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SINTERING SODIUM CHLORIDE CRYSTALS FOR APPLICATIONS IN OPTICALLY STIMULATED LUMINESCENCE (OSL) DOSIMETRY

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ABSTRACT

The main objective of this work was to study a new technique for the sintering of marine sodium chloride (NaCl) crystals obtained from seawater. In order to obtain an efficient luminescence, a better control in the amount of sample to be used, a better distribution of crystals in every aliquot and verify its applicability as a dosimeter, with dosimetric requirements testing. The common salt is a material that have been already studied in the area of dosimetry, because it has a high sensitivity when exposed to ionizing radiation, therefore can thus be used in luminescent dosimetry. With the purpose of synthesizing the marine crystals with low cost and easy fabrication, we pulverized a concentrated sea salt solution, on 1 cm recycled aluminum discs placed on an oven at 70 ºC, with this process we obtained homogeneous aliquots. The salt has a hygroscopic property, we waterproof it using a commercial enamel, in order to inhibit this property. For analyzing the crystalline structure formed with this new technique, we used X-ray diffraction (XRD). For OSL measurements, we use the RISØ TL/OSL reader by blue light stimulation (470 nm) coupled with a beta source, at first, the heat treatment was carried out on the aliquots at 400 ºC, at different times to observe the effect on the OSL signal, irradiated with a dose of 162 mGy, with preheating at 160 °C for 1 s, afterwards we perform a measurement with an assisted temperature of 110 °C for 40 s with blue light. Lastly analyze the dosimetric requirement tests.

Keywords: Sintering, Crystals, OSL, NaCl, Dosimetry.

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1. INTRODUCTION

For the manufacture of personal or environmental dosimeters using thermoluminescence (TL) and optically stimulated luminescence (OSL) emissions, common salt (NaCl) is a material that has already been studied, as it has high sensitivity when exposed to ionizing radiation [1, 2]. Thus, sea salt crystals have great possibilities to be used for the manufacture of a dosimeter. They also have a high sensitivity when exposed to the beta source and excellent reproducibility [3]; in addition to being crystals that are easy to manufacture, very low cost and above all it would not harm the environment. However, NaCl crystals still have some details that need to be studied in order to be used as dosimeters.

NaCl crystals have hygroscopic properties, that is, they absorb humidity from the air [4, 5]. That way salt requires specific environmental conditions to be used. Therefore, the focus of this work is based on three main point; the hygroscopic treatment implementing the waterproofing of the aliquots using a commercial enamel, synthesizing the marine crystals using the method of pulverizes the concentrated sea salt solution on the aliquots, and evaluate these samples through dosimetric performance requirements such as OSL reproducibility, linearity, fading and sensitivity.

2. MATERIALS AND METHODS

2.1. Preparation of aliquots

The samples were prepared from seawater collected in the aquarium in Guarujá city, São Paulo state. Sample holder discs made with recycled aluminum plates, with a 1 cm diameter cutter, were used to support the crystals. For more homogeneous samples, we sprayed the concentrated sea salt solution, on aluminum discs placed on a stove at 60 ºC, so the deposited water evaporates completely and the NaCl crystals grow evenly. Then, we carry out a heat treatment at 400 °C for 48 hours. Lastly, we performed a waterproofing with commercial enamel, because the salt has a hygroscopic property (Figure 1). In conclusion, we obtain aliquots ready to realize Optically Stimulated Luminescence (OSL) measurements.

