Thermoluminescent characteristics of Diopside - Teflon composites for radiation dosimetry

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Abstract

Diopside - Teflon composites were been studied in relation to their dosimetric properties for high-dose dosimetry. Diopside from Minas Gerais, Brazil, $CaMg(Si_2O_6)$, was obtained in form of rude mineral with inclusions of quartz. The samples were prepared and only Diopside grains obtained. Pellets of Diopside-Teflon composites were prepared in the proportion of 2(Teflon):1(Diopside). The TL response repeatibility presented a maximum coefficient of variation of 7.5%. The calibration curve is linear between 0.5Gy and 1kGy. TL emission spectra present three emissions of similar intensities at 570nm, 590nm and between 610-635nm. The results suggest that the material presents good characteristics for use as high-dose radiation detectors.

1. INTRODUCTION

Almost all dosimetric systems present some limitations for their use, as their physical and chemical properties, or their production cost [(1)]. Therefore, several materials as fluorides, oxides, borates and sulfates, among others, have been investigated in order to find new materials for radiation dosimetry, specially for processes that involve high doses in the industrial areas (gammagraphy, water purification, pasteurization), medicine (radiodiagnostic, radiotherapy, sterilization) and agriculture (disinfestations, inhibition of sprouting). The search for a thermoluminescent dosimeter that reaches applications in radiation dosimetry, including its low cost, has been motivating the research with new synthetic and natural materials [(2)]. The silicates represent 92% of the whole percentage volume of the minerals, and they represent an abundant source for research of new materials for high-dose dosimetry [(3)]. In the last years several silicates as sand [(4)], commercial glasses [(5)], special glasses [(6)], quartz [(7)], topaz [(8)] and jade [(9)] have been investigated in relation their dosimetric properties. Diopside is a silicate that belongs to the pyroxene group and a mineral original from several metamorphic rocks. It occurs in South Africa, India, Italy, United States and Brazil [(10)]. In this work pellets of Diopside - Teflon composites were studied in relation to their main dosimetric characteristics.

2. MATERIALS AND METHODS

The material tested in this work was the natural Diopside: $CaMg(Si_2O_6)$, from the farm Benedito Honório in Malacacheta city, Minas Gerais State, Brazil. The sample was received with quartz inclusions (Figure 1). The sample was cleaned with a nylon brush and alcohol isopropilic solution. After that, the Diopside sample was separated optically from quartz using a geological hammer with vidia tip and a magnifying gemologic glass. The Diopside crystals were powdered and the granulometric selection was performed with sieves of 80mesh and 200mesh. Grains were obtained with diameter between 0.074 and 0.177mm. These grains were mixed manually with Teflon (in open atmosphere of nitrogen) in the proportion of 2(Teflon):1(Diopside). The mixture was pressed, and pellets of Diopside-Teflon of 50mg with 6mm of diameter and 0.8mm of thickness were produced. The pellets were sintered at 300°C/1h followed by a 400°C/1.5h thermal treatment. Its cooling was slow in the own oven. To avoid residual TL and for their reutilization, the pellets were thermally treated at 300°/1h. The samples were irradiated at a gamma source Gamma-Cell (^{60}Co). The TL emission glow curves for absorbed doses between 0.5Gy and 20kGy were obtained using a Harshaw TL reader of Nuclear Instruments Systems, model 2000 A/B, and the data acquisition was performed using a virtual instrument (ADC-212 Pico Technology Ltd.) and a personal microcomputer. The TL emission spectrum was obtained in the range from 200 to 700nm with steps of 10nm using a monochromator UNICROM 100, adapted to a photomultiplier EMI 9789QB, of a home-made TL reader with associated electronics.

Figure 1. Sample of Diopside from Minas Gerais, Brazil, with quartz inclusions.

