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Analyzing gamma irradiated Spectrolite in relation to the photo-transfer TL and OSL effects

Antonio[a*], P. L.; Caldas[a], L. V. E.

[a] Instituto de Pesquisas Energéticas e Nucleares, 05508-000, São Paulo, SP, Brazil

*Correspondence: patrilan@ipen.br

Abstract: Thermoluminescence (TL) and optically stimulated luminescence (OSL) are two techniques based in the luminescence phenomenon. They can be applied to study the response of materials which present the property of emitting light after the steps of irradiation and subsequent stimulus, that can be thermal (in the case of TL) or optical (OSL). These materials may also be capable of exhibiting phototransfer effect in their response, and this characteristic can be observed through the TL photo-transfer (PTTL) and OSL photo-transfer (PTOSL). The purpose of this work was to verify the presence of the PTTL and PTOSL responses on the Spectrolite material, after irradiation with gamma source (^{60}Co) and illumination with LEDs (wavelengths in the UV region), for application in gamma radiation dosimetry. For this, the signal of Spectrolite samples was studied in relation to their TL/PTTL and OSL/PTOSL responses by means of three steps: 1) irradiation and measurement of TL and OSL responses; 2) irradiation, post-irradiation thermal treatment (PITT) and measurement of TL and OSL signals; and 3) irradiation, PITT, illumination with LEDs and measurement of PTTL and PTOSL signals. The results obtained showed the presence of photo-transfer effect in the PTTL response, but not in the PTOSL response; this fact demonstrates the need for further studies to verify the PTTL and PTOSL responses, with variations in the wavelength of light and the illumination time. For application of this material in gamma radiation dosimetry, these other studies are needed.

Keywords: Spectrolite, thermoluminescence, optically stimulated luminescence, photo-transfer phenomenon.

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Análise da Espectrolita submetida à radiação gama em relação aos efeitos da TL e OSL fototransferidas

Resumo: A termoluminescência (TL) e a luminescência opticamente estimulada (OSL) são duas técnicas baseadas no fenômeno da luminescência. Elas podem ser aplicadas no estudo da resposta de materiais que apresentam a propriedade de emitir luz após as etapas de irradiação e estímulo subsequente, o qual pode ser térmico (no caso da TL) ou óptico (OSL). Esses materiais também podem ser capazes de exibir o efeito de fototransferência em sua resposta, e essa característica pode ser observada através da TL fototransferida (PTTL) e da OSL fototransferida (PTOSL). O objetivo deste trabalho foi verificar a presença das respostas PTTL e PTOSL no material Espectrolita, após irradiação com fonte gama (^{60}Co) e iluminação com LEDs (comprimentos de onda na região do UV), para aplicação em dosimetria de radiação gama. Para isso, o sinal das amostras de Espectrolita foi estudado em relação às suas respostas TL/PTTL e OSL/PTOSL por meio de três etapas: 1) irradiação e medição das respostas TL e OSL; 2) irradiação, tratamento térmico pós-irradiação (TTPI) e medição dos sinais TL e OSL; e 3) irradiação, TTPI, iluminação com LEDs e medição dos sinais PTTL e PTOSL. Os resultados obtidos mostraram a presença de efeito de fototransferência na resposta PTTL, mas não na resposta PTOSL; este fato demonstra a necessidade de estudos adicionais para verificar as respostas PTTL e PTOSL, com variações no comprimento de onda da luz e no tempo de iluminação. Para aplicação deste material para dosimetria de radiação gama, estes outros estudos são necessários.

Palavras-chave: Espectrolita, termoluminescência, luminescência opticamente estimulada, fenômeno de fototransferência.

1. INTRODUCTION

There are materials that have the property of emitting light when they are irradiated with a certain radiation source and subsequently suffering an optical or thermal stimulus which allows the signal to be released; this luminescence represents the stored energy, in form of light, in the material, and it is studied by means of the thermoluminescence (TL) and optically stimulated luminescence (OSL) phenomena. These materials can still present a photo-transfer effect on their luminescence signal, with displacement of the electrons from deeper traps to the shallower traps after illumination; this condition can be observed with the photo-transfer TL (PTTL) and photo-transfer OSL (PTOSL) processes [1-4].

In previous works, Spectrolite, a gemstone known for its iridescence and originating from Finland, had its luminescent signal studied using TL and OSL techniques by Antonio and col. after exposing the samples to beta ($^{90}Sr+^{90}Y$) [5] and gamma (^{60}Co) [6] radiation beams, to verify its potential application for beta and gamma radiation dosimetry.

The purpose of this work was to verify the presence of the PTTL and PTOSL responses on the Spectrolite signal after exposure to gamma radiation (^{60}Co) and illumination by light-emitting diodes (LEDs) with wavelengths in the UV region, for application in gamma radiation dosimetry.

