

Influence of Thermal and Optical Treatments on the OSL Response of $\text{Al}_2\text{O}_3:\text{C}$ Pellets Using Blue Light Stimulation

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Abstract—This work presents a study of the OSL residual signal of $\text{Al}_2\text{O}_3:\text{C}$ pellets after different annealing/bleaching treatments. It is shown that this luminescent material has deep trapping centers which are not associated with the TL main peaks and they are not completely emptied with an annealing up to 800°C . This fact was noticed when using blue light for the OSL stimulation. Optical bleaching using high power LEDs (blue, green and white) demonstrated that lower energies (green) result into higher residual OSL signal; and bleaching with similar energy (of that used for stimulation) shows better results.

Index Terms— $\text{Al}_2\text{O}_3:\text{C}$, annealing, optical bleaching, optically stimulated luminescence.

I. INTRODUCTION

THE use and application of optically stimulated luminescence (OSL) dosimeters in personal dosimetry have increased in the past years due to their great advantages in relation to other kinds of dosimeters. One good example of a widely used solid state dosimeter is carbon-doped aluminium oxide ($\text{Al}_2\text{O}_3:\text{C}$), which was initially suggested for thermoluminescent (TL) dosimetry in the early 1990s [1]. However, a few years after its development, its high sensitivity to light was determinant for use as OSL dosimeter [2].

In theory, this kind of dosimeter may be used several times, since its signal can be erased by an optical (bleaching) or a thermal (annealing) treatment. When this dosimeter is used for high dose measurements it may require 900°C annealing to completely empty the deep traps and erase all luminescence signal [2]. However, some $\text{Al}_2\text{O}_3:\text{C}$ samples, used only for OSL measurements, cannot be annealed, and there is only few available information on bleaching procedures for this purpose.

Usually, OSL measurements of $\text{Al}_2\text{O}_3:\text{C}$ are stimulated with green light, because it facilitates the discrimination between the stimulation light and the main emission luminescence, at 420 nm, and provides efficient stimulation of the trapped

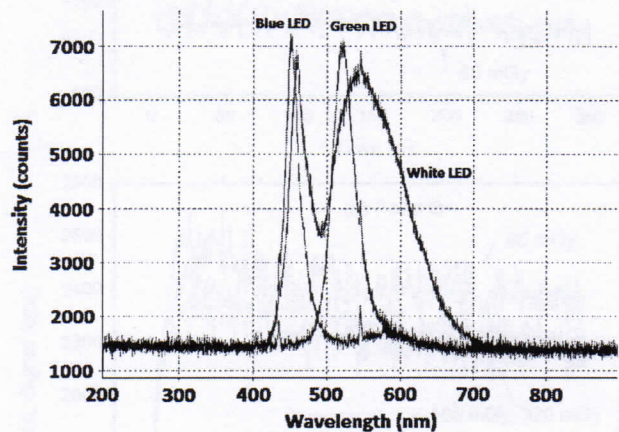


Fig. 1. High power LEDs emission spectra. The spectra intensity shown in the figure is only qualitative and do not correspond to the real intensity at the sample position.

charges. But, as it is suggested, $\text{Al}_2\text{O}_3:\text{C}$ can be stimulated with a large range of wavelength light sources since there is a wide variety of trapping states in this material, which contributes to the OSL signal [3]. Whitley and McKeever [3] observed that 90% of the measured OSL signal originates from the traps corresponding to the TL peak around 500 K with stimulation at 465 nm. Higher energy stimulation de-traps deeper charges that also contribute to the OSL signal.

In 2010, Umisedo *et al.* [4] studied the influence of stimulation light wavelength on the OSL signal of $\text{Al}_2\text{O}_3:\text{C}$. They found interesting and intriguing results using blue light stimulation, especially with respect to the residual signal after bleaching.

