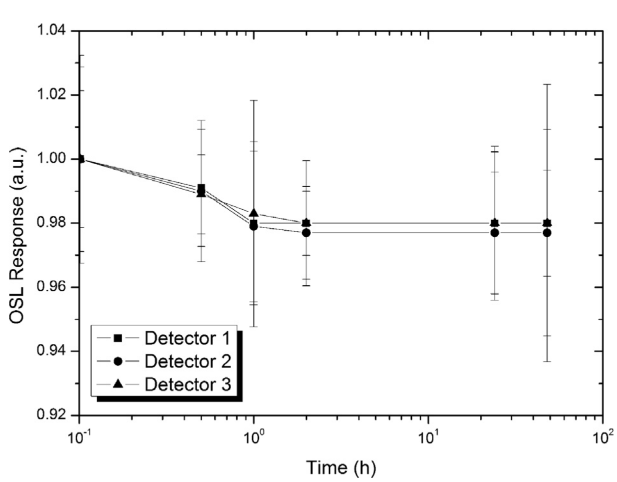

Fig. 3. Fading of assembled detectors exposed to environmental fluorescent light (280 lux).

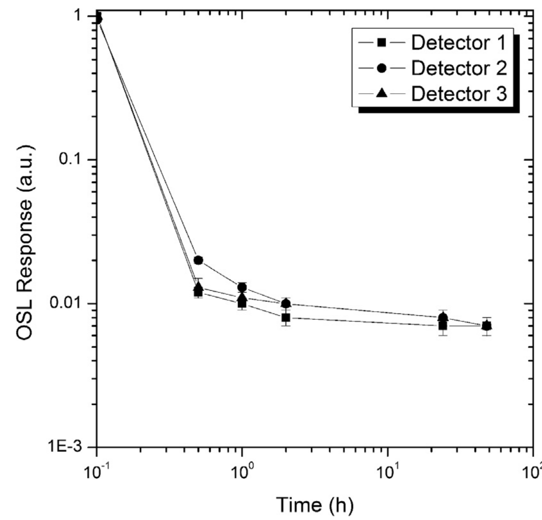

Fig. 4. Fading of open detectors exposed to semiconductor light inside a box (3.0×10^4 lux).

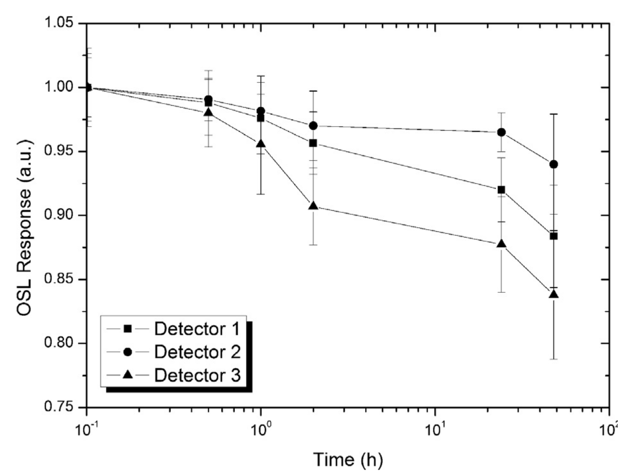

Fig. 5. Fading of assembled detectors exposed to semiconductor light inside a box (3.0×10^4 lux).

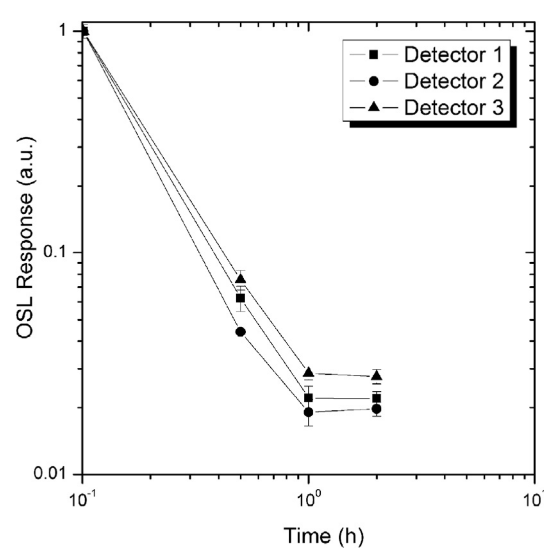

Fig. 6. Fading of open detectors exposed to sun light (1.0×10^5 lux).

