Influence of Thermal and Optical Bleaching on the OSL Response of Al_2O_3:C Pellets Using Blue Light Stimulation

Maíra T. Yoshizumi, Marcos Xavier and Linda V. E. Caldas

***Abstract*—This work presents a study of the OSL residual signal of Al_2O_3:C pellets after different 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 a thermal bleaching 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 treatment with similar energy (of that used for stimulation) shows better results.**

***Index Terms*—Al_2O_3:C, Optical bleaching, Optically stimulated luminescence.**

I. Introduction

THE use and application of solid state dosimeters have increased in the past few 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 (Al_2O_3:C), which was initially suggested for thermoluminescent dosimetry in the early 1990s [1]. However, a few years after its development, its high sensitivity to light was determinant for use as optically stimulated luminescence (OSL) dosimeter [2].

In theory, this kind of dosimeter may be used several times, since its signal can be bleached by an optical or a thermal treatment. When this dosimeter is used for high doses measurements it may require 900°C annealing to completely empty the deep traps and bleach all luminescence signal [2]. However, some Al_2O_3:C pellets, used only for OSL measurements, cannot be thermally treated, and there is only few available information on optical treatments for this purpose.

Usually, OSL measurements of Al_2O_3: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 charges. But, as it is suggested, Al_2O_3: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 observed that 90% of the measured OSL signal originates from the traps corresponding to the TL peak around 500K with stimulation at 465 nm. Higher energy stimulation de-traps deeper charges that contribute more significantly to the OSL signal.

In 2010, Umisedo et al. [4] studied the influence of stimulation light wavelength on the OSL signal of Al_2O_3: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 bleaching treatments on the blue stimulated OSL response of Al_2O_3: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. Material and Methods

The Al_2O_3:C samples used to carry out this work are TLD-500 pellets manufactured by Rexon Inc., USA. These pellets are 5 mm in diameter by 1 mm thickness discs, and they are commercially available for individual and environmental dosimetry. The reproducibility and linearity of TL response of a group of 20 pellets were obtained and 4 of them were chosen to be used in this work. The 4 pellets, so-called A, B, C and D, presented similar TL response. The manufacturer recommends an annealing at 800°C for 15 minutes to empty the sample traps.

The Risoe reader is also equipped with a $^{90}Sr+^{90}Y$ beta source with approximately 40 mCi, and a dose rate in quartz of 80 mGy.s^{-1}. All irradiations were carried out using this source.

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Four bleaching procedures were tested: thermal treatment or annealing, and optical bleaching using high power LEDs of three different colors (blue, green and white).

The annealing was performed on a muffle furnace, model MFL 1000, Provecto Analítica, Brazil, according to manufacturer recommendations.

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 ~2,5W. In both cases (thermal and optical) the bleaching process was performed during 15 minutes. The LED emission spectra were obtained using a spectrometer USB4000, Ocean Optics, USA, and they are shown in Fig. 1.

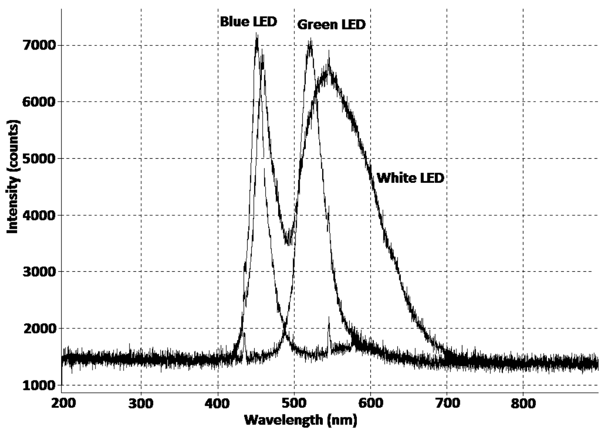


Fig.1. High power LEDs emission spectra. The spectra intensity shown in the figure is only qualitative and do not correspond to the real intensity at the sample position.

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, Al_2O_3:C pellets present high background signal.

Initially, pellets A, B, C and D were irradiated with 80 mGy. The OSL measurements were carried out before and after they were thermally bleached. After that, doses of 160 mGy and 320 mGy were delivered to the samples and the same procedures were adopted. Pellets B, C and D presented very similar responses; therefore only the results obtained for pellets A and D are presented in this work.

Fig. 3 shows the residual OSL signal after thermal bleaching. As can be seen, pellet A presents a lower background signal than pellet D and, in both cases, they are dose dependent.