3. RESULTS

3.1 Response reproducibility

A group of ten numbered pellets of Diopside-Teflon composites were submitted five times to an identical procedure of thermal treatment at 300°C/1h (defined for re-utilization); irradiation at 10Gy (^{60}Co); and TL reading. This experiment resulted in a maximum variation coefficient (VC%) of the pellets of 7.5%.

Table 1. Reproducibility of TL response of pellets of Diopside – Teflon composites, irradiated with 10Gy (^{60}Co).

TL pellet	TL intensity (nC)					Mean Value (nC)	Standard Deviation (nC)	Variation Coefficient (%)
	s_1	s_2	s_3	s_4	s_5			
d_1	1.30	1.23	1.16	1.18	1.18	1.21	0.06	4.73
d_2	1.88	1.67	1.72	1.77	1.77	1.76	0.08	4.40
d_3	1.43	1.29	1.39	1.41	1.41	1.38	0.06	4.11
d_4	1.70	1.38	1.51	1.51	1.51	1.52	0.11	7.50
d_5	1.80	1.51	1.57	1.56	1.56	1.60	0.11	7.06
d_6	2.19	1.86	1.95	1.90	1.90	1.96	0.13	6.85
d_7	1.44	1.32	1.37	1.41	1.41	1.39	0.04	3.16
d_8	1.23	1.05	1.13	1.14	1.14	1.14	0.07	5.91
d_9	1.69	1.74	1.51	1.60	1.60	1.63	0.09	5.35
d_{10}	2.09	1.79	1.87	1.82	1.82	1.88	0.12	6.50

3.2 TL glow curves

Figure 2 presents the TL glow curves of the pellets of Diopside - Teflon composites treated at 300°C/1h and irradiated with doses between 0.5Gy and 20kGy (^{60}Co). The TL glow curves present two peaks at 130°C (peak 1) and 215°C (peak 2). Peak 2 is the most prominent. The positions of the peaks are independent of the absorbed dose, but the intensities increase in the relation of 3:1 between peak 2 and peak 1 up to 1kGy. From 1kGy up to 20kGy the relation between the TL intensities is 2(peak 2):1(peak 1). It can be observed that as greater is the dose, more defined are the two peaks.

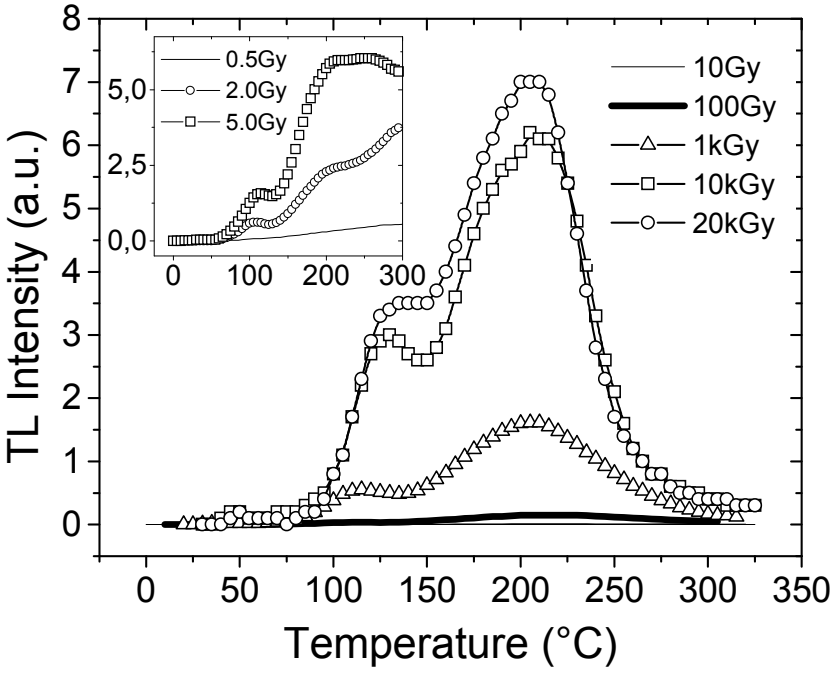

Figure 2. TL glow curves of Diopside-Teflon composites (pellets), treated at 300°C/1h and irradiated with doses between 0.5Gy e 20kGy (^{60}Co).

