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TSEE response of silicates of the jade family in gamma radiation beams

Adeilson P. Melo[a,b], Maria Inês Teixeira[a], Linda V.E. Caldas[a,*]

[a] *Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, São Paulo, Brazil*
[b] *Centro Federal de Educação Tecnológica de Sergipe, Aracaju/SE, Brazil*

Abstract

In the present work some dosimetric characteristics of pellets of Brazilian silicates with Teflon as: actinolite-Teflon, tremolite-Teflon, rhodonite-Teflon and diopside-Teflon were investigated in gamma radiation beams of ^{60}Co using the thermally stimulated exoelectronic emission (TSEE) technique. The TSEE response reproducibility did not exceed 20%. The TSEE curves are simple, with a peak at 240 °C. The dose response curves show a sublinear behavior between 100 Gy and 20 kGy, and the lower detection limit for the pellets was (2.0 ± 0.4) Gy. These results may be considered satisfactory for applications at high-dose dosimetry.

Keywords: TSEE; Dosimetry; Gamma radiations; High doses

1. Introduction

A large number of thermoluminescent dosimeters (TLDs) utilized in Brazil are imported and of relatively high economic cost. The search for a TLD of low cost has motivated the research with new synthetic and natural minerals.

The silicates can be an interesting source to research for solid state dosimetry. They are abundant and represent 92% of the minerals volume of the earth's crust (Klein and Dana, 2002).

Some studies of glasses and silicates applied to dosimetry have already been published, and they are promising (Teixeira and Caldas, 2002; Melo et al., 2004). In this work, the technique of thermally stimulated exoelectronic emission (TSEE) was chosen because of its attractive potential application for radiation dosimetry (McKeever et al., 1995).

2. Materials and methods

The silicates studied in this work were the pyroxenes: rhodonite, $MnSiO_3$, and diopside, $CaMg(Si_2O_6)$; and the amphiboles: tremolite, $Ca_2Mg_5(Si_4O_{11})_2(OH)_2$ and actinolite, $Ca_2Fe_5(Si_4O_{11})_2(OH)_2$. All samples were acquired in Brazil.

The samples were cleaned with a nylon brush and alcohol isopropilic solution. Then, the samples were separated from quartz optically using a geological hammer with vidia tip and a magnifying geological glass. An X-ray diffraction spectrum did not present the quartz fase.

The ferromagnetic minerals presented in the samples were extracted with a Frantz Isodynamic magnetic separator. The Frantz separator was adjusted for an angle of 25° of longitudinal leaning, 10° of lateral leaning and current between 0.5 and 1.5 A.

The samples were powdered, and grains with diameter between 0.074 and 0.177 mm were selected to be mixed with Teflon. They were prepared manually in the proportion of 2(Teflon):1(silicates) in open atmosphere of nitrogen.

The mixture was pressed (Fred Frey model FC5), and pellets of silicates–Teflon of 50 mg with 6 mm of diameter and 0.8 mm of thickness were produced.

The pellets were sintered at 300 °C/1 h, followed by a thermal treatment at 400 °C/1.5 h. Its cooling was slow in the own oven. For reutilization and to avoid residual TL, the pellets were thermally treated at 300 °C/1 h. The samples were irradiated at a gamma-cell system (^{60}Co).

The TSEE readout system procedure was performed using a continuous flow of gas and associated electronics,

* Corresponding author. Tel./fax: +55 11 3133 9716.
E-mail address: lcaldas@ipen.br (L.V.E. Caldas).

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and a temperature programmer that supplies a linear rate of 5 °C/s.

3. Results

In all the TSEE measurements 10 samples of each material were used, so that each measurement point corresponds to the medium reading of these detectors. Before each TSEE measurement, the number of counts of the proportional detector was measured 10 times with a control source of ^{14}C, for checking the system stability. The maximum uncertainty was 3.1%.

3.1. TSEE emission curves

Silicate powdered samples were initially measured, and they showed TSEE response. Teflon powder did not present any TSEE response.

Fig. 1 presents the TSEE curves of silicates–Teflon composites (ACT, TRE, ROD, DIO) treated at 300 °C/1 h and irradiated with 20 kGy (^{60}Co). A peak at 240 °C can be observed for all materials.

In Fig. 2, the shape of the TSEE emission curves and the maximum temperature of the curves (240 °C) do not depend on the nature of the silicates–Teflon pellets; however, the maximum intensities of the TSEE response depend on the silicates–Teflon.

The pellets of ACT–Teflon and TRE–Teflon presented maximum intensities of the TSEE response larger than the TSEE response of the pellets ROD–Teflon and DIO–Teflon. Fig. 2 presents the TSEE emission curves of the composites of silicates–Teflon (50 mg), treated at 300 °C/1 h and irradiated with ^{60}Co with absorbed doses of 10, 100 Gy, 1, 10 and 20 kGy. In all cases an increase of the TSEE peak is observed with the absorbed dose that depends on the sample type.