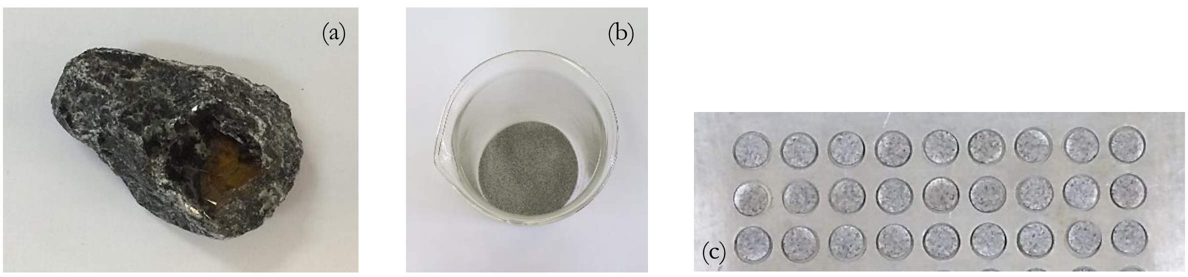
2. MATERIALS AND METHODS

Spectrolite is a Labradorite, a feldspar mineral from silicate family (tectosilicate group) [7]. The stone used in this work was purchased in Helsinki, Finland, and it is from the rugged bedrock of Ylämaa, in the south east of this country. The original stone has an irregular appearance and surface, with dimensions of 8.1 cm wide and 3.2 cm high, and an initial weight of 153.2 g.

In previous works, Antonio and col. [5-6] investigated and evaluated this material in relation to its dosimetric characteristics, in addition to its structure and chemical properties and composition.

The preparation process of the pellets was made according to the following procedure: The Spectrolite stone in its natural form (Fig. 1a) was broken into smaller pieces, which were ground in sequence using a mortar and a porcelain pestle. The grains obtained in this grinding process were passed through two sieves, with opening sizes of 177 µm and 74 µm. The powder resulting from sieving was weighed, washed with distilled water and placed in a glass beaker, which was placed in a stove at 100°C for 24 hours, in order to dry all the water and leave only the powdered material of the Spectrolite (Fig. 1b). This powder was mixed to Teflon in a proportion of [2 (Spectrolite):1 (Teflon)] and the pellets were produced with dimensions of 6.0 mm of diameter and 0.2 mm of thickness (Fig. 1c).

Figure 1: Finnish Spectrolite: (a) in natural form, (b) powder and (c) Spectrolite+Teflon pellets.



The pellets were studied in relation to their TL/PTTL and OSL/PTOSL responses. In order to verify the presence of the PTTL and PTOSL signals, the experimental procedures occurred in three steps: 1) irradiation and measurement of TL and OSL responses; 2) irradiation, post-irradiation thermal treatment (PITT) and measurement of TL and OSL signals; and 3) irradiation, PITT, illumination with LEDs and measurement of PTTL and

PTOSL signals. In all steps, the samples were irradiated to an absorbed dose of 1 kGy with a ^{60}Co source from a Gamma-Cell system, model 220, Atomic Energy of Canada (absorbed dose rate of 347.29 Gy/h at July/23). The thermal treatment procedures of PITT of the second and third steps were performed with 200°C/15 min, and for the illumination of the third step, the samples were exposed to a LED with wavelength of 265nm/15 min. In all measurements, the signal was evaluated using the TL/OSL reader system Risø, model TL/OSL-DA-20, and thereafter, the samples were thermally treated at 400°C/1 h for reutilization. For the TL/PTTL signal, the readings were carried out until a maximum temperature of 400°C and a heating rate of 10°C/s. The OSL/PTOSL measurements were taken under the following conditions: light of blue LEDs (total of 28 LEDs that emit light at a wavelength of 470 nm [8]) as stimulus for signal emission, LED power of 90% and stimulation time of 100 s.