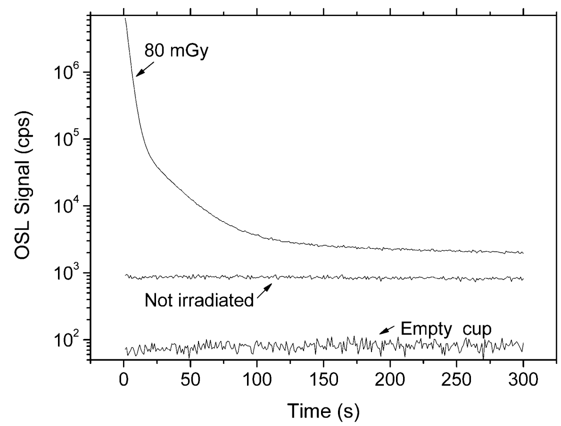


Fig. 2. OSL signal profiles form an irradiated sample, a non-irradiated sample and an empty cup.

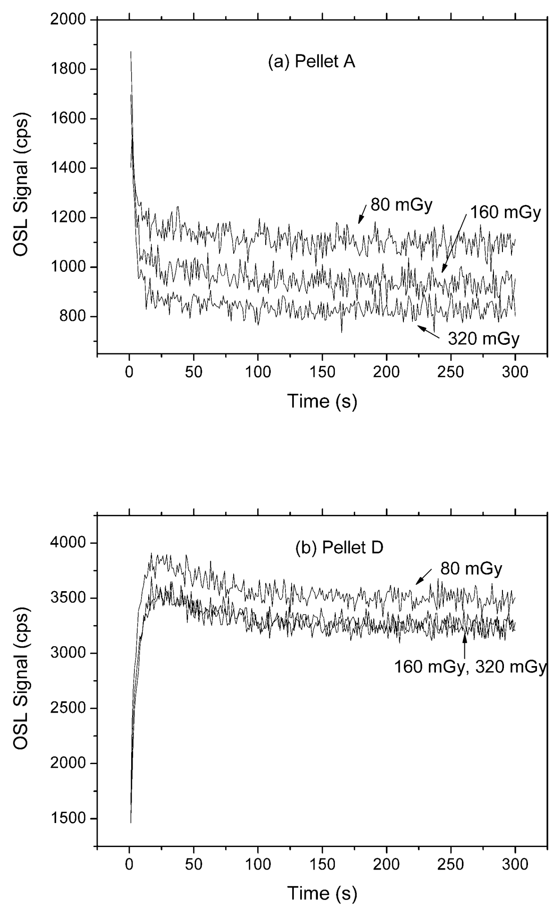


Fig. 3. OSL residual signal of pellets (a) A and (b) D after thermal bleaching.

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.

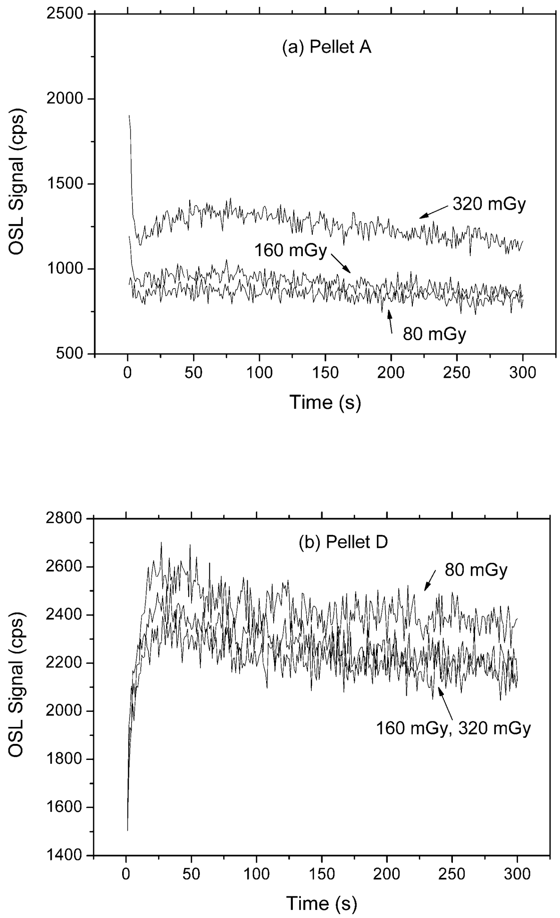


Fig. 4. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high power blue LED.