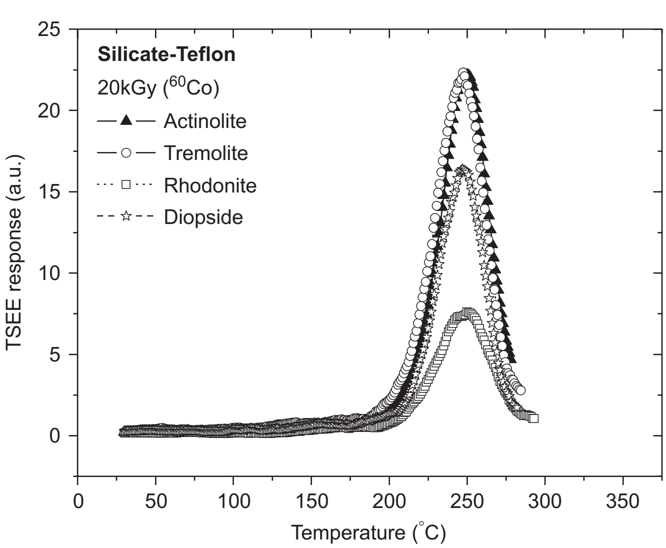

Fig. 1. TSEE emission curves of pellets of silicates–Teflon (ACT, TRE, DIO, ROD) treated at 300 °C/1 h and irradiated with an absorbed dose of 20 kGy (^{60}Co).

The shape of the TSEE curve and the position of the TSEE emission peak at 240 °C are independent of the composite type of silicates–Teflon. These results suggested that the responsible trap for the TSEE emission may have the same depth, that is, the same activation energy (McKeever, 1985).

3.2. Reproducibility of TSEE response

Ten pellets of each type of material were utilized. They were treated at 300 °C/1 h (reuse temperature), and they were irradiated with an absorbed dose of 10 Gy (^{60}Co). The TSEE measurements were taken in the interval from 50 to 300 °C. This procedure was repeated 10 times for each pellet.

The calibration factor of each sample was obtained by the quotient between the value of the absorbed dose and the average value of their response. The reproducibility in this experiment is given by the percentage variation coefficient (CV%), that is the quotient between the standard deviation of the measurements and the average of measurements of each pellet.

The maximum values are presented in Table 1.The results of $CV_{Máx}(\%)$ did not exceed 20%.They were between 12.3% (TRE–Teflon) and 18.8% (DIO–Teflon). Similar results were obtained by Rocha (1997): 10.2% for $CaSO_4$; 15% for $CaSO_4$ with 10% of graphite; 12% for LiF (Al); and 22% for LiF (inox).

3.3. Lower detection limit

The lower detection limit for the TSEE pellets of silicates–Teflon composites, defined as three standard deviations of five measurements of their mean zero dose reading (thermal treatment at 300 °C/1 h and non-irradiated samples, expressed in units of absorbed dose) was determined for all pellets of the studied silicates (ACT, TRE, DIO and ROD). The value obtained for the lower detection limits was (2.0 ± 0.4) Gy.

3.4. Dose response

The dose–response curves of the pellets of silicates–Teflon were obtained using gamma radiation (^{60}Co). Fig. 3 presents the TSEE dose–response curves of the pellets of silicates–Teflon, treated at 300 °C/1 h and irradiated with absorbed doses between 10 Gy and 20 kGy.

The dose–response curves of all silicates–Teflon pellets have approximately the same form, and they also suggest a sublinear behavior in the studied dose interval. The useful dose interval of these curves is only between 100 Gy and 20 kGy.

4. Conclusions

The TSEE peak at 240 °C is present in all tested samples and it is very well defined for absorbed doses starting from 10 Gy. Between 100 Gy and 20 kGy, the TSEE response in