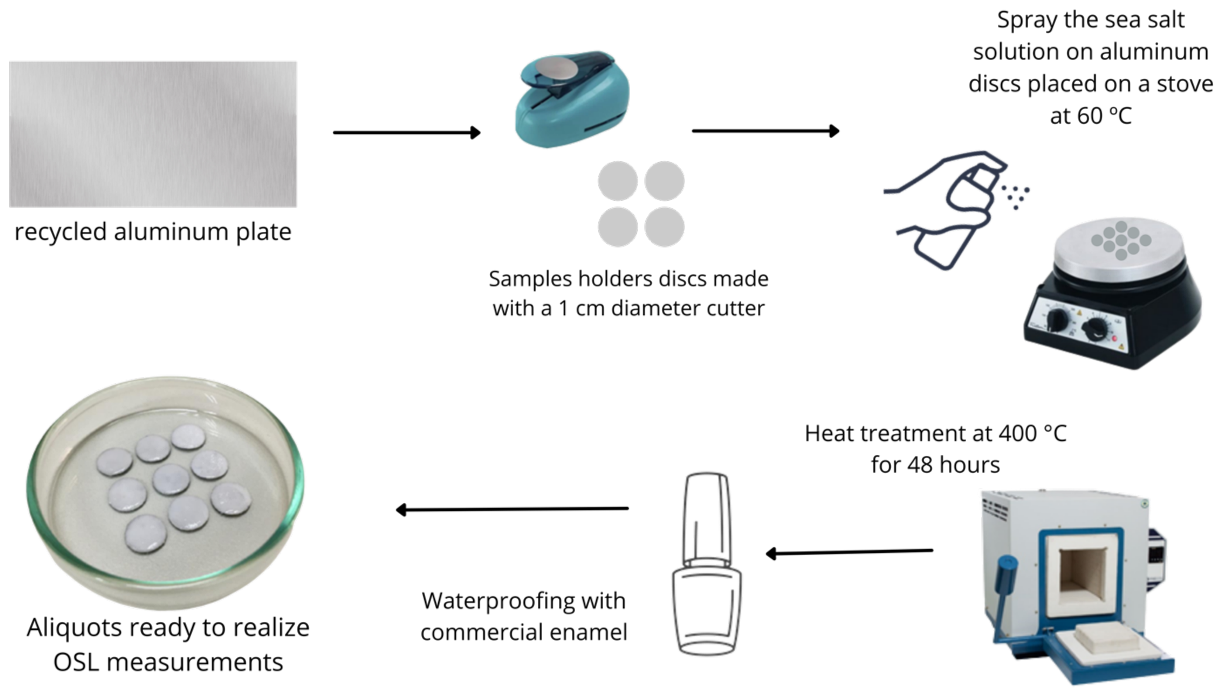

Figure 1: *Schematic representation of aliquot preparation.*

2.2. X-Rays Diffraction (XRD) and OSL

We used a MiniFlex 300, Rigaku spectrometer for X-Rays Diffraction (XRD) measurements to identify the crystalline structures and OSL measurements were made using a RISØ TL/OSL reader (model DA-20), with blue light stimulation (470 nm), coupled with a 90Sr/90Y beta source, with a dose rate of 162 mGy/s, it was used in the aliquots irradiations. TL measurements were performed at a rate of 5 °C/s.

3. RESULTS AND DISCUSSION

To analyze XRD data it was used the X'Pert highscore plus program. We identified the highest intensity peaks, which are in agreement with the literature, as Sodium Chloride (Figure 3).

