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EVALUATION OF TL RESPONSE AFTER OSL MEASUREMENTS OF BEO SAMPLES

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ABSTRACT

In this work, initially BeO samples were irradiated using a beta source (^{90}Sr+^{90}Y) available in the Risø TL/OSL-DA-20 reader, which was also used to carry out the TL and OSL readings. The OSL measurements were taken between 20°C and 400°C. After each OSL measurement, a TL reading was taken. In the case of OSL, the OSL response decreases as the TL measurement temperature increases. The TL response obtained decreases as the OSL reading temperature increases. This study allowed the observation of the temperature effect on the charge release during OSL measurements, and to define until which temperature the TL response can be verified after the OSL measurements of BeO samples.

1. INTRODUCTION

The ionizing radiations are applied with great success in different areas such as medicine (diagnostic radiology and therapeutic applications) and industry. The thermoluminescence (TL) and optically stimulated luminescence (OSL) phenomena are widely used as dosimetric techniques for many applications. Knowing exactly the main parameters that can influence the luminescent response of dosimeters, the best conditions for the measurements may be defined.

Beryllium oxide (BeO) has been used as OSL dosimeter presenting advantages as high sensitivity to ionization radiation, linear dose response and effective atomic number (Zeff = 7.2) similar to human soft tissue (Zeff ~ 7.6) (Botter-Jensen et al, 2003). Furthermore, the low-cost material, easily handled to a ceramic disc form and good thermal conductivity make it even more attractive (Bulur and Gösku, 1998).

The main objective of this work was to verify the occurrence of thermoluminescent response after the OSL measurements and to define until which temperature (OSL reading) the TL response can be observed after OSL measurements.

In order to understand the results of this work, a study of thermal quenching in beryllium oxide (BeO) was previously conducted using the TL and OSL techniques. As the temperature varies during the TL and OSL with heating measurements, it was possible to notice a change in the luminescent response. The thermal quenching is the phenomenon related to the decreased luminescent response of materials due to the TL/OSL readings with increasing temperature heating.

2. MATERIALS AND METHODS

2.1. BeO samples

The BeO samples were in the form of discs of 4 mm in diameter and 0.8 mm in thickness, weighing (27.9 ± 0.45) mg; they consist of pressed pellets with some impurities: Si, K, Al, Fe and Mn (Groppo and Caldas, 2014).

2.2. Irradiations

The irradiations of the BeO samples were performed using a $^{90}Sr+^{90}Y$ source available in the Risø TL/OSL-DA-20 reader. The beta radiation absorbed dose rate was 0.1 Gy/s, according to the manufacturer´s manual. The nominal activity of the beta source was 1.48 GBq according to the calibration certificate (06/10/2010). To determine the exposure time, a correction due to the radioactive decay was applied for the measurement date. All samples were irradiated with a 1 Gy of absorbed dose.

2.3. TL and OSL measurements

The TL and OSL measurements were carried out using a Risø TL/OSL-DA-20 reader. The TL measurements were performed until 450°C and a constant flow of nitrogen gas of 1L/min. For each sample a calibration factor was obtained. The OSL measurements were taken using the continuous wave mode (CW-OSL), with blue LEDs for stimulation; an UV transmitting broad-band glass filter Hoya U-340 was used in front of the photomultiplier tube. Each OSL measurement was carried out during 100 s of LED stimulation with 90% of power.

2.3.1. Thermal quenching

For the thermal quenching tests, the TL measurements were taken using several heating rates between 0.1ºC/s and 10°C/s, and the OSL measurements were taken using reading temperatures between 20ºC and 400ºC, after the exposure of the samples to a beta radiation beam, with 1 Gy of absorbed dose. The TL emission was integrated from 100°C to 300°C, depending on the peak position, and the OSL response was integrated from 0 s to 100 s, in both cases after subtracting the background signal.

2.3.2. TL after OSL

The OSL measurements were taken using reading temperatures of 25°C, 50°C, 75°C, 100°C, 125°C, 150°C, 200°C, 300°C and 400°C, after the exposure of the BeO samples to the beta radiation beam (1Gy). The TL measurements were taken after each cycle of irradiation and OSL reading. The intensity of the second TL peak (which occurs at approximately 350°C) was the TL response.

