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Dosimetric characteristics of jasper samples for high dose dosimetry

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ABSTRACT

Different colored jasper samples from Brazilian mines were powdered and mixed with teflon (composites jasper-teflon^{TM}). This paper describes a preliminary study of a thermoluminescent method (TL) to verify the possibility of their use as high dose dosimeters or irradiation indicators in industrial areas. The jasper samples were exposed to different radiation doses, using the gamma-cell 220 system (^{60}Co) of IPEN. The TL emission curves of samples presented two peaks at 130 °C and 190 °C. Calibration curves were obtained for the jasper samples between 50 Gy and 20 kGy. All five types of jasper samples showed their usefulness as irradiation indicators and as high-dose dosimeters.

1. Introduction

Radiation processing using high doses has presented various advantages in the areas of sterilization of pharmaceutical products, food preservation and treatment of several materials.

The dosimeter characteristics of silicate samples were studied for application in dosimetry. The silicates are abundant and represent 92% of the volume of minerals of the terrestrial crust. Glass silicates (Caldas and Quezada, 2002; Teixeira and Caldas, 2002; Rodrigues Jr. and Caldas, 2002; Caldas and Teixeira, 2004), quartz (Santos et al., 2001; Navaro et al., 2002), amethyst (Rocha et al., 2002, 2003), topaz (Souza et al., 2002), jade (Melo et al., 2008), and bioglass (Costa et al., 2007) and watch glasses (Teixeira et al., 2008) were tested for the possibility of their use in gamma dosimetry, using the technique of thermoluminescence (TL).

In this work preliminary studies of the dosimetric properties of jasper samples are presented. Chalcedony is a group name for the compact varieties of silica composed by minimum crystals of quartz with submicroscopic pores. Their color and texture vary considerably according to the impurities present, but in general such materials may be sub-divided into chalcedony (sometimes called jasper) and agate (Klein and Dana, 2002). Jasper color is fairly uniform (green, red, brown, ocean and striped), and agate color is arranged in bands or concentric zones.

2. Materials and methods

The jasper samples used in the present work were obtained from different Brazilian mines: green, red, brown, ocean and striped.

An analysis of the main elements of the jasper samples was obtained by neutron-activation analysis technique at the Radiochemistry Department of IPEN. Results are presented in Table 1. This analysis was performed to identify which are the chemical elements in the samples, and for future studies about which of these elements are responsible for the TL signal. In these samples, the major elements present are barium, sodium and iron, except in the case of striped and red jasper samples that did not present barium and sodium respectively. Chromium is responsible for the green color in green jasper and iron is responsible for the red color in red jasper.

All samples were initially cleaned, pulverized, and grain diameters between 0.074 and 0.177 mm were obtained. The samples were thermally treated at 300 °C for 1 h in open atmosphere.

For easy handling, sintered jasper pellets were prepared at the Laboratory for Production of Dosimetric Materials, IPEN, using Teflon as a binder, in the ratio 2 (teflon):1 (powdered sample). This mixture was cooled with liquid nitrogen to optimize the homogenization. Pellets of 50 mg were obtained with 1 mm of thickness, and diameter of 6 mm. For sintering, the samples were thermally treated at 300 °C for 30 min followed by 400 °C for 1.5 h.

The thermal treatment for reutilization of the materials was 300 °C for 1 h. The samples were packed in aluminum foils for the irradiations, at a Gamma Cell-220 System of ^{60}Co (dose rate of 2.88 kGy/h), for doses of 50 Gy up to 30 kGy. The irradiations were made at ambient temperature, and the samples were fixed between 3 mm thick polymethyl methacrylate plates (Lucite), to guarantee the occurrence of electronic equilibrium. The TL measurements were taken using a Harshaw Chemical Co. reader, model 2000 A/B, and the data acquisition were realized using a virtual instrument (ADC-212), Pico Technology Ltd., and a personal computer.

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Table 1
Results of neutron activation analysis of jasper samples.

Element (mg kg^{-1})	Green jasper	Red jasper	Brown jasper	Ocean jasper	Striped jasper
Ba	76 ± 8	468 ± 23	695 ± 79	5.2 ± 0.6	–
Ce	54 ± 4	23 ± 3	1.5 ± 0.1	0.74 ± 0.05	2.0 ± 0.2
Cr	75 ± 5	4.42 ± 0.02	–	0.16 ± 0.02	0.66 ± 0.02
Hf	3.4 ± 0.3	4.17 ± 0.05	0.020 ± 0.002	0.95 ± 0.05	–
Na	4.4 ± 0.2	–	63 ± 3	572 ± 26	155 ± 10
Nd	24 ± 3	11.7 ± 0.6	2.0 ± 0.2	–	0.80 ± 0.02
Th	8.9 ± 0.6	12.5 ± 0.3	–	–	0.087 ± 0.006
Zn	139 ± 6	9.3 ± 0.3	6.1 ± 0.4	2.4 ± 0.3	4.0 ± 0.3
Fe	4 ± 0.2	5477 ± 74	4707 ± 175	556 ± 21	138 ± 2

