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Waterproofing pellets for Optically Stimulated Luminescence dosimetry

Rocca[a] R.R., Fernandes[a] C.P.

[a] *Instituto do Mar, Universidade Federal de São Paulo, 11070-100 Santos, SP, Brazil*

rrocca@unifesp.br

ABSTRACT

Several materials are being studied for dosimetric applications; some of them have the hygroscopic property that is not suitable for dosimetry. In this research, a new low-cost option for performing OSL measurements is presented. A transparent enamel was tested for sticking the powdered samples on an aluminum disc. Also, to avoid the absorption of humidity, the samples were covered with enamel. Although the signal decreases with waterproofing, the reproducibility and fading will no longer depend on their hygroscopic properties. Therefore, the aliquots with enamel may be submitted to irradiation and OSL reading with pre-heating up to 160 °C safely. Finally, by carrying out the irradiation and reading process, more than 100 times with an assisted temperature of 120 °C, the reproducibility was verified.

Keywords: **OSL, hygroscopy, dosimetry, humidity.**

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1. INTRODUCTION

Optically Stimulated Luminescence (OSL) measurements occur with photon excitation. Sometimes it is necessary to heat samples, in order to eliminate electrons trapped in shallow traps with unstable signals. Several production methods of these dosimetric materials produce powder samples agglomerated to form pellets, with fixed volume and mass. Some attempts to manufacture dosimeters using Teflon® have already been carried out. However, the homogeneous mixture between the sample of interest and polytetrafluoroethylene (PTFE) - which is a bad heat conductor - generates a temperature gradient between the heating plate and the sample. Likewise, PTFE presents a luminescent signal when exposed to ionizing radiation, in addition to a non-transparent whitish color. Thus, a correction of the signal emitted by the sample must be realized, since the whitish color absorbs part of the photons from the stimulation and emission of the sample. Even when all grains are placed on top of the aliquot to avoid losing luminescent signal [1], the temperature gradient is still an issue due to the thickness that the Teflon pellet needs to acquire mechanical resistance. Thus, in this work, a new possibility to study hygroscopic materials for dosimetric application was analyzed. Commercial enamel can be used for sticking the powdered sample on the surface of an aluminum disc, because a thin layer is enough to hold the grains. On the other hand, a second layer can be used to cover the samples, this second one is necessary when samples are hydroscopic [2], serving as a waterproofing layer.

Quartz grains are widely used for dating sedimentary deposits, because of their high OSL emission, stable luminescent signal and abundance on the sediments. The OSL signal is obtained by stimulating the quartz grains with blue light, while they are heated at 120°C.

2. MATERIALS AND METHODS

Natural quartz grains, between 0.075 and 0.150 mm were used, because it is the commonly selected range for dating. However, other sample sizes can also be tested. Since aluminum is a good heat conductor, discs of this material were used as a base for the aliquots. Commercial enamel was used because it takes the form of the applied surface [3] and almost ~85% is composed of solvent (transparent nail polish). When the solvent is evaporated, only ~15% of the resins form a thin layer [3]. The effect of the refraction can be disregarded due to layer thickness, around 0.02 mm. Furthermore, the enamel cover is almost uniform around every grain. As the grains are randomly placed, there is no preferential direction for the luminescence, even if some photons are diffracted out of the PMT, some others must be diffracted toward the PMT.

Three groups were prepared to test the influence of the enamel:

- Discs + enamel
- Discs + enamel + sample
- Discs + enamel + sample + enamel

The enamel used was the one commonly applied on nails, forming a uniform layer. The first group is a test for the emission of the enamel dried at room temperature. On the second group, the sample was uniformly sieved after the fresh enamel and left to dry at room temperature. For this group, the enamel is only for sticking the samples to the aluminum disc. For the third group, part of the second group was covered with a new layer of enamel and left to dry at room temperature. This group represents the actually waterproofed samples. Hygroscopic materials need this second layer of enamel for keeping the samples protected from humidity. For non-hygroscopic materials, the second layer of enamel is just to fix the grains completely.

OSL measurements were carried out using a Risø TL/OSL reader, DA/20 model, coupled with a source of $^{90}Sr/^{90}Y$. All OSL measurements were performed using a U-340 filter, blue stimulation, and some preheating into the reader.