In the present work, the influence of different treatments used to erase the blue stimulated OSL response of $\text{Al}_2\text{O}_3:\text{C}$ samples was studied. Pellets of TLD-500 were annealed, as recommended by the manufacturer for TL measurements, and they were bleached using different high power LEDs.

II. MATERIALS AND METHODS

The $\text{Al}_2\text{O}_3:\text{C}$ samples used to carry out this work were TLD-500 pellets purchased from Rexon Inc., USA. These pellets are 5-mm diameter by 1-mm-thick disks, and they are commercially available for individual and environmental dosimetry. As these samples are mainly used for TL measurements, their responses were first characterized with this technique. The reproducibility and linearity of TL response of a group of 20 pellets were obtained, and four of them were chosen to be used in this work. The four pellets, so-called A,

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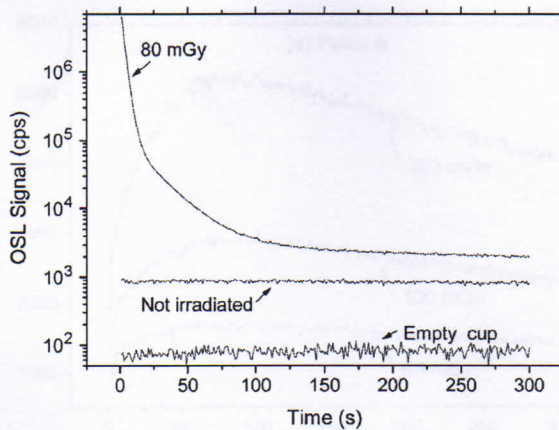


Fig. 2. OSL signal profiles form an irradiated sample, a non-irradiated sample and an empty cup.

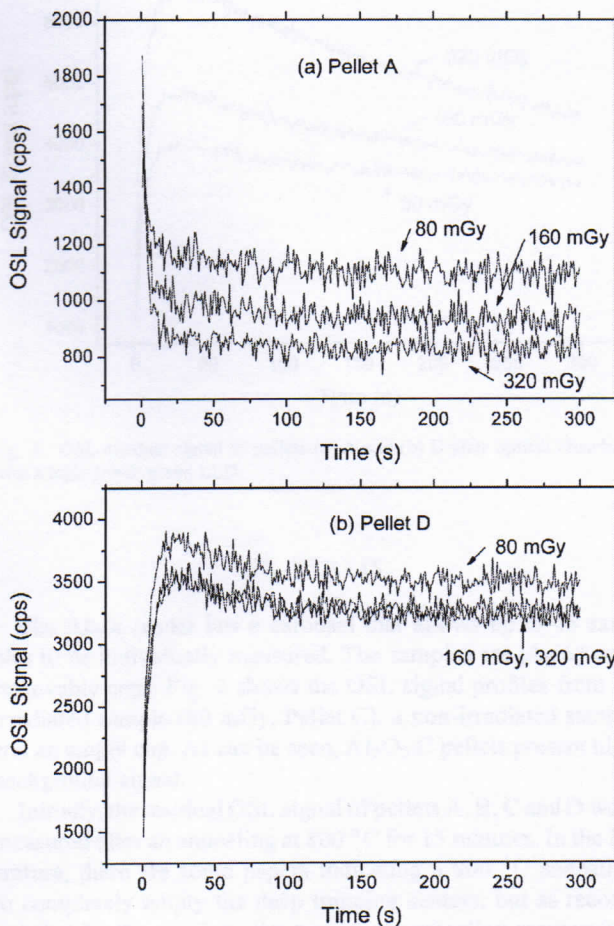


Fig. 3. OSL residual signal of pellets (a) A and (b) D after annealing.

B, C, and D, presented similar TL response. The manufacturer recommends an annealing at 800 °C for 15 minutes to empty the sample traps. It is worth noting that TL measurements were performed exclusively to choose the pellets with similar responses.