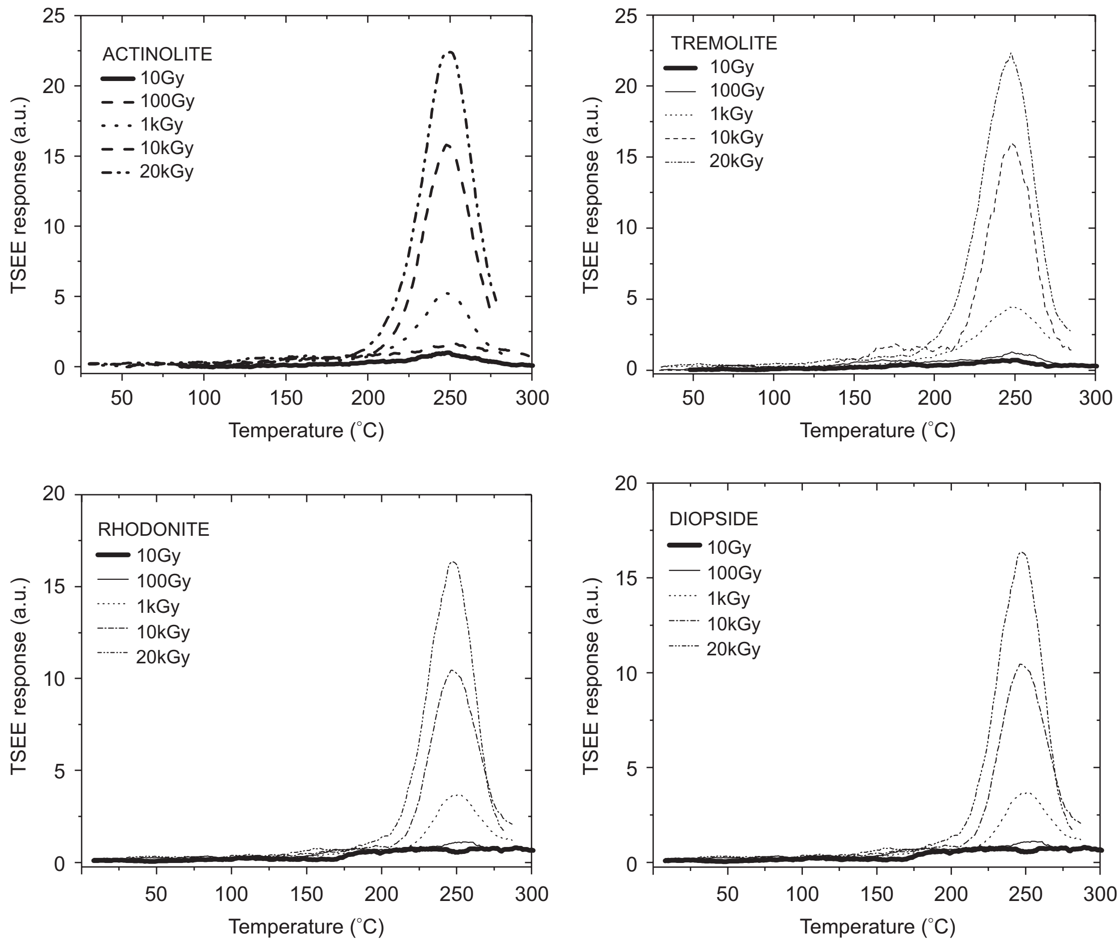

Fig. 2. TSEE emission curves of the pellets of 50 mg of silicates–Teflon treated at 300 °C/1 h and irradiated with absorbed doses between 10 Gy and 20 kGy (^{60}Co).

Table 1
TSEE response reproducibility as $CV_{Máx}$(%) of the pellets of silicates–Teflon

Silicates–Teflon	$CV_{Máx}$(%)
ACT	17.4
ACT	17.4
TRE	12.3
ROD	15.1
DIO	18.8

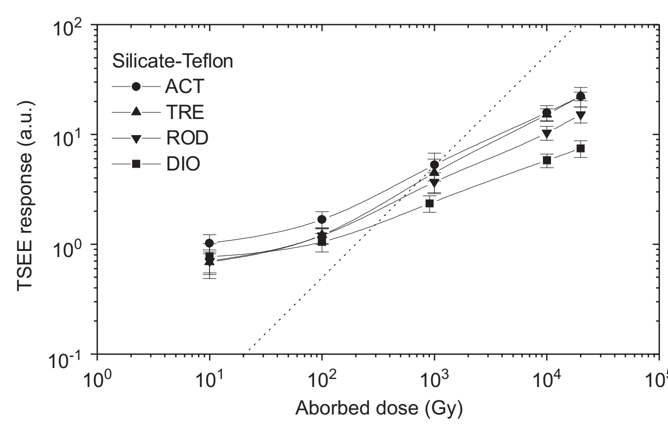

Fig. 3. TSEE dose-response curves of pellets of silicates–Teflon (ACT, TRE, DIO, ROD) of 50 mg, treated at 300 °C/1 h and irradiated with absorbed doses between 10 Gy and 20 kGy (^{60}Co). The dotted line just indicates a linear behavior.

function of the absorbed dose presents a sublinear behavior. These results show the possibility of use of these materials for dosimetry of "low doses" (100 Gy to 3 kGy), used for inhibition of the germination and treatment of grains and foods, as well as of "medium" dose dosimetry (1–10 kGy), used in the processes of purification of water, pasteurization and disinfection of objects (McLaughlin et al., 1989). The applications of these materials may be also extended up to 20 kGy for "high" gamma radiation doses. Therefore, the TSEE response of the silicates–Teflon samples may be useful for high-dose dosimetry processes.

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