2.4. Thermal bleaching

Initially, the samples were heated at 750ºC during 15 s in a muffle furnace with microwave heating (MFLO1000 by Provecto Analítica), to empty their traps. After each cycle of irradiation followed by TL measurement, the samples were submitted to the same heating process. In the case of double measurements (OSL and TL), the samples were submitted to the thermal treatment again.

3. RESULTS

3.1. Temperature influence on thermoluminescence measurements

To verify the effect of the thermal quenching in the TL response of beryllium oxide, 3 sets of TL measurements were taken at different heating rates: 1.0°C/s, 2.0°C/s, 3.0°C/s, 4.0°C/s, 5.0°C/s, 6.0°C/s, 7.0°C/s, 8.0°C/s, 9.0°C/s and 10.0°C/s. Some TL curves obtained are shown in Figure 1 (heating rates: 1°C/s; 5°C/s and 10°C/s).

As can be seen in Figure 1, there is a shift of the TL peaks to the right with increasing heating rate, as already observed by other authors (Chen and McKeever, 1997). A decrease in the intensity of the TL peaks can also be observed.

In the crystal there are several types of charge traps. When the crystal is heated slowly, it remains a “long” time in a certain temperature range, increasing the chances of emptying the charges at this energy level, while a “faster” heating rate cannot discharge so many traps (Chithambo, 2014). This fact may explain the displacement of the TL peak observed in Figure 1. The decrease in the TL peak intensity can be explained by the fact that the thermal energy empties the shallow traps, decreasing the trap population that would recombine (Chithambo, 2014).

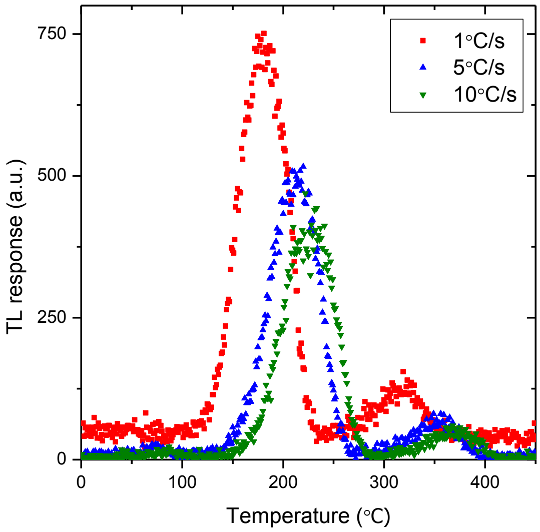

Figure 1. TL emission curves of BeO samples for different heating rates, after irradiation with ^{90}Sr+^{90}Y (1 Gy).

For a better visualization of this TL reduction, a graph of the luminescent intensity versus heating rate was obtained, as shown in Figure 2. A notable decrease is observed in the TL response as the heating rate increases.

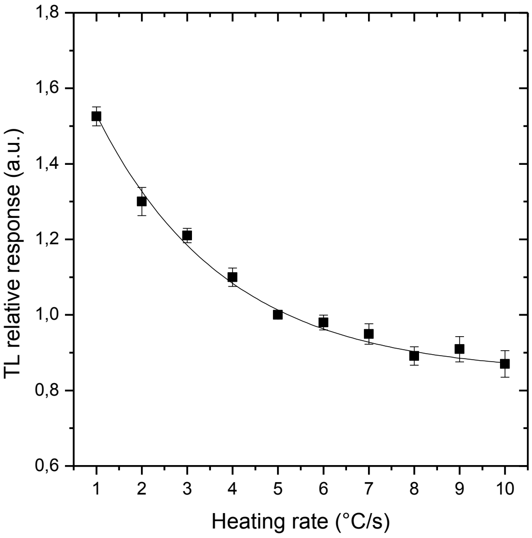

Figure 2. TL relative response of BeO samples for various heating rates, normalized to 5°C/s.

Figure 1 shows that the background signal (BG) is higher for lower heating rates. This fact can be associated with the duration of the photomultiplier tube use, which increased its BG due to the longer time reading.