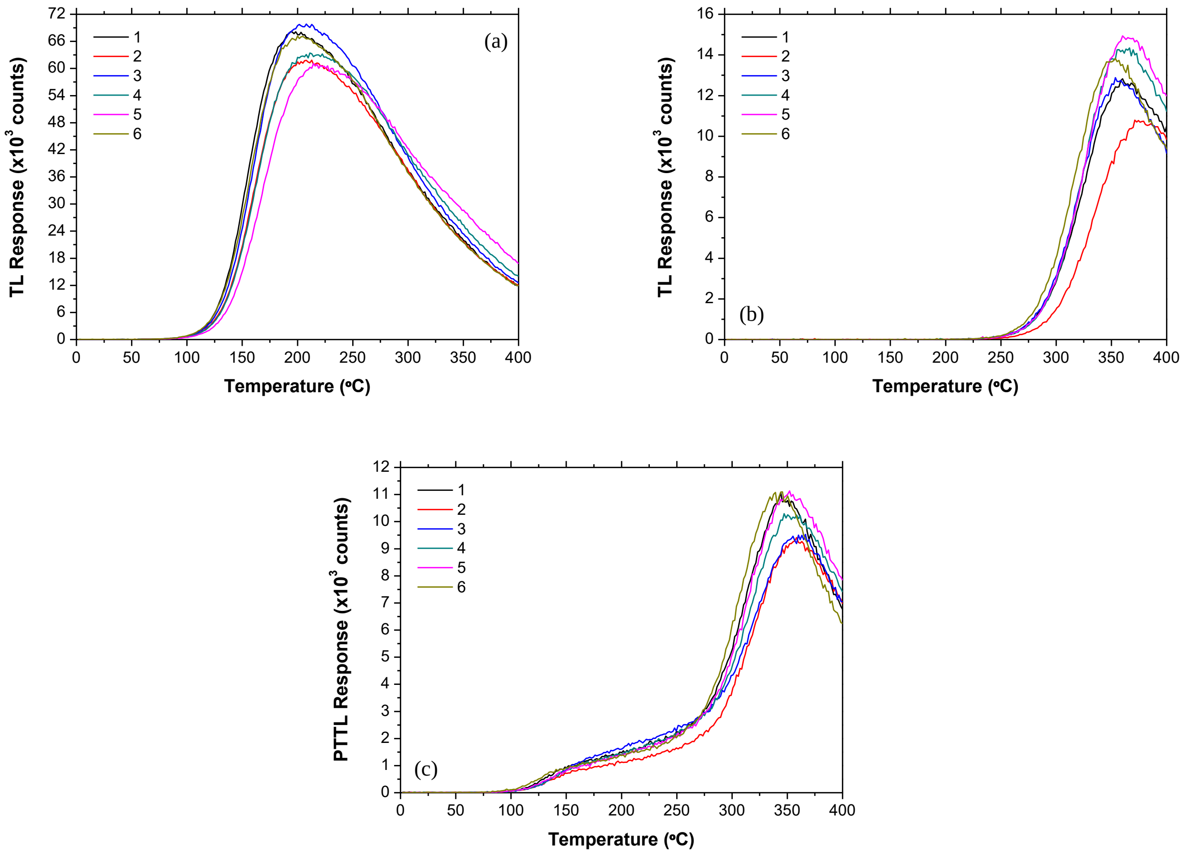
3. RESULTS AND DISCUSSIONS

The results obtained for the TL/PTTL and OSL/PTOSL responses are presented next.

3.1. TL and PTTL Responses

For the first step, the TL response was obtained after irradiation with 1 kGy and evaluation of the signal. The result revealed a glow curve with the emission dosimetric peak at about 210°C (which is in agreement with reference [6]), with peak maximum intensity in about 63×10^3 counts (integral medium value of 6.8×10^6 counts, with relative standard deviation of 3.8%) (Fig. 2a). In the second step, the PITT of 200°C/15 min emptied practically all shallow traps, leaving only a low intensity TL signal in a peak at 350°C, and showing a peak maximum intensity in about 12×10^3 counts (the integral medium value was 6.9×10^5 counts, and the relative standard deviation was 6.9%) (Fig. 2b). The last step of the TL group measurements was to verify the existence of PTTL signal after lighting; in this case, it was possible to observe a peak at the beginning of TL glow curve at 200°C (integral medium value of 7.5x10^5 counts and relative standard deviation of 4.3%), which suggests a photo-transfer effect, with electrons migrating from the deep traps to the shallow ones, after exposing the samples to light (Fig. 2c).

Figure 2: Response measurements of six Spectrolite samples: (a) TL signal after irradiation (1 kGy, ^{60}Co); (b) TL after irradiation (1 kGy, ^{60}Co) and post-irradiation thermal treatment (PITT, 200°C/15 min); and (c) PTTL after irradiation (1 kGy, ^{60}Co), PITT (200°C/15 min) and illumination with LEDs (265 nm/15 min).