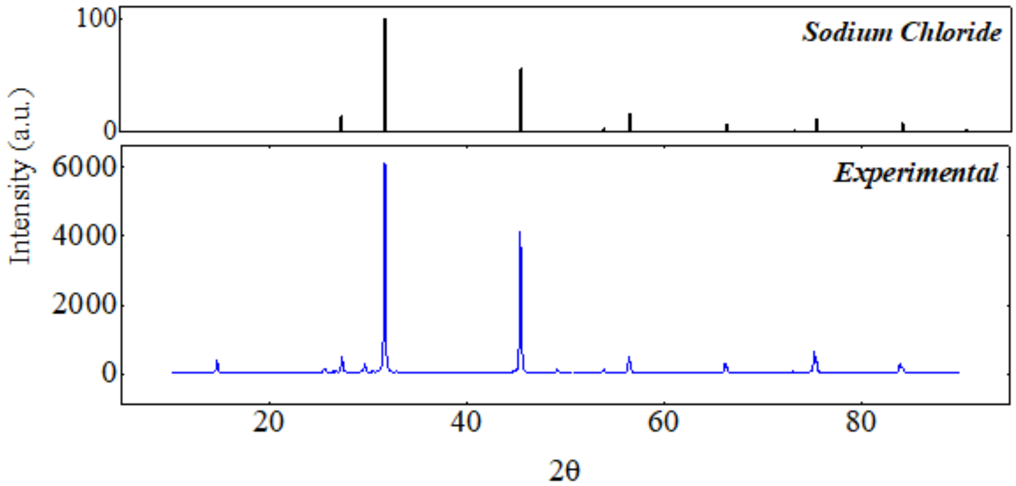

Figure 2: *Results of the samples using an X-ray diffraction.*

The deconvolution of the TL was carried out showing the existence of 6 peaks, at 98, 125, 154, 213, 272 and 378 °C, with the purpose to avoid and remove possible shallow traps, we remove the unstable peaks being the three first, with a preheat to 160 ºC. Thus, letting only the stable peaks (Figure 3).

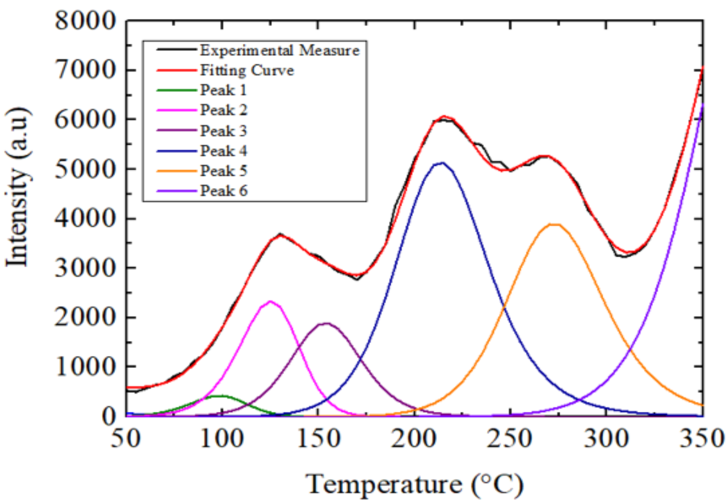

Figure 3: *Deconvolution of TL glow curve.*

Heat treatment on samples is used for improving the properties, showing an increase in its luminescent intensity. To observe this performance, we first tested with different temperatures and with three different periods (Figure 4). We performed the treatment at temperatures from 150 to 450 °C, we noticed that at 450 °C the intensity was higher, but we did not choose this temperature, since we noticed that the aliquots were damaged. Thus, the temperature of 400 °C was the one that presented a good intensity and did not affect negatively the samples.

We performed the heat treatment at different times, 30 min, 1 and 2 days. In addition, we concluded that with the heat treatment done for 2 days, the intensities increased more than two time in relation to the intensity obtained with treatment for 1 day.