3. RESULTS AND DISCUSSION

Several enamels were tested to verify which one presents the lowest absorption of the luminescence emitted by the sample. Thus, the one with the lowest absorption reduces the OSL signal by 36% - when reading is performed with assisted temperature (see Figure 1).

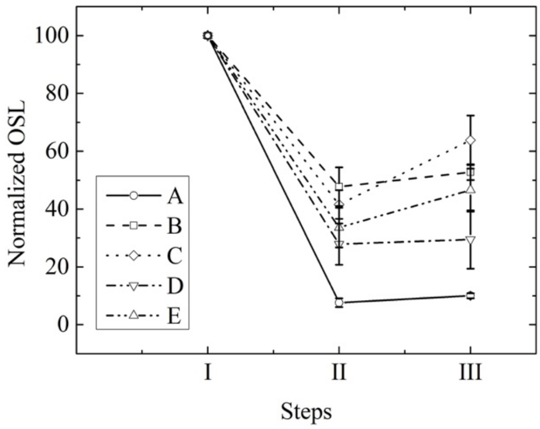

Figure 1: *OSL measurements of five samples: I - without enamel; II - with 5 different commercial enamels (labeled A-E); III - with an additional temperature treatment of 110 °C*

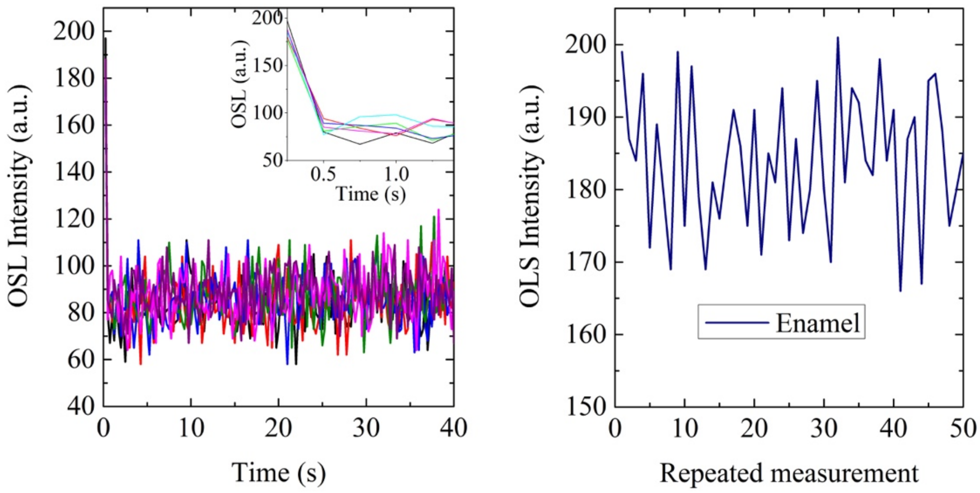

Figure 2: *OSL decay curves correspond to 6 measurements for disc with only enamel (left side), on the right is plotted the maximum intensity for OSL decay curves of enamel, for several consecutive measurements with the same dose (4.42 Gy).*

Discs prepared with only enamel were tested in order to determine the influence on the OSL signal. From Figure 2 it can be seen that enamel emits a very low OSL intensity when irradiated with beta particles, presenting some small fast decay curve. Besides, as we can see on the inset of Figure 2 the small decay curve vanishes after 0.5 seconds of blue light stimulation.

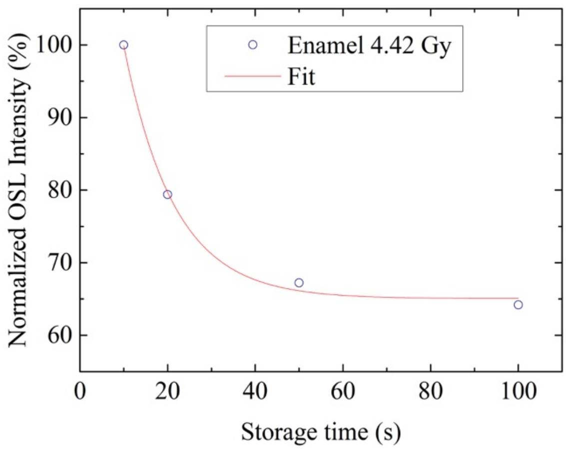

Figure 3: *Fading of OSL signal for samples with only enamel.*

The background signal (last part of the decay curve on Figure 2) is very low when compared to some OSL measurements with quartz samples. This means that the contribution can be disregarded. Even though enamel is a resin with no crystalline structure, it has OSL emission; this fact must be attributed to the other components used to produce the commercial enamel [4].