The TL/OSL reader used in this work is a Risoe, model DA-20. This equipment allows the measurement of 48 samples

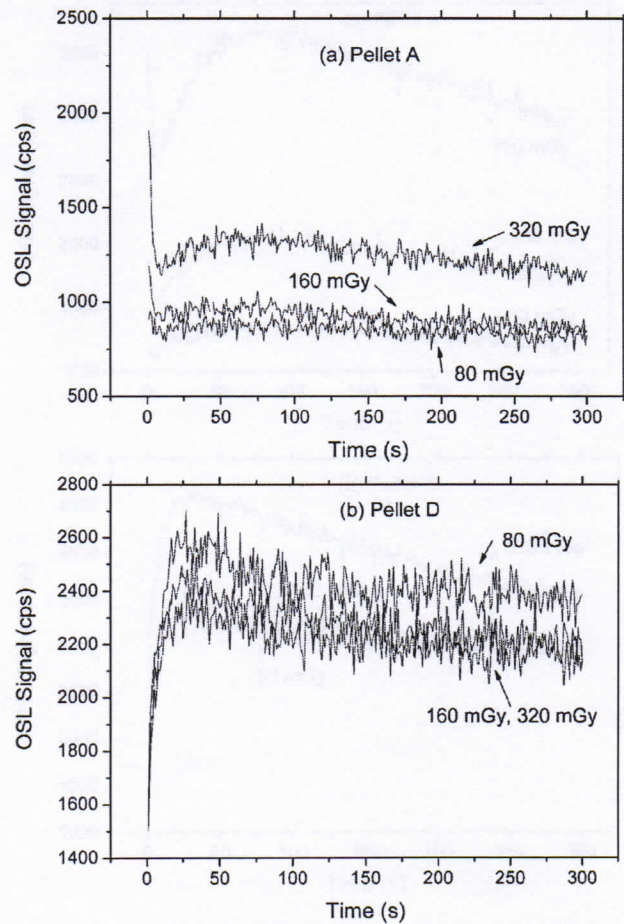


Fig. 4. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high-power blue LED.

which can be individually stimulated, and it is equipped with a $^{90}\text{Sr} + ^{90}\text{Y}$ beta source with approximately 40 mCi, and a dose rate in quartz of $80 \text{ mGy}\cdot\text{s}^{-1}$. The reader has also an alpha source (^{241}Am) that was not used in this work. All irradiations were carried out using the beta source. For thermal stimulation, the samples can be heated up to 700 °C; and for optical stimulation, the equipment has LED systems in the blue and infrared regions. In this work, TL measurements were performed heating the pellets up to 270 °C at a rate of 5 °C/s, and OSL measurements were performed using the blue LEDs and a Hoya U-340 filter.

Four different procedures to erase the OSL signal were tested: annealing at 800 °C for 15 minutes (as recommended by Rexion, Inc., for TL measurements), and bleaching using high-power LEDs of three different colors (blue, green, and white) during 15 minutes.

The annealing was performed on a muffle furnace, model MFL 1000, Provetco Analítica, Brazil.

The high-power LEDs were mounted in a special box totally closed to avoid external interference, and they were connected to a digital power supply set to provide $\sim 2.5\text{W}$. The LED emission spectra were obtained using a spectrometer USB4000, Ocean Optics, USA, and they are shown in Fig. 1.