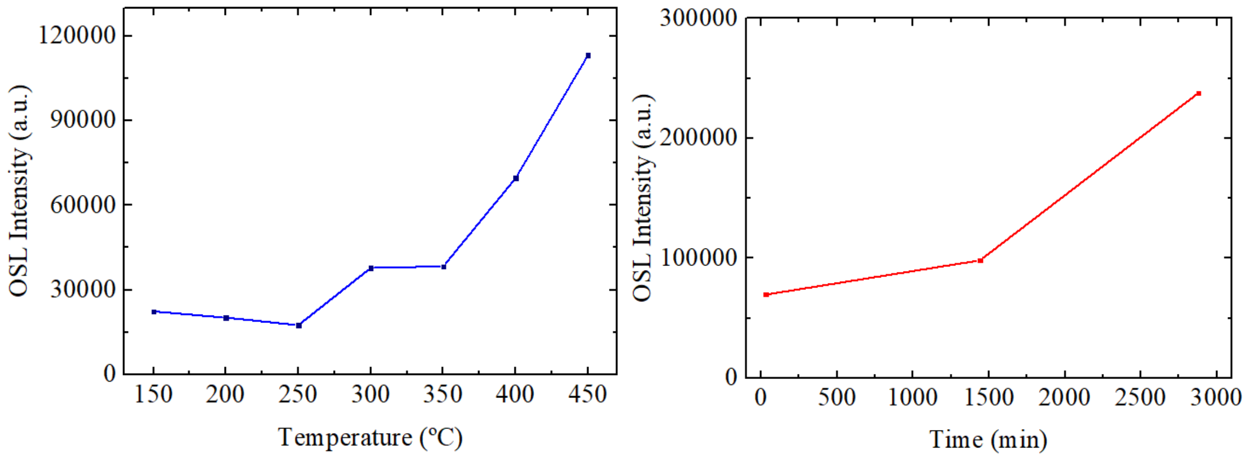

Figure 4: *Heat treatment with differente temperatures (left) and with three different periods (right).*

To perform the OSL growth curve, the sample was measured with doses ranging from 81 to 8100 mGy. In Figure 5, a linear response of OSL intensities up to 1000 mGy can be seen, and we note that a saturation starts next to this dose (Figure 5).

For the reproducibility test, several consecutive measurements were performed in the same laboratory condition, using a constant dose of 162 mGy, with an assisted temperature of 110 °C and stimulated for 40 s with blue light, we found good reproducibility, with a variation of only 4% (Figure 6).