3.3 Calibration curves

For the calibration curve of the pellets of Diopside - Teflon composites, they were thermally treated at 300°C/1h and irradiated to doses between 0.5Gy and 20kGy of ^{60}Co. Figure 3a presents the TL intensity (a.u.) as a function of the absorbed dose (Gy). The linear fit between 0.5Gy and 1kGy resulted a correlation coefficient of 0.9998. Figure 3b presents the integrated charge (nC) between 50°C and 300°C as a function of the absorbed dose. The linear fit between 0.5Gy and 10kGy resulted in a correlation coefficient of 0.9999. After the linear behavior, both curves present a tendency to saturation.

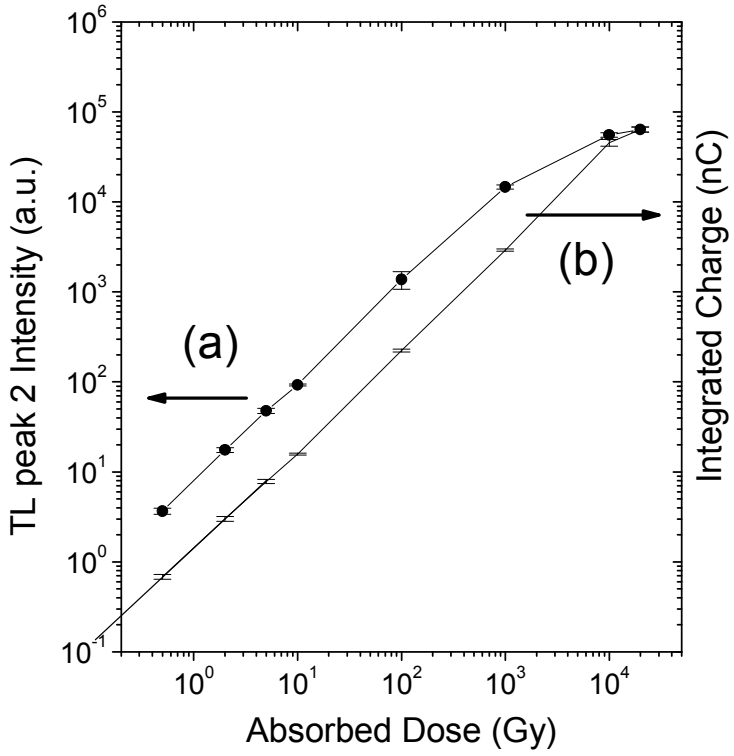

Figure 3. Calibration curves of Diopside - Teflon composites (pellets) for TL peak 2 intensity (curve a) and for curve in integrated charge (curve b) as a function of absorbed dose.

3.4 TL emission spectra

The isometric and contour plots of the TL emission between 400nm and 650nm of Diopside samples are presented in Figure 5. The resolution is 10nm. The TL peaks 1 and 2 present three emissions of similar intensities at 570nm, 590nm and between 610-635nm. This suggests that peaks 1 e 2 are from the same recombination center group.