3.2. Thermoluminescent response after OSL measurements

Initially, the samples were irradiated with the beta source (1 Gy). The samples were submitted to the OSL evaluation, then the TL measurements were taken, and finally the samples were thermally treated for reutilization.

In the Risø system, the OSL readings can be performed by varying the measurement temperature. Therefore, all of the previously measurements taken were carried out again using heating with temperature from 25°C until 400°C.

3.2.1. Optically Stimulated Luminescence

The samples were irradiated with a dose of 1 Gy. The OSL decay curves were obtained for various heating temperatures: room temperature, 30°C, 50°C, 60°C, 75°C, 100°C, 125°C, 150°C, 200°C, 300°C and 400°C. Figure 3 presents some of the OSL decay curves, only for a visualization effect. The results for the OSL response in function of the reading temperature are shown in Figure 4.

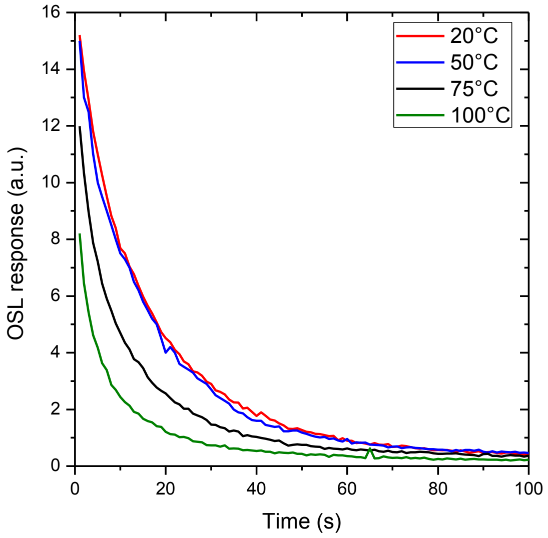

Figure 3. OSL decay curves of BeO samples for different reading temperatures.

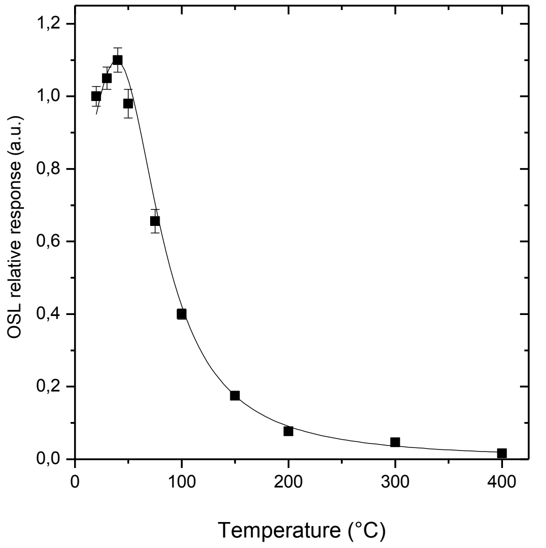

Figure 4. OSL relative response of BeO samples for different reading temperatures, normalized to 20°C (room temperature).

The increase in the temperature reduced the luminescent efficiency and lifetime, because it leads to a higher probability of non-radiative transitions from excited states to the ground state of luminescence centres, as already observed by Akselrod *et al* (1998). The OSL response decreases as the temperature increases; this reduction is similar to that obtained by Yukihara (2011). The initial increase of OSL response at low temperatures (Figure 4) may be due to the influence of shallow traps which released charges during the light stimulation (charge release); this fact may slow down the OSL decay process. Nevertheless, at higher temperatures, the charge trapping becomes less effective (McKeever et al, 1997). For temperatures above 40ºC, the thermal quenching occurs, i.e., the loss of luminescence efficiency with increasing temperature (Botter-Jensen *et al*, 2003). This phenomenon can be observed by the decrease of the OSL response in Figure 4.

3.2.2. Thermoluminescence response after OSL measurements

After each OSL measurement, a TL response was obtained. Figure 5 presents TL emission curves after the OSL measurements with temperatures of 20°C, 100°C, 200°C, 300°C and 400°C. The TL characteristic emission curve of beryllium oxide presented two peaks about 220°C and 350°C. The first characteristic peak at 220°C (shown in Figure 1) becomes imperceptible when the OSL was taken before the TL reading. This fact may occur because the released charges by the OSL technique are probably the same ones responsible for the TL dosimetric peak.