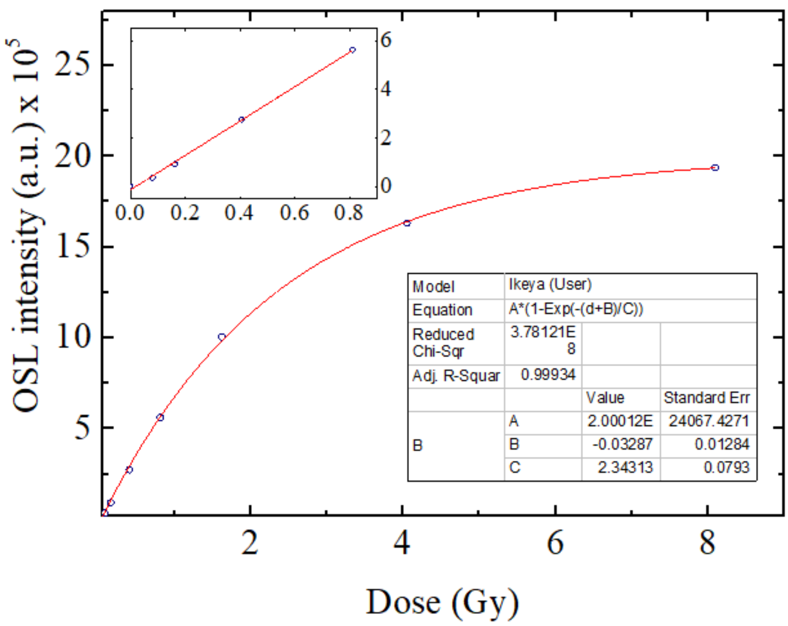

Figure 5: *OSL growth curve, inset shows the linear behavior for low doses.*

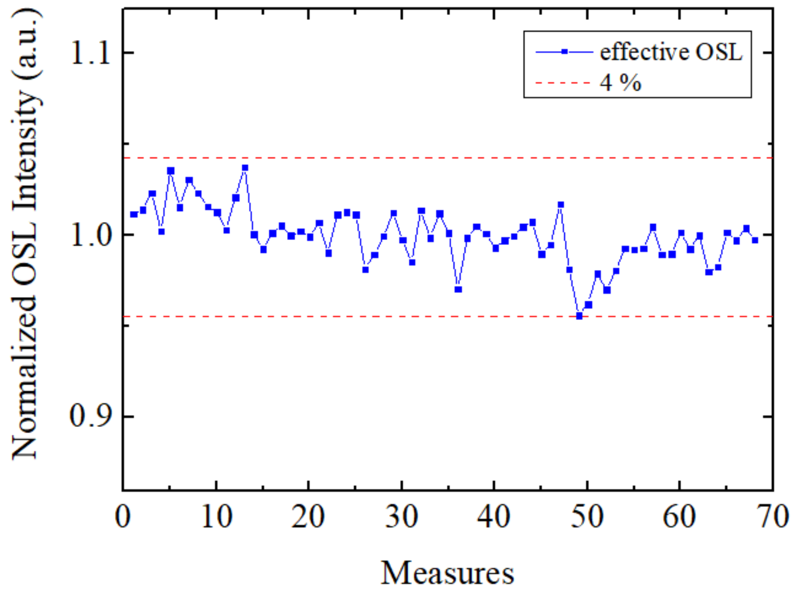

Figure 6: *OSL reproducibility, for several measurements with same conditions in one aliquot.*

Fading is the long-term decay, that is, it is the measurement of the intensity for one aliquot with a pause for a certain time, between the irradiation and the measurement of the OSL emission. We realized pauses from 20 seconds to 20000 seconds, in aliquots without and with the heat treatment of 400 ºC for 48 hours, by the graph we notice that there was a fading about 3,34% in the aliquot with heat treatment, different from the aliquot without heat treatment, that start to decay above 500 seconds (Figure 6). With this, we can notice the advantages of heat treatment in the aliquots.

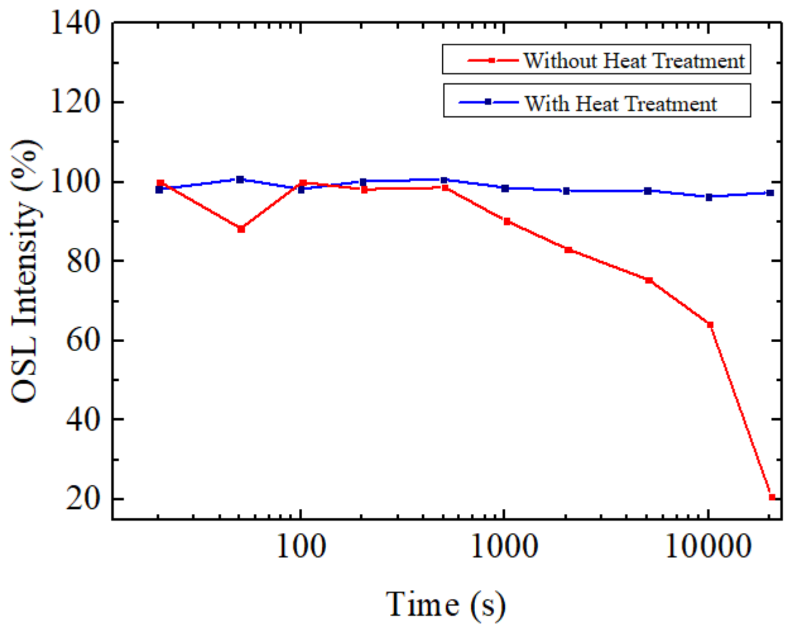

Figure 6: *Fading tests with pauses of 20 to 20000 seconds between irradiation and reading, in aliquots with and without heat treatment.*

4. CONCLUSIONS

Marine Sodium Chloride crystals sintered from spraying concentrated seawater solution onto recycled aluminum discs at 70°C is a technique that increased the luminescent signal. With this technique, the aliquots showed homogeneity among them, with the salt evenly distributed over the discs, and it was possible to produce a large batch of samples in one go, thus optimizing time, easy production, and low cost. Using the X-ray diffraction technique, we attest to the formation of the sodium chloride structure in the aliquots formed by the new technique without the presence of an amorphous part.

Sea salt is a very sensitive material when exposed to $^{90}Sr/^{90}Y$ beta radiation and afterwards stimulated by blue light, therefore, we were able to find parameters, in which the aliquots increases their dosimetric performance, that is, higher luminescence and more stability.

Therefore, sea salt crystals present high sensitivity and could be used for manufacturing of an environmental or personal dosimeter, with a low cost and without any damage to the ecosystem.

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