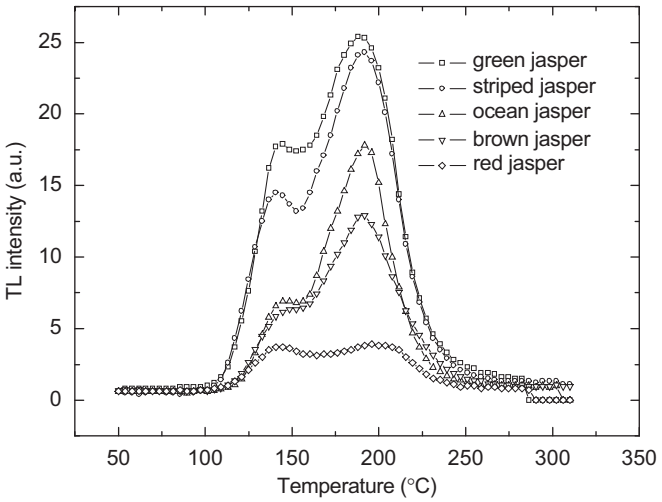

Fig. 1. TL glow curves of jasper–teflon pellets irradiated with 10 kGy (^{60}Co).

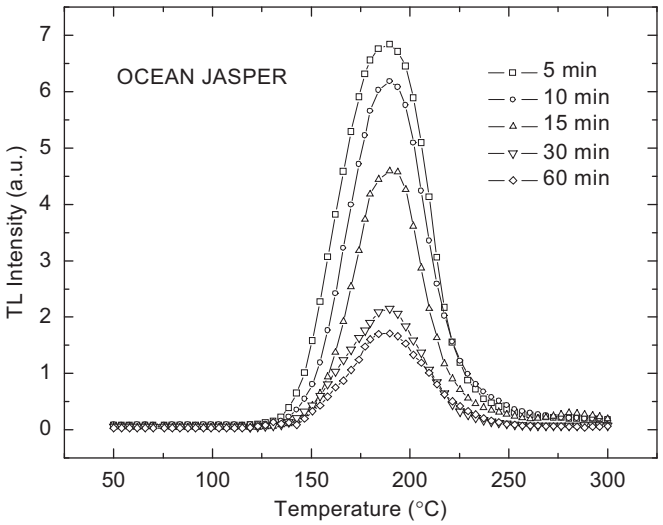

Fig. 2. TL glow curves of ocean jasper pellets irradiated with 5 kGy (^{60}Co) and treated thermally at several time intervals after irradiation.

Table 2
TL response reproducibility as CV_{max} (%) of jasper pellets.

Samples	CV_{max} (%)
Jasper–Teflon	
Green	4.4
Striped	4.7
Ocean	5.3
Brown	4.6
Red	4.5

3. Results

The main dosimetric properties studied of the jasper samples in this work were reutilization, lower detection limits, thermal treatments and calibration curves. The properties of the studied jasper samples using the TL technique are probably due to the same mechanism of commercial TL dosimeters. Fig. 1 shows the thermoluminescent glow curves of the jasper samples: green, red, brown, ocean and striped taken 1 h after their irradiation with 10 kGy. All samples present two main TL peaks, one around 130 °C and the second near 190 °C.

For the reutilization study of the TL glass samples, several thermal treatments have been tested. Caldas and Quezada (2002) verified that a thermal treatment at 300 °C for 15 min was enough so that the samples returned to their initial conditions, presenting the same measurements as previously to the irradiation. Caldas and Teixeira (2004) verified that for colored glasses the most efficient thermal treatment was 300 °C for 30 min.

However, the jasper samples studied in this work did not present good results with these thermal treatments; other thermal treatments were tested: 250 °C for 1 h; 300 °C for 15 min; 300 °C for 30 min; 300 °C for 45 min; 300 °C for 1 h. The best results were obtained with the thermal treatment of 300 °C for 1 h. The samples returned to their initial conditions, reproducing the same measurements obtained prior to the second irradiation process.

To remove the TL peak 1 (130 °C) of the jasper samples after irradiation, thermal treatments at 130 °C during different time intervals (5–60 min) were tested. All thermal treatments present the same results: TL peak 1 was removed (Fig. 2) and the thermal treatment of 130 °C/5 min was chosen as adequate. All jasper samples (green, red, brown, ocean and striped) presented the same results.

Five sets of both types of jasper pellets were submitted five times to the same procedure of thermal treatments at 300 °C for 1 h (defined for the reutilization). They were irradiated with an absorbed dose of 2 kGy (^{60}Co), and thermally treated at 130 °C/5 min, in order to study their response reproducibility. The maximum values are presented in Table 2. The results of standard deviations do not exceed 5.4% for the five types of jasper samples.

The jasper samples were irradiated in the ^{60}Co source beam between 50 Gy and 20 kGy. Fig. 3 presents the calibration curves of the five types of jasper samples; they were thermally treated at 130 °C/5 min after irradiation. The maximum standard deviation of these measurements was 2.3%. It can be observed that the TL response presents a suitable behavior for high-dose dosimetry for all types of jasper samples, although the curves presented sublinear behaviors.