The presented OSL signal is stable along many measurements, as we can see in Figure 2, with the measurements being performed consecutive to the irradiation. Thus, this signal has a very high fading, decaying in only 60 seconds after irradiation (see Figure 3). For dosimetry purposes, this time is too short.

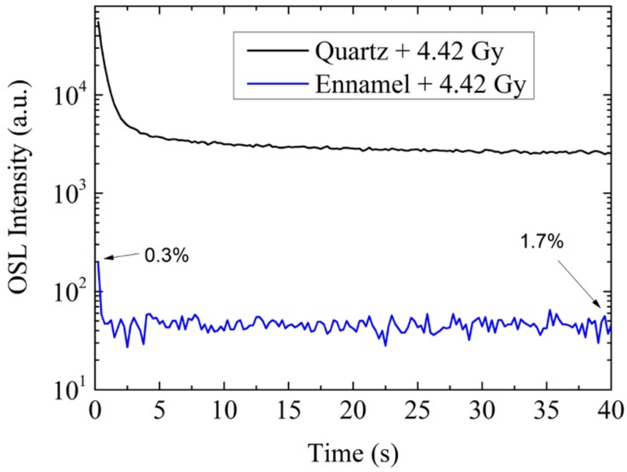

Figure 4: *Comparison of OSL decay curve for quartz sample and enamel.*

One decay curve for a regular OSL measurement of quartz is plotted in Figure 4 compared to a disc with only enamel - both irradiated with 4.42 Gy. This graph is in logarithmic scale for comparing the intensities (maximum intensity and background). The enamel emission intensity is compared to the quartz signal noise. For lower doses the contribution of the enamel does not affect the quartz signal or any other samples used [5,6].

In Figure 5, we can compare the reduction of the intensity when a thin layer is covering the quartz grains. For this aliquot, the OSL signal is reduced to ~76%, but the behavior of the decay signal of the quartz remains the same. It was tested normalizing the reduced signal in order to compare the shape of the decay curve. After normalization, the curves are similar, the enamel does not change the original OSL signal, only reduces the intensity. This reduction is due to the fact that the dose received for the quartz grains is lower than provided by the calibrated source. Because beta particles pass through the enamel layer and can interact with this one. The enamel layer also can absorb some part of the quartz emission

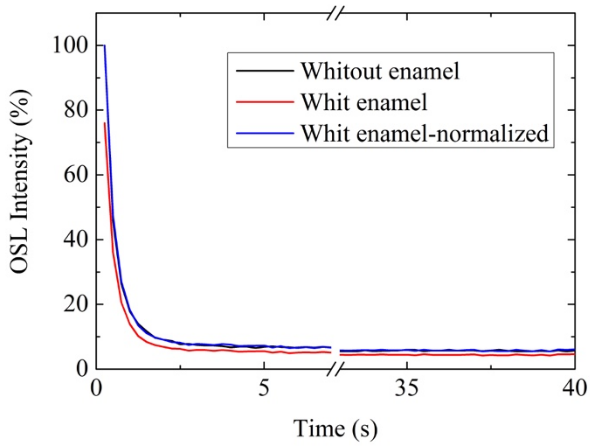

Figure 5: *OSL decay curve for quartz samples, showing the effect of the enamel.*

Even though it is not expected, the OSL intensity of enamel also grows with the dose, as it is shown in Figure 6 (right). However, the intensity is very low compared to the emission of the quartz - around 1000 times less for this range of tested doses. It is known that the OSL signal of quartz grows linearly with the dose, so the quartz covered with enamel also increases linearly [7]. By normalizing the intensity, the behavior is the same.

