Study of agate using the OSL technique and application in high-dose dosimetry

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Abstract. The possibility of using Brazilian stones in gamma high-dose dosimetry was investigated at IPEN using the optically stimulated luminescence (OSL) technique. Agate samples were studied in relation to their OSL dosimetric properties, in this work. The samples were irradiated at a Gamma-Cell system (^{60}Co). The calibration curves show a sublinear behavior between 50 Gy and 300 kGy, and the lower detection limits for the OSL pellets were determined. The results were satisfactory for application in high-dose dosimetry.

Keywords: High-dose dosimetry/OSL/agate

1. Introduction

In the last decade, at the radiation metrology group of IPEN, different stones have been studied as new materials for application in high-dose dosimetry. Amethyst [Rocha et al, 2003], quartz [Navarro et al, 2002; Santos et al, 2001], topaz [Souza et al, 2002], jade [Melo et al., 2004), jasper [Teixeira and Caldas, 2007], and onyx [Teixeira et al, 2011] have already shown their usefulness for gamma dosimetry, using the thermoluminescent technique (TL).

McLaughlin et al [1989] described several kinds of high-dose dosimeters, showing their advantages and disadvantages. A study of the optically stimulated luminescence (OSL) of the samples was reported in that work.

The mineral silicates correspond to 92% of the earth crust, and due to this fact the interest in their use in high-dose dosimetry appeared. Chalcedony is a group name for the compact varieties of silica composed of minute crystals of quartz with submicroscopic pores. The colour and texture vary considerably according to the impurities present, but in general such materials may be sub-divided into chalcedony, in which the colour is fairly uniform, and agate, in which the colour is arranged in bands or concentric zones [Deer et al, 1974].

The objective of this work was to study the possibility of application of agate to high-dose dosimetry using the OSL techinique.

2. Materials and methods

In this work the Brazilian chalcedony agate was studied. The samples were prepared from four different types of agate from Brazilian mines: gray, purple, moss green and yellow. An analysis of the

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elements of the agate samples was 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 which are the chemical elements in each sample, and to justify in a future study which of these elements is responsible for the OSL signal. The samples were initially cleaned, pulverized, and grain diameters between 0.075 and 0.180 mm were obtained. At the Laboratory for Production of Dosimetric Materials, IPEN, sintered agate pellets were prepared using Teflon as binder, and the parts were mixed in the ratio 2 (Teflon):1 (powdered sample) in open atmosphere of nitrogen, to facilitate its handling. For the sintering process, the samples were thermally treated at 300°C for 30 min followed by 400°C for 1.5h. The mixture was pressed, and pellets of agate-Teflon of 50 mg with 6 mm of diameter and 2 mm of thickness were produced.

The thermal treatment for reutilization was 300°C during 1h. The samples were irradiated using a Gamma Cell-220 system of ^{60}Co (dose rate of 1.52 kGy/h), for 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, and the data acquisition was realized using a personal computer.

Table 1 - Neutron activation analysis results of agate samples: concentration of the elements

Element ($mg.kg^{-1}$)	Gray agate	Purple agate	Moss green agate	Yellow agate
As	0.16±0.01	0.06±0.01	- - -	0.41±0.04
Ba	6.06±0.09	19±3	- - -	8.4±1.6
Ce	0.12±0.2	0.48±0.04	3.6±0.3	- - -
Cr	0.43±0.01	- - -	0.11±0.02	0.31±0.02
Na	286±18	69±6	71±5	105±2
Sb	0.38±0.01	0.93±0.04	0.035±0.005	0.47±0.03
Zn	1.7±0.1	1.1±0.1	3.2±0.2	- - -
Fe	75±1	46.2±0.7	1303±65	853±12

3. Results and discussion

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

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3.1. OSL response

The OSL response versus time is presented in Figure 1 for all agate samples irradiated with 5 kGy. It can be observed that the white agate presents a lower OSL signal, while the purple agate response is higher relative to the other agate samples.