4. Conclusions

The calibration curves obtained in this work show that the five types of jasper samples may be applied to high-dose dosimetry. The TL emission curves of the samples exposed to gamma doses presented two peaks at 130 °C and 190 °C. Green jasper samples presented higher radiation sensitivity than other jasper samples, perhaps related to their higher concentration of zinc. The basic advantage of jasper samples is their very low cost. Jasper samples may be applied for dosimetry in the main radiation processes of seed stimulation, mutation breeding, industrial radiography, and insect population control, pasteurization and water purification.

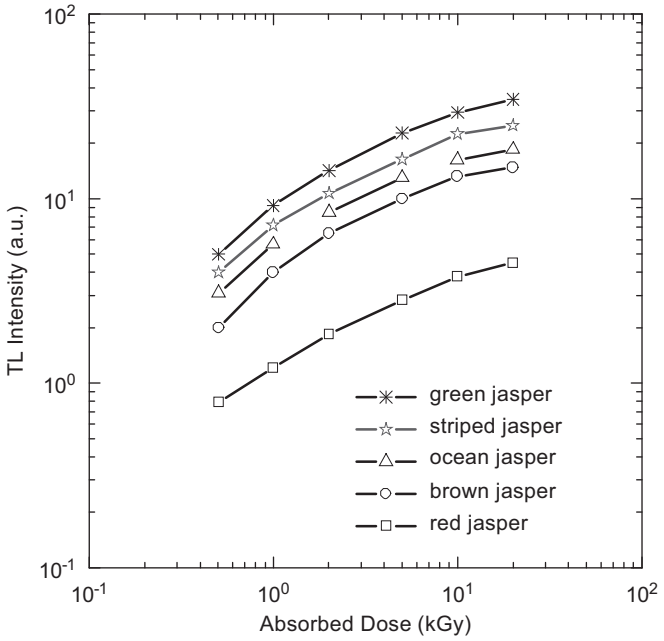

Fig. 3. Dose–response curves of jasper samples for ^{60}Co radiation. Measurements were taken after irradiation and thermal treatment at 130 °C/5 min.

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References

Caldas, L.V.E., Quezada, V.A.C., 2002. Commercial glass for high doses using different dosimetric techniques. Radiat. Prot. Dosim. 101, 149–152.
Caldas, L.V.E., Teixeira, M.I., 2004. Colored glasses for high dose dosimetry using the thermoluminescent technique. Radiat. Prot. Dosim. 111, **1**3–15.
Costa, Z.M., Melo, A.P., Giehl, J.M., Ludwig, V., Pontuschka, W.M., Caldas, L.V.E., 2007. Defects induced in bioglass by gamma radiation for dosimetric purposes. J. Phys. Status Solidi (C) 4, 1118–1121. (ISSN 1610-1642).
Klein, C., Dana, J.D., 2002. Manual of Mineral Science, 22nd ed. John Wiley and Sons, New York.
Melo, A.P., Teixeira, M.I., Caldas, L.V.E., 2008. TSEE response of silicates of the jade family in gamma radiation beams. Radiat. Meas. 43, 397–400.
Navaro, M.S., Lima, J.F., Valerio, M.E.G., 2002. Effects of thermal treatments on the TL emission of natural quartz. Radiat. Meas. 35 (2), 155–159.
Rocha, F.D.G., Cecatti, S.G.P., Caldas, L.V.E., 2002. Dosimetric characterisation of Brazilian natural stones using the thermally stimulated exoelectron emission technique. Radiat. Prot. Dosim. 100 (1–4), 417–420.
Rocha, F.D.G., Oliveira, M.L., Cecatti, S.G.P., Caldas, L.V.E., 2003. Properties of sintered amethyst pellets as thermoluminescent dosimeters. Appl. Radiat. Isot. 58, 85–88.
Rodrigues Jr., A.A., Caldas, L.V.E., 2002. Commercial plate window glass tested as routine dosimeter at a gamma irradiation facility. Radiat. Phys. Chem. 63, 765–767.
Santos, A.J.J., Lima, J.F., Valerio, M.E.G., 2001. Photo transferred thermoluminescence of quartz. Radiat. Meas. 33 (4), 427–430.
Souza, D.N., Lima, J.F., Valerio, M.E.G., Caldas, L.V.E., 2002. Performance of pellets and composites of natural colorless topaz as radiation dosimeters. Radiat. Prot. Dosim. 100 (1–4), 413–416.
Teixeira, M.I., Caldas, L.V.E., 2002. Dosimetric properties of various colored commercial glasses. Appl. Radiat. Isot. 57, 407–441.
Teixeira, M.I., Costa, Z.M., Costa, C.R., Pontuschka, W.M., Caldas, L.V.E., 2008. Study of the gamma radiation response of watch glasses. Radiat. Meas. 43, 480–482.