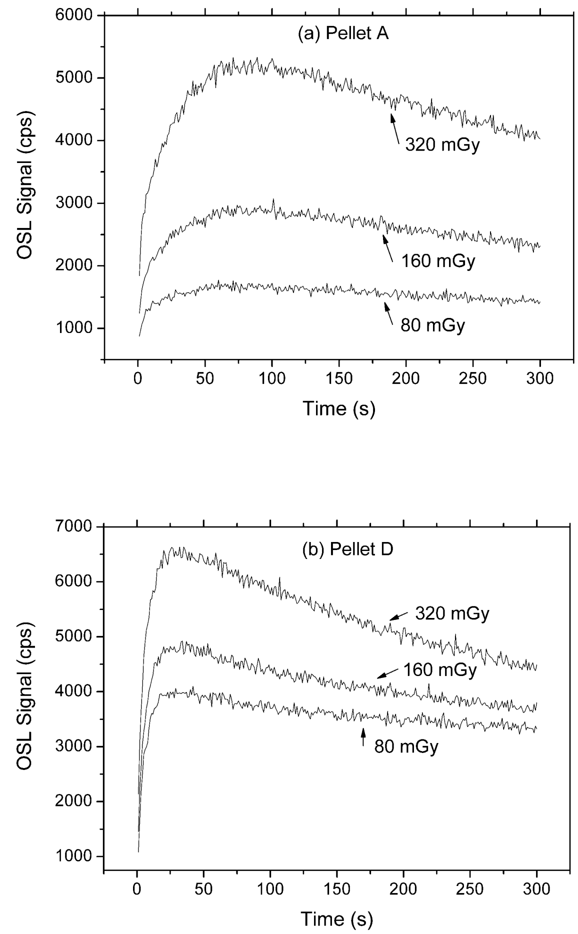


Fig. 5. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high power green LED.

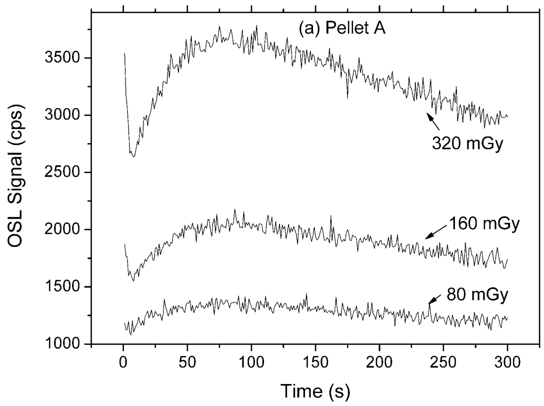
As can be seen in Figs. 3 and 4, the residual signal after thermal bleaching and optical bleaching with blue light are very similar. Pellet A shows an OSL decay dependent on the previous dose. Maybe, increasing the duration of the optical bleaching process, this initial signal decreases or even disappears. In the case of the thermal bleaching there is nothing to do as the manufacturer recommendations were followed.

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).

Even with a thermal bleaching at 800°C, the Al_2O_3:C pellets used in this work showed a background signal higher than that of an empty cup. Umisedo et. al. [4] suggested a phototransfer mechanism to explain this residual signal and confirmed this fact heating Al_2O_3:C powder up to 900°C and the trapping center were all emptied.

After all the attempts described, the optical bleaching using blue light is the most promising procedure to empty this kind of detector. The thermal bleaching showed good results too, but more tests are necessary to determine its effectiveness for higher doses since the samples have heating restrictions.

Although the samples were not completely emptied, the dose-response curve for all cases was linear (correlation coefficient $R > 0.999$). This result can be seen in Fig. 7. Those curves show a loss of OSL signal when using the green instead of the blue light for the bleaching treatment. This is one reason to be careful about when using this dosimeter for low dose measurements.



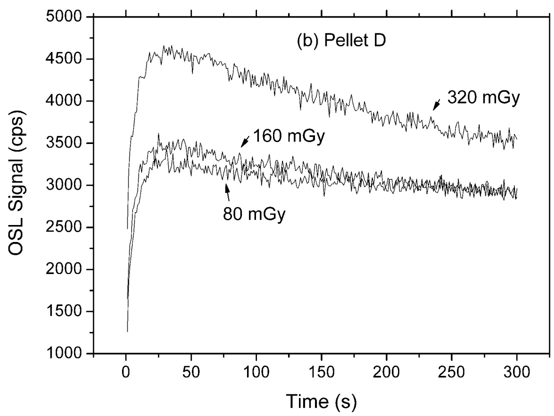


Fig. 6. OSL residual signal of pellets (a) A and (b) D after optical bleaching with a high power white LED.

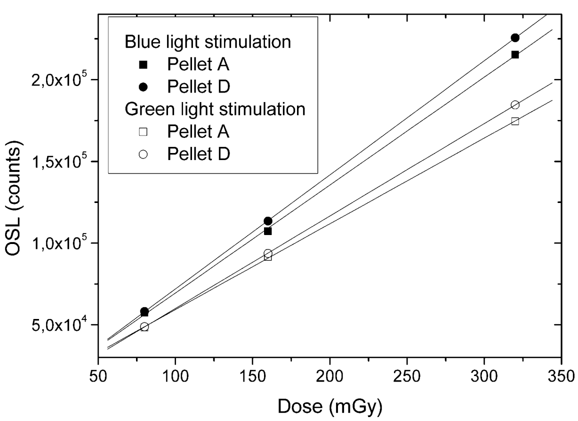


Fig. 7. Dose-response curves for samples A and D using the blue and green high power LEDs for the optical bleaching.

IV. Conclusion

Blue light stimulation of Al_2O_3:C samples causes residual OSL signal. This residual signal depends on the bleaching treatment and the previous absorbed dose. The thermal treatment 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.

References

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