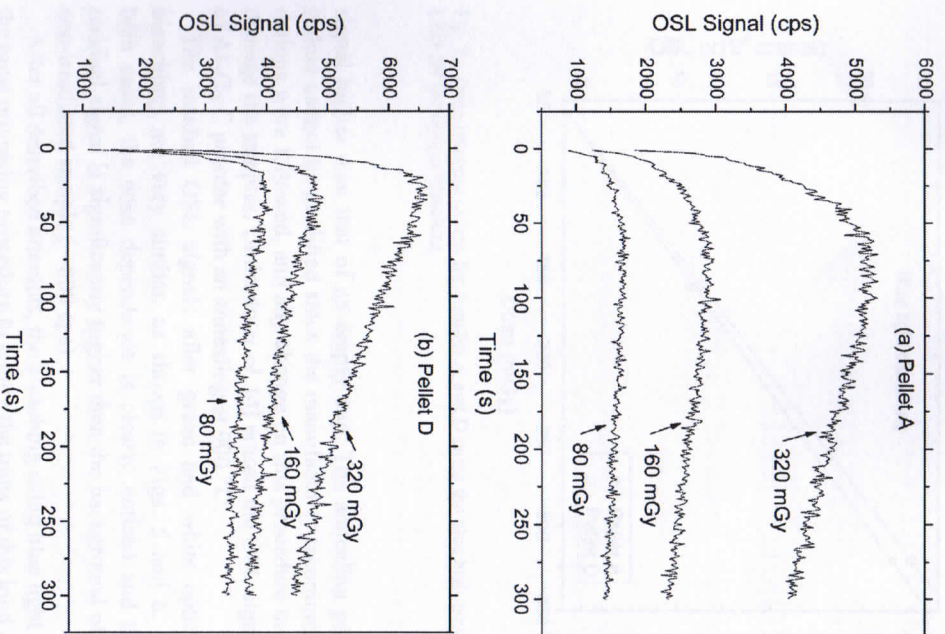


Fig. 5. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high-power green LED.

III. RESULTS

The Risoe reader has a carousel that allows up to 48 samples to be individually measured. The samples are placed onto removable cups. Fig. 2 shows the OSL signal profiles from an irradiated sample (80 mGy, Pellet C), a non-irradiated sample and an empty cup. As can be seen, $\text{Al}_2\text{O}_3:\text{C}$ pellets present high background signal.

Initially, the residual OSL signal of pellets A, B, C and D were measured after an annealing at 800°C for 15 minutes. In the literature, there are some papers indicating a 900°C annealing to completely empty the deep trapping centers, but as recommended by Rexon, Inc., the maximum annealing temperature used was 800°C . The samples were irradiated with 80 mGy. OSL measurements were carried out before and after they were annealed. Doses of 160 and 320 mGy were also delivered to the samples, and OSL measurements were performed before and after the annealing. Fig. 3 shows the residual OSL signal after annealing.

The described procedure was repeated using the high-power LEDs to bleach the samples. The results obtained with the blue, green, and white LEDs are shown in Figs. 4, 5, and 6, respectively.

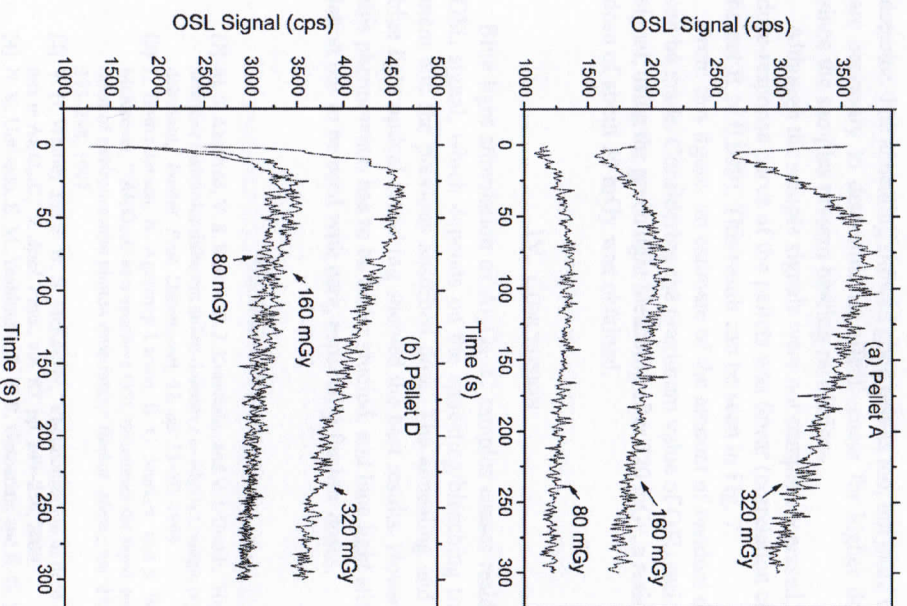


Fig. 6. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high-power white LED.