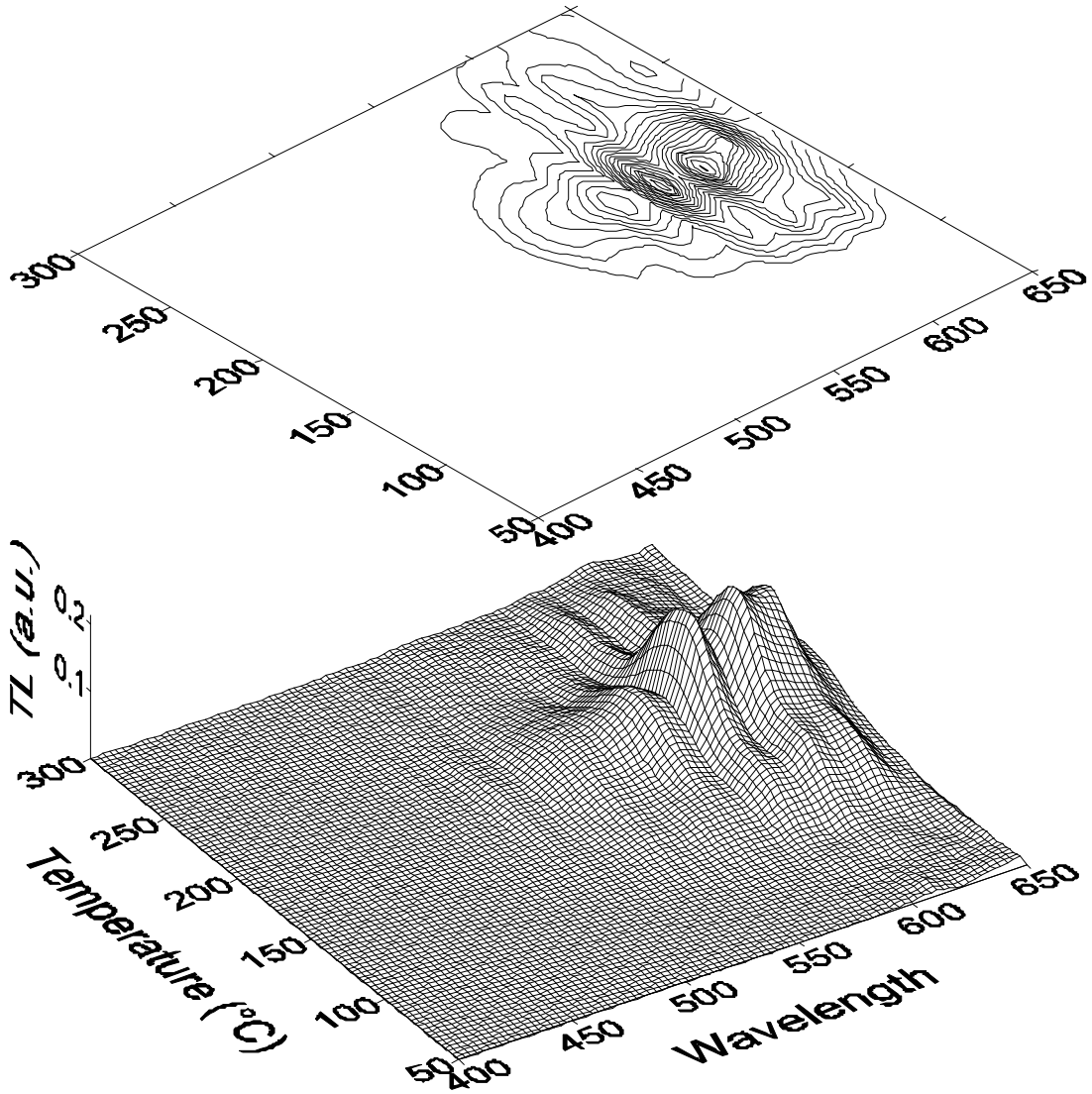

Figure 5. TL emission spectra of the natural Diopside from Minas Gerais, Brazil. The sample in the powder form was thermally treated at 300°C/1h and irradiated with 10kGy (^{60}Co).

4. CONCLUSION

The repeatibility experiment resulted in the maximum variation coefficient of the TL response of the pellets of 7.50%. The TL curves present two peaks at 130°C (peak 1) and 215°C (peak 2). Peak 2 is the most prominent. The calibration curve of the pellets of Diopside-Teflon composites presents a linear behavior from 0.5Gy up to 10kGy. Peaks TL 1 and 2 show three emissions of similar intensity at 570nm, 590nm and between 610-635nm. This fact suggests that TL peaks 1 e 2 are from the same recombination center group.

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