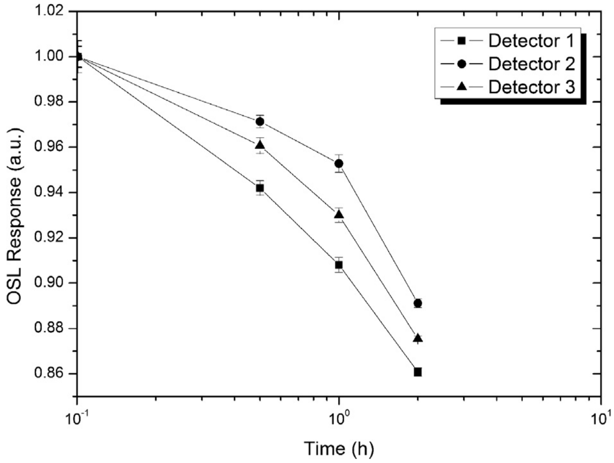

Fig. 7. Fading of assembled detectors exposed to sun light (1.0×10^5 lux).

exposed to strong fluorescent light (1.5×10^4 lux) showed a loss in OSL signal of 70 up 90% in 7.75 h and the exposure to the florescent room light (260 lux) during 7.75 h, situation that simulated a workday, caused a loss in the OSL signal of 20 up to 40%.

However, the nanoDot covered with the Mylar filter (superficial density 7.12 mg cm^{-2}), exposed to 260 lux fluorescent lamps, presented a loss in OSL response of only 2.5% in 50 min. The nanoDot with this geometry may be used as beta extremity dosimeter in operations with short duration – up to 50 min – such as inoculation with radiopharmaceuticals beta emitters.

4. Conclusions

The loss in the OSL signal was expected for the open detectors, when the OSL sensitive elements were exposed to light sources directly, but this OSL loss still occurs when the detectors were covered with the manufacturer's black plastic cover.

In the condition of a simulation of a workstation (the assembled detectors on the laboratory bench, exposed to fluorescent lamps), the loss was not significant, although the fading obtained

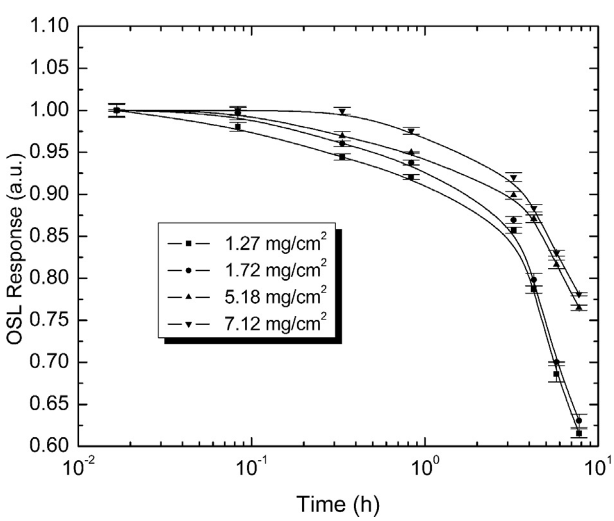

Fig. 8. Fading of open detectors covered with Mylar filters exposed to fluorescent room light (260 lux).

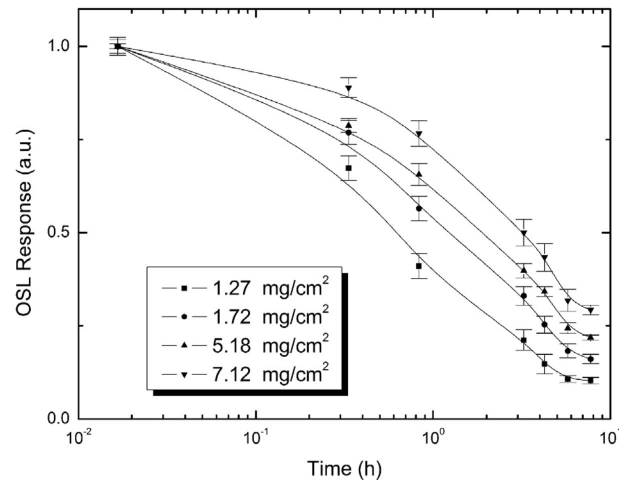

Fig. 9. Fading of open detectors covered with Mylar filters exposed to strong fluorescent light (1.5×10^4 lux).

when the assembled detectors were exposed to a higher illumination level (the assembled detectors exposed to semiconductor light source) was significant. This fact may indicate light leaks occurring in the nanoDots, especially because the temperature in the semiconductor box is controlled by the forced ventilation.

The assembled detectors exposed to sun light (another possible simulated workstation) presented a significant loss in the OSL signal that may result in loss of dose information. Further studies are necessary to verify the temperature influence on the loss of the OSL response, and the OSL fading when black Mylar foils are used on the detectors.

Mylar filters were used to delay the fading of the OSL signal and nanoDot covered with the Mylar filter (superficial density 7.12 mg cm^{-2}) may be used as beta extremity dosimeter in operations with short duration.

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