Dosimetric properties of agate stones

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Abstract
Brazilian stones have been studied for use in gamma high-dose dosimetry. Agate samples were studied in relation to their TL dosimetric properties, in this work. The TL curves obtained due to absorbed doses of 50 Gy up to 10 kGy exhibit two peaks around 150^0C and 210^0C. The minimum detection limits, dose-response curves and reproducibility of the TL response were obtained. The results indicate the possibility of use of these agate samples as radiation detectors for gamma high-doses, using the TL technique.

Introduction
Quality control programs in radiation dosimetry play an important role. Radiation processing presents several advantages such as food preservation, sterilisation of pharmaceutical and medical products and treatment of various materials. McLaughlin et al described several kinds of high-dose dosimeters, discussing their advantages and disadvantages. At the Radiation Metrology Laboratory of IPEN, Brazil, different stones have been studied for application in high-dose dosimetry. Amethyst [Rocha et al, 2003], quartz (Santos et al, 2001 and Navaro et al, 2002), topaz [Sousa et al, 2002] and jasper [Teixeira and Caldas, 2007] have already shown their usefulness for gamma dosimetry, using the thermoluminescent technique (TL).
Agate is a variety of chalcedony, a form of quartz, in which the color appears in bands or concentric zones. The bands may be of different colors or also of a uniform tone. The samples for this study were prepared from four different types of agate stones: yellow, moss green, gray and purple. The objective of the work was to characterize agate stone samples as detectors for gamma high dose radiation.

Materials and methods
Brazilian agate samples were studied in the work. All samples were initially cleaned, pulverized, and grain diameters between 0.075 and 0.180 mm were obtained. To facilitate easy handling, sintered agate pellets were prepared at the Laboratory for Production of Dosimetric Materials, IPEN, using Teflon as binder, and the parts were mixed in the ratio 2 (Teflon):1 (powdered sample). For the sintering process, the samples were thermally treated at 300^oC for 30 min followed by 400^oC for 1.5h.
The thermal treatment for reutilization of the material was established as 300^oC for 1h. The irradiations of the samples were performed using a Gamma Cell-220 System of

^{60}Co (dose rate of 2.18 kGy/h), for doses from 50 Gy up to 10 kGy. The irradiations were made at ambient temperature; to guarantee the occurrence of electronic equilibrium during the irradiations, the samples were fixed between 3.5 mm thick polymethyl meth-acrylate plates (Lucite). The TL measurements were taken using a Harshaw Chemical Co. reader, model 2000 A/B, and the data acquisition was realized using a virtual instrument (ADC-212), Pico Technology Ltd., and a personal computer.

Results and discussion

Dosimetric properties such as lower detection limits, reproducibility and dose-response curves were obtained in this work. Figure 1 shows the thermoluminescent glow curves of the agate samples: gray, purple, moss green and yellow, taken 1h after their irradiation with 10 kGy. All samples present two main TL peaks, one around 150^0C and the second about 210^0C (dosimetric peak).

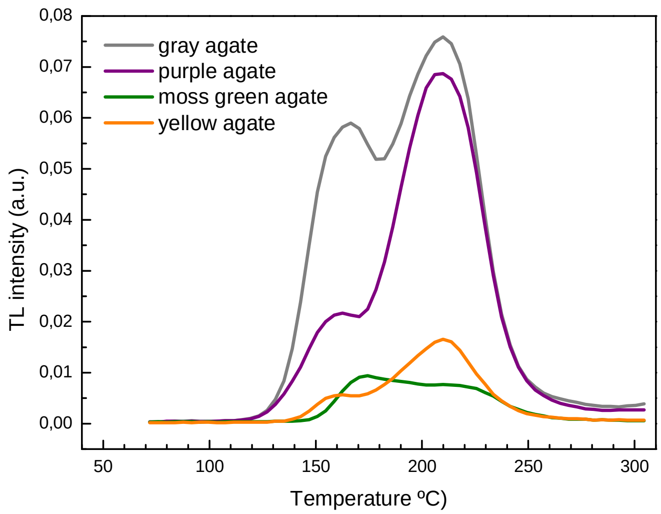

Fig. 1. TL glow curve of an agate-Teflon pellet irradiated with 10 kGy (^{60}Co)

To remove the first TL peak (150^0C) of the agate sample glow curves, thermal treatments at 130^0C during different time intervals: 5 min, 10 min, 15 min, 30 min and 60 min were tested. All thermal treatments presented the same results: peak 1 was removed and the thermal treatment of 130^0C/5min was chosen as adequate (Figure 2). All agate samples (gray, purple, moss green and yellow) presented the same results.
The TL response of the agate sintered pellets as a function of the absorbed dose was measured from 50 Gy up to 10 kGy (Figure 3). The standard deviation values were less than 3.2%. The lowest detectable value was determined studying the variation of the signal obtained by the reading of non-irradiated samples. The lowest detectable value was 4 mGy, 1.5 Gy, 1.0 Gy and 0.2 Gy for gray, purple, moss green and yellow agate samples, respectively. Figure 3 shows that the dose response is linear up to 5 kGy in case of gray agate samples and supralinear for the other samples.

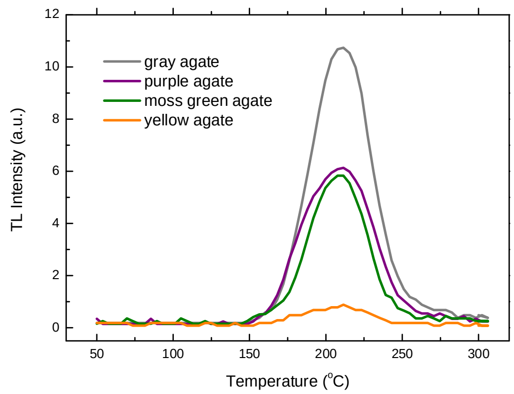

Fig. 2. TL glow curves of agate samples irradiated with 5 kGy (^{60}Co), after thermal treatments of 130^{0}C/5min

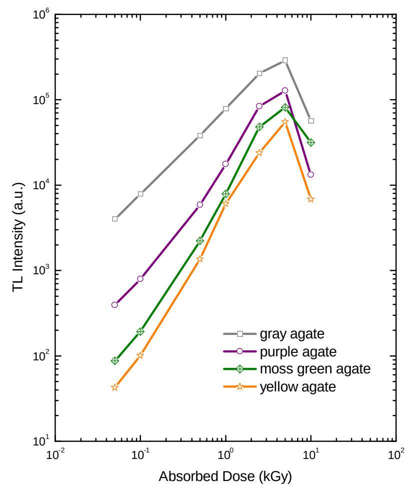

Fig. 3. Dose-response curves of agate samples for ^{60}Co radiation. Measurements were taken after the irradiation and the thermal treatment at 130^{0}C/5min.

Conclusions

The results obtained on the main dosimetric characteristics (reproducibility, dose response up to 5 kGy and lower detection limits) show that agate samples can be applied in high-dose dosimetry. The advantages of this kind of material are: found in Brazilian natural mines, easy to handle and very low cost. Agate samples may be applied for dosimetry in the main radiation process of pasteurization, processes of water purification, sterilization and disinfestations of products, among others.

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