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Optical stimulated luminescence from Citrine for high-doses dosimetry

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Abstract: Several Brazilian stone samples were already studied at IPEN for use in radiation dosimetry, using the techniques of thermoluminescence, optical absorption and optically stimulated luminescence. The possibility of using semi-precious stones from Brazilian have been studied and tested, using the technique of thermoluminescence. The objective of this work was to study citrine samples for application in high-dose dosimetry, using the OSL technique. The samples exposed to gamma irradiated (^{60}Co) with doses up to 300 kGy. The reproducibility of the response and the OSL lower detection limit were obtained. The results show is a material that can be useful for high-dose dosimetry

Keywords: High-dose dosimetry; OSL; citrine

1. INTRODUCTION

In some industrial processes high radiation doses are utilized for sterilization of materials, food germination, treatment sprouts of seed and grains, and water purification [1,2]. Several samples were tested using different techniques as optical absorption (OA), thermoluminescence (TL) and electron paramagnetic resonance (EPR) for high-dose dosimetry.

Samples of Brazilian and imported glasses [3], sand samples from Brazilian beaches [4] and from Descalvado, Brazil [5], were studied at IPEN and showed favorable characteristics for their use for high-dose dosimetry.

The possibility of using Brazilian stone samples from mines of Minas Gerais, Brazil, as topaz [6], amethyst [7] and jasper [8] and samples of jade from different parts of the world [9], have been studied and tested at IPEN, using the technique of thermoluminescence.

McLaughlin et al [1] described several kinds of high-dose dosimeters, showing their advantages and disadvantages.

Citrine belongs to the chemical silica group. This material can be found in several countries, as Brazil, Argentine, Melgaxe Republic, USA, Spain, Namibia, Burma, Russia and Scotland. The citrine can be confused with other stones such as amethyst which becomes pale-yellow when heated to 470°C, or smoky quartz when heated to 300-400 °C. All citrine samples have a warm reddish tone, while natural citrine samples are predominantly of yellow color and when heated they present no pleochroism. [10,11,12].

The objective of this work was to study citrine samples for application in high-dose dosimetry, using the OSL technique.

2. MATERIALS AND METHODS

The citrine samples were from a Brazilian mine in Minas Gerais State. The elements of the citrine samples were obtained by the neutron-activation analysis technique at the Radiochemistry Department of IPEN. The results are presented in Table 1. This analysis was performed to identify the chemical elements in the citrine samples. As can be observed, Fe and Na are the most important elements. The samples acquired as citrine were cleaned and then powdered, and only the grains with diameter between 0.075 and 0.180 mm were utilized in this work. At the Laboratory for Production of Dosimetric Materials, IPEN, pellets were prepared in open atmosphere, and the compounds were mixed in the ratio 2 (powdered Teflon): 1 (powdered sample) in open atmosphere, to facilitate their handling.

This mixture was cooled down with liquid nitrogen to optimize the sample homogenization. The pellets of 50mg were obtained with 6.0mm of diameter and 2.0mm of thickness after a pressure procedure. The samples were thermally treated at 300°C during 30 min followed by 400°C during 1.5h. The cooling of the samples was performed slowly in the same oven.

Table 1. Neutron activation analysis results of citrine samples: concentration of the elements

Element	Concentration ($mg.kg^{-1}$)
Co	0.030±0.001
Cr	0.30±0.02
Na	44±3
Fe	58±2
Zn	2.1±0.2

The thermal treatments for reutilization of the materials were 300ºC during 1h in an unsealed oven. The samples were irradiated using a Gamma Cell-220 system of ^{60}Co (dose rate of 1.47 kGy/h), with doses from 50 Gy up to 300 kGy. The irradiations were made at ambient temperature; the samples were fixed between 3.5 mm thick polymethyl meth-acrylate plates (Lucite) to guarantee the occurrence of electronic equilibrium during the irradiations. The OSL measurements were taken using a RISÖ TL/OSL Reader and Controller, model DA-20, blue leds, and the data acquisition was realized using a personal computer.

3. RESULTS AND DISCUSSION

The dosimetric properties of citrine samples were studied in this work: reproducibility of the response, lower detection limits and dose-response curve to gamma radiation (^{60} Co).

3.1. OSL response

Figure 1 shows the OSL response versus time for citrine samples irradiated with absorbed doses of 0.5 kGy, 5 kGy, 50 kGy and 100 kGy in ^{60}Co beams. An increase in the OSL signal can clearly be observed in these curves as a function of the absorbed dose.

3.2. Reproducibility

The reproducibility of the OSL response of the citrine samples was obtained by five measurements of each OSL sample. These measurements were taken after the reutilization procedure (thermal treatment) and irradiation with the ^{60}Co source to an absorbed dose of 1.0 kGy. This procedure was repeated five times consecutively. The maximum variation coefficient was 5.7% (1σ). The result shows an efficient reproduction of the citrine samples OSL response for high-dose dosimetry.

3.3. Lower detection limits

Taking three times the standard deviation of five measurements of non-irradiated citrine pellets, after a thermal treatment at 300°C/1h, the lower detection limit expressed in units of absorbed dose was determined. The value obtained for the lower detection limit was 350 mGy for the citrine pellets.

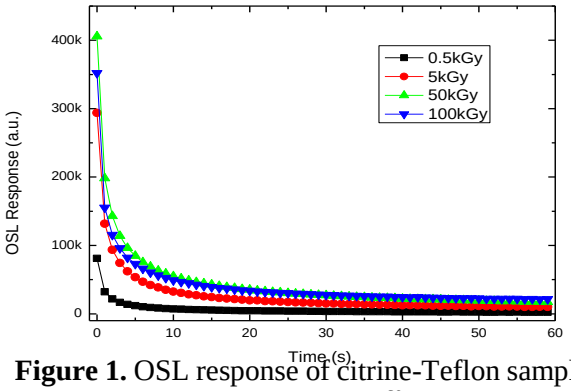

Figure 1. OSL response of citrine-Teflon samples irradiated with different doses (^{60}Co).

3.4. Dose-response curve

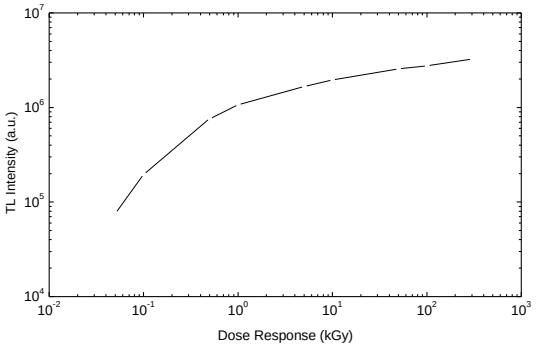

Figure 2. Dose-response curve of OSL response of citrine-Teflon samples for ^{60}Co radiation.

The OSL dose-response curve of the detectors was obtained as a function of the absorbed dose of gamma radiation (^{60}Co) from 50 Gy to 300 kGy. Figure 2 presents the dose-response curve of the citrine pellets; these measurements present a maximum relative standard deviation of 2.3%, not visible in the figure. The citrine samples presented initially a supralinear behavior, and then a sublinear behavior.

4. CONCLUSIONS

The OSL detectors based on citrine may be useful for high-dose dosimetry in industrial processes and in the sterilization of materials in hospitals. An advantage of the OSL technique is the possibility that the measurements can be carried out several times with only a small decrease in their response. Another remarkable benefit of these citrine samples is the fact that they are found in quantity in nature ensuring their reasonably low cost.

Acknowledgments

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