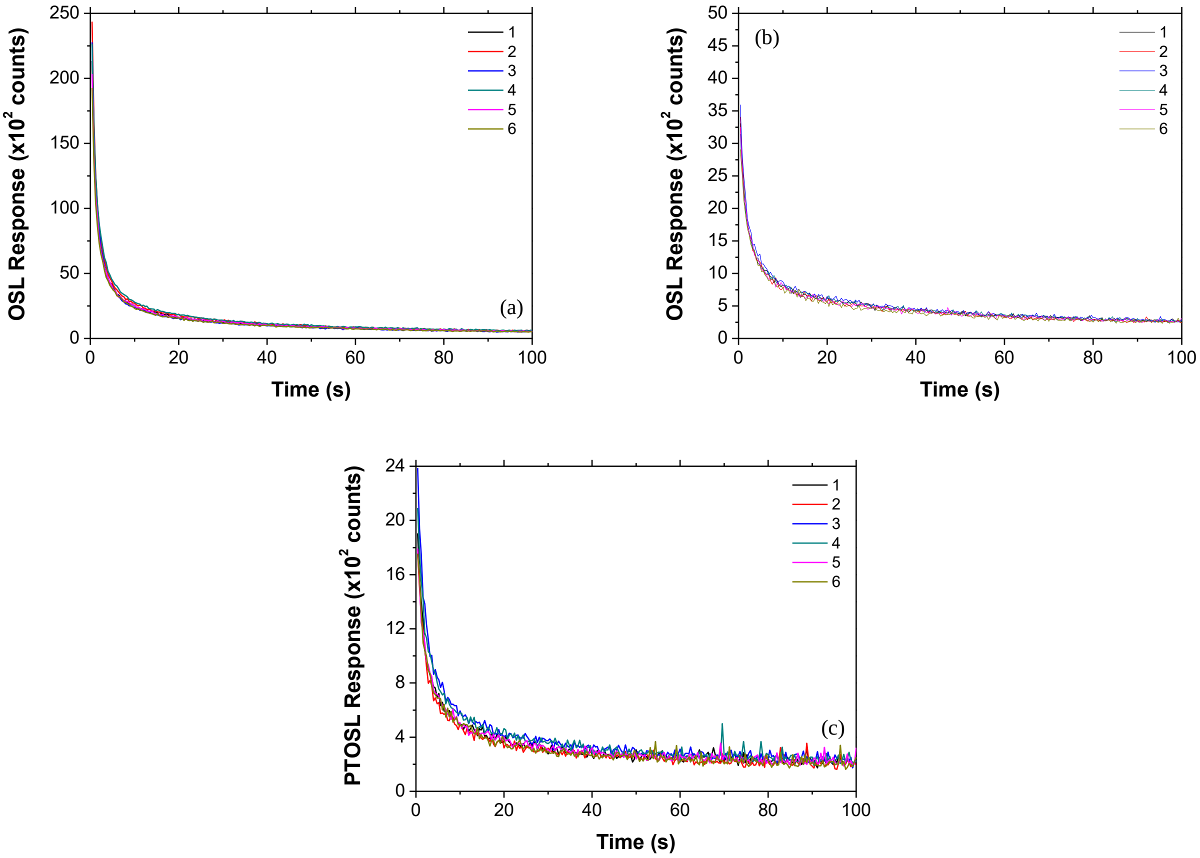


3.2. OSL and PTOSL Responses

Regarding the OSL measurement in step 1, the beginning of the decay occurred at about 2.5x10^4 counts (average value corresponding to the integral under the decay curve of 3.7x10^5 counts, with standard deviation of 6.5%) (Fig. 3a). During the analysis of the

OSL signal after PITT (step 2), the curve started to decay at a medium value of $3.3\text{x}10^3$ counts (while the average value of the integral was of $1.2\text{x}10^5$ counts and the standard deviation was 3.8%) (Fig. 3b). In relation to the third step, of PTOSL measurement, the signal represented by the decay curve emerged in about $2.0\text{x}10^3$ counts (average integral average value of $8.4\text{x}10^4$ counts and standard deviation of 6.5%), still below the previous result (OSL response after PITT) (Fig. 3c). This fact shows that there was no photo-transfer effect for the PTOSL measurement.

Figure 3: Response measurements of six Spectrolite samples: (a) OSL signal after irradiation (1 kGy, ^{60}Co); (b) OSL after irradiation (1 kGy, ^{60}Co) and post-irradiation thermal treatment (PITT, 200°C/15 min); and (c) PTOSL after irradiation (1 kGy, ^{60}Co), PITT (200°C/15 min) and illumination with LEDs (265 nm/15 min).



4. CONCLUSIONS

The data obtained in this work allow observing the presence of photo-transfer effect in the PTTL response, but not in the PTOSL response. These results open a possibility for a continuation of the study with these samples in order to analyze the dosimetric characteristics from their photo-transfer luminescence, including other studies of the PTTL and PTOSL signals, as the response in function of the wavelength and illumination time. Therefore, for application of this material for gamma radiation dosimetry, using these techniques demonstrated here, more studies are needed.

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CONFLICT OF INTEREST

We have no conflicts of interest to disclose.

All authors declare that they have no conflicts of interest.

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