Pellets B, C, and D presented very similar responses; therefore, only the results obtained for pellets A and D are presented in this work.

As can be seen, pellet A presents a lower background signal than pellet D and, in all cases, they are dose dependent.

Figs. 3 and 4 show that the residual signal after annealing and optical bleaching with blue light are very similar. However, pellet A shows an OSL decay while pellet D seems to increase the signal rapidly at the beginning of the measurement. The increasing signal in pellet D can be explained by a phototransfer process, in which the free electrons can be trapped by the main dosimetric traps, competing with recombination centers. The inverse behavior observed in pellet A may have occurred due to the presence of impurities in the pellet resulting into this spurious signal, but it is only an assumption. A dependence on the previous dose was expected, since the OSL signal is not completely erased. In Figs. 3 and 4, the dose dependence is not very clear. Perhaps, the samples had not achieved equilibrium yet. These testes may be repeated to verify this behavior. As the blue LED bleaching was the most promising treatment, tests increasing the duration of the bleaching process may improve the results.

In the case of annealing, even with a temperature at 800°C , the $\text{Al}_2\text{O}_3:\text{C}$ pellets used in this work showed a background

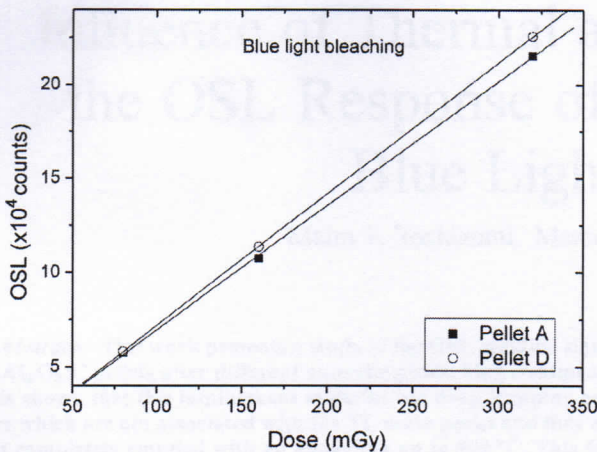


Fig. 7. Dose-response curves for samples A and D using the blue high-power LED for the optical bleaching.

signal higher than that of an empty cup. The annealing procedure cannot be modified since the manufacturer recommendations were followed, and any change on this procedure may damage the samples. Umisedo *et al.* [4] erased the OSL signal of Al₂O₃:C powder with an annealing at 900 °C.

The residual OSL signals after green and white optical bleachings are very similar, as shown in Figs. 5 and 6. In both cases, the dose dependence is clearly noticed and the residual signal is significantly higher than the background of a non-irradiated sample (~800 cps).

After all described attempts, the bleaching using blue light is the most promising procedure to empty the traps of this kind of

detector. The annealing showed good results too, but more tests are necessary to determine its effectiveness for higher doses since the samples present heating restrictions.

Although the sample signals were not completely erased, the dose-response curve of the pellets was linear (correlation coefficient $R > 0.999$). This result can be seen in Fig. 7.

From this figure, an estimate of the amount of residual dose can be made. Considering the maximum value of OSL residual signal, using the green light bleaching after 320 mGy, a residual dose of about 50 mGy was obtained.

IV. CONCLUSION

Blue light stimulation of Al₂O₃:C samples causes residual OSL signal, which depends on the annealing/bleaching treatment and the previous absorbed dose. The annealing and the blue light optical bleaching showed the best results. However, this phenomenon has to be better studied, and blue light stimulation has to be used with care, especially for low doses.

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