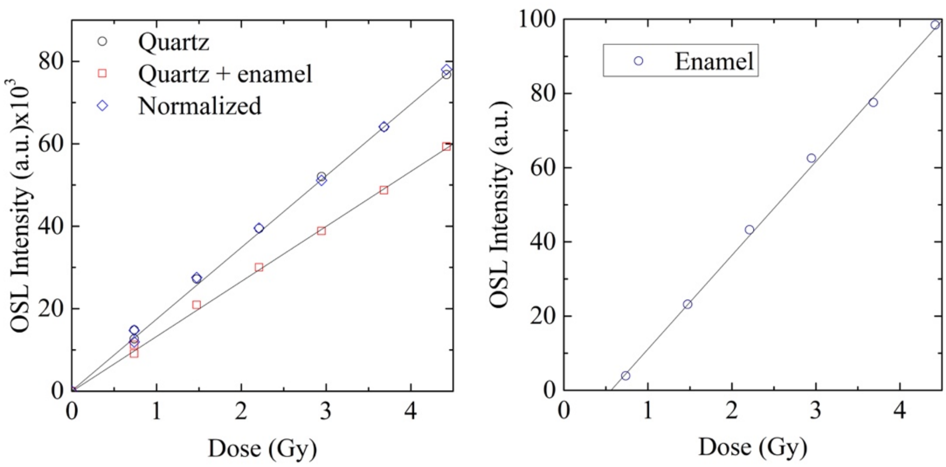

Figure 6: *In the left side is the* dose *response for quartz samples without enamel coating (circles), compared to the intensity when the enamel is used to cover the grains (squares), at right side only for enamel.*

Some samples need some thermal treatment for removing the electrons trapped in shallow traps. The signal from shallow traps is not stable over the time. All previous measurements were carried out at 120 °C, as it is required for quartz grains. The enamel has withstood very well to this heating. The maximum temperature that the enamel can withstand without degrading was tested. When the enamel is completely dry, the aliquots may be submitted to irradiation and OSL reading with pre-heating up to 160 °C safely, the enamel can support up to 170 °C as shown in Figure 7.

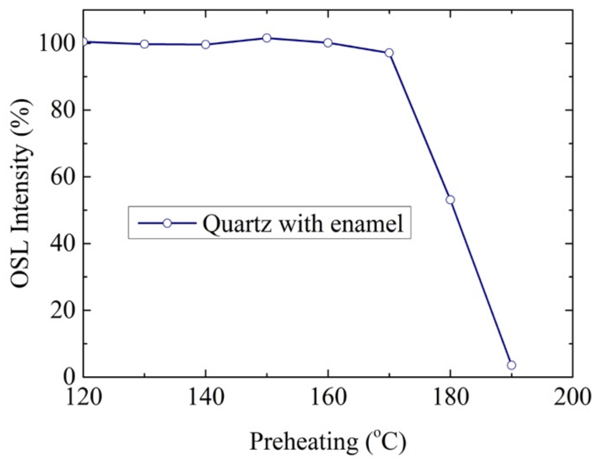

Figure 7: *OSL intensity of quartz covered with enamel for several measurements by preheating the sample (10 seconds of preheating).*

If the process of irradiation and OSL reading is carried out with fresh enamel, it will be denatured and may start to change from transparent to brown. When a thermal treatment is required at temperatures higher than 170 °C, it may be performed on the samples before placing the enamel [8]. Reproducibility was tested by carrying out the irradiation process and reading the OSL more than 100 times with assisted temperature of 120 °C, resulting in a reproducible signal within the sample's own fluctuation.

4. CONCLUSION

Different brands of enamel decrease the intensity in different proportions.

This method enables the use of hygroscopic samples as OSL dosimeters. Also, it is useful in cases where the luminescent reader is far from the irradiation source and successive readings of the dosimeters are necessary.

The final luminescent intensity decreases due to the interaction of the beta particles with the enamel layer, before reaching the sample. In addition, the excitation photons may be partially absorbed by the enamel before interacting with the sample - the final intensity is around 76% of the original.

This reduction of the OSL intensity is due to the beta particles are not so penetrating, for gamma rays it is expected that the intensity does not decrease too much.

Since it is an enamel, the aliquots can even be washed without harming the sample being analyzed.

Aluminum discs can be reused for other samples, just removing the enamel with acetone.

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