3.2. Reproducibility

The reproducibility of the OSL response of the agate samples was obtained by five measurements of each OSL sample. These measurements, for each sample, were taken after the reutilization procedure (thermal treatment) and irradiation with the ^{60}Co source to an absorbed dose of 10 kGy. This procedure was repeated five times consecutively. The reproducibility of the agate samples was 4.3% (1σ). The result shows an efficient reproduction of the agate pellet response for high-dose dosimetry.

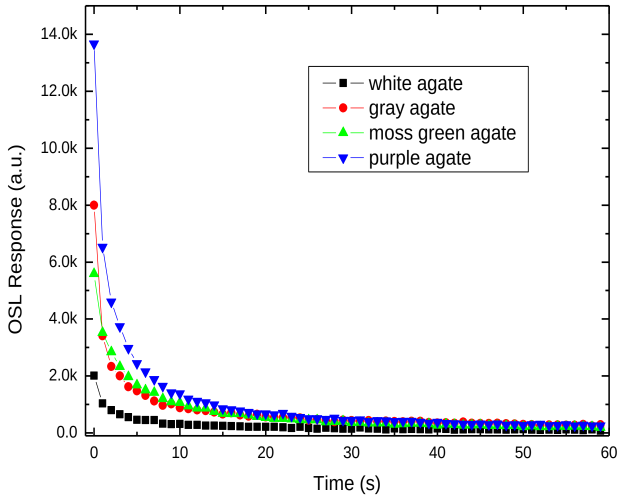

Figure 1. OSL response of agate-Teflon pellets irradiated with 5 kGy (^{60}Co)

3.3 Lower detection limits

The lower detection limits for the OSL agate samples, defined as three standard deviations of five measurements of their mean zero dose reading (thermal treatment at 300°C/1h and non-irradiated samples, expressed in units of absorbed dose) was determined for all agate samples. The values obtained for the lower detection limits were: 70 mGy, 100 Gy, 150 mGy and 600 mGy for the white agate, purple agate, gray agate and moss green agate samples respectively.

3.4. Dose response curve

The OSL dose response curves of the agate samples were obtained for ^{60} Co in the dose range of 50 Gy to 300 kGy. Figure 2 presents the dose-response curves of the agate pellets; these measurements present a maximum relative standard deviation of 2.0%. All detectors presented a sublinear behavior, in the range 50Gy – 50 kGy; the purple agate samples are the most sensible to the OSL technique.

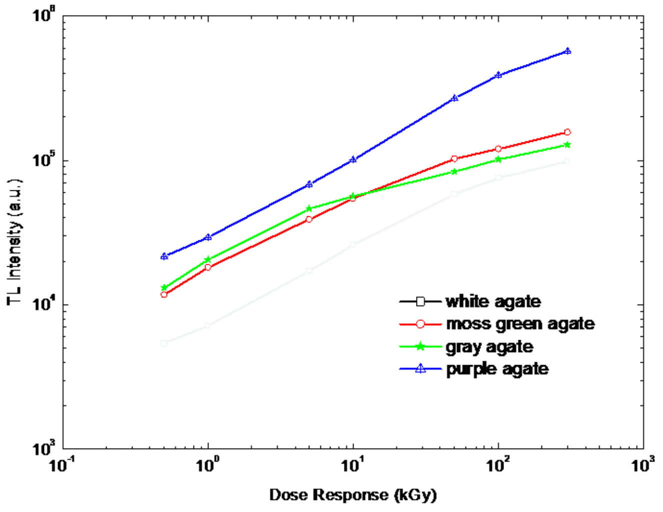

Figure 2. Dose-response curves of OSL response of agate samples for ^{60}Co radiation.

4. Conclusions

The results on the main dosimetric characteristics investigated in this work show that the OSL detectors based on agate 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 that the measurements can be carried out several times.

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