In this case, the dosimetric peak is the second TL peak, about 350°C. As the temperature of the OSL measurement increases, the intensity of the TL response decreases. After 200°C, the TL response is negligible.

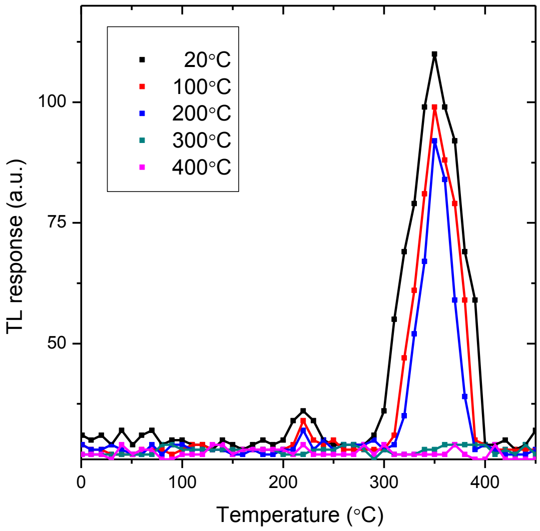

Figure 5. TL emission curves of BeO samples for different OSL measurement temperatures, after irradiation with ^{90}Sr+^{90}Y (1 Gy).

To understand the behaviour of TL response, Figure 6 shows a TL response for the following OSL reading temperatures: 20°C, 50°C, 75°C, 100°C, 125°C, 150°C and 200°C. The responses were normalized by the TL response for room temperature (20°C). It is possible to note an exponential behaviour in this temperature range. From 200°C to higher temperatures, the TL response cannot be applied to dosimetric purposes.

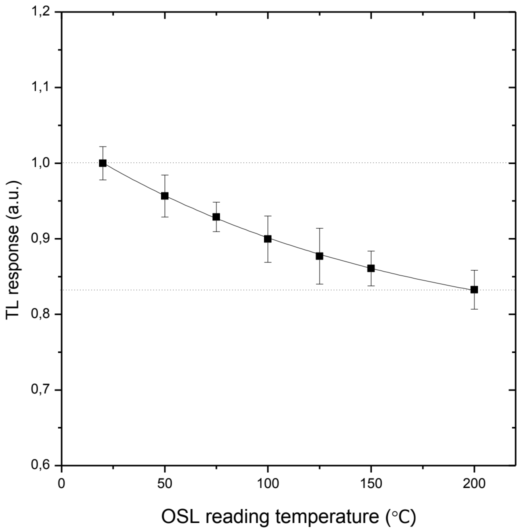

FIGURE 6. TL relative response of BeO samples for various OSL measurement temperatures, normalized to 20°C.

4. CONCLUSION

In relation to the thermal quenching test, a shift of the dosimetric TL peak to the higher temperature region was possible to observe with the increase of the heating rate. Furthermore, there was a decrease in the peak intensity. In the case of the OSL technique, the response decreases as the reading temperature increases; however, it was possible to view an initial increase of the OSL response at low temperatures (until 40ºC), which may be due to the influence of the released charges from the shallow traps during the light stimulation (charge release); this fact may slow down the OSL decay process. It was possible to observe the thermal quenching effect on both TL and OSL readings.

For the TL measurements realized after the OSL evaluations, it was possible to note the presence of a second TL peak (350°C); it differs from the characteristic TL response (obtained at the thermal quenching test) of this material to beta radiation, where the main dosimetric peak appeared around 220°C. As the temperature of the OSL readings increases, the intensity of the TL response decreases, and when reaching 200°C (OSL temperature) the TL response is negligible.

The knowledge of the temperature effect at a given material allows the choice of the technique to be used and to achieve the best efficiency of the luminescent signal, taking into account the studied parameters. The TL response behaviour obtained after OSL evaluation allows a second luminescence evaluation, even if the material is susceptible to temperature variations up to 200°C. This implies that a second dose evaluation of the same irradiated samples is possible using these OSL/TL techniques.

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