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TL and TSEE response of Wollastonite–Teflon composites in X-ray beams

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Abstract

Pellets of Wollastonite–Teflon composites were studied in relation to some TSEE and TL dosimetric characteristics: emission curves, calibration curves, and energy dependence (X-rays). The calibration curves of TSEE and TL response show a prominent and isolated dosimetric peak with maximum around 200 °C that presents linearity between 1.5 and 6.0 Gy and a low energy dependence. TL and TSEE properties as glow peak positions and dose responses were determined and analyzed and the results showed that Wollastonite can be used in dosimetry, provided that energy dependence of its response is been properly taken into account.

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1. Introduction

Several authors have studied how to improve the combination between techniques and materials to investigate the evaluation of new detectors for radiation dosimetry of low cost. The techniques of thermally stimulated exoelectron emission (TSEE) and thermoluminescence (TL) are interesting to this aim, because they are of low cost and high resolution (ppm) [1–4].

Electrons near the insulator's surface or the crystals can be elevated to higher energy states into impurities sites and electron traps when those materials are exposed to ionizing radiation. A thermal stimulation of the solid may release these electrons from the traps. If their energy exceeds the electron affinity or the work function, they will be able to leave the surface of the insulator or crystal. The emitted electrons are called exoelectrons and the curve of this emission as a function of temperature is called the TSEE glow curve [3,4].

The silicates represent 92% of the volume of the earth crust minerals, and they constitute an abundant source of research for the development of new materials for radiation dosimetry [6]. Wollastonite, $Ca[SiO_3]$, occurs in alkaline igneous rocks, and it can be easily found all over the world, mainly in Csiklova (Romania), Black Forest (Bretagne), Chiapas (Mexico) and Minas Gerais (Brazil) [7]. It can also be obtained artificially, for example through coalition of the limestone and silica in electric ovens.

X and gamma rays remain the most widely used radiations in medicine, industry, research, agriculture and in nuclear activities. In view of their power, these radiations are of prime importance for radiation protection, and they remain the main contributors to the doses [8].

In a previous work [9] it was seen that when Wollastonite–Teflon pellets were irradiated with a gamma source (^{60}Co), the TL glow curve presents three peaks with different intensities at different temperatures. A prominent and isolated TL peak with maximum around 200 °C can be used for dosimetric purposes. The response of the pellets to irradiation was found to be linear with dose in the dose range of 1.0 and 10 Gy, and supralinear between 0.5 and

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Table 1
Specifications of the X-ray Rigaku Denki generator, model Geigerflex, with Philips tube, model PW/2184/00

Voltage (kV)	Half-value layer (mmAl)	Effective energy (keV)	Air kerma rate (Gy/h)
50	1.79	27.15	24.06
70	2.35	30.15	47.15
90	2.95	33.05	74.51
120	3.84	37.05	121.8
150	4.73	40.75	175.19

7.0 kGy. The analyses of the TL response of these pellets as a function of absorbed dose up to 7.0 kGy suggests that it will may be a useful material for high dose measurements. Moreover, reproducibility of TL results after five successive irradiation–reading–annealing cycles showed that Wollastonite pellets can be used without appreciable change in their sensitivity whereas the variation of the reproducibility results was less than 6.3%.

In this work characterization analyses of Brazilian Wollastonite for X-ray dosimetry were realized using the TL and TSEE techniques.

2. Experimental

Wollastonite from Minas Gerais, Brazil, was studied. Wollastonite is a silicate of calcium, $Ca[SiO_3]$, and it was acquired in the form of rude mineral with some Andradite inclusions. In the present work the stones were cleaned, cleaved and triturated to obtain grains with diameter between 0.074 and 0.177 mm. The ferromagnetic minerals presented in the samples were extracted with a Frantz Isodynamic magnetic separator. At that stage, the Frantz separator was adjusted for an angle of 25° of longitudinal inclination, 10° of lateral inclination and amperage current between 0.5 and 1.5 A.

In order to produce thin sintered pellets of Wollastonite–Teflon composites the mineral was prepared in the following way: the Wollastonite powdered crystals were thermally treated at 300 °C for 30 min, followed by another thermal treatment at 400 °C for 1.5 h. These are the same treatments that are used for the $CaSO_4:Dy$ dosimeters produced by IPEN, Brazil. The thermally treated Wollastonite powder was mixed with Teflon in the ratio 1:2 (wt) and pressed, producing pellets of size 6 mm diameter and 1 mm thickness.

X-ray irradiations were provided by a Rigaku Denki generator, model Geigerflex, with a Philips tube model PW/2184/00 (Tungsten target and Beryllium window, 60 kV). The doses were between 1.5 and 6.0 Gy (Table 1).

A Harshaw Nuclear System, model 2000A/B, with a linear heating rate of 10 °C/s was used as a TLD reader. TL readouts were performed within 35 s, with a constant flow of high purity nitrogen at the rate of 4.0 l/min. The integration area between 50 and 300 °C was used. The output data were recorded with a two-channel x-t recorder ECB, model RB-101. The readings were always taken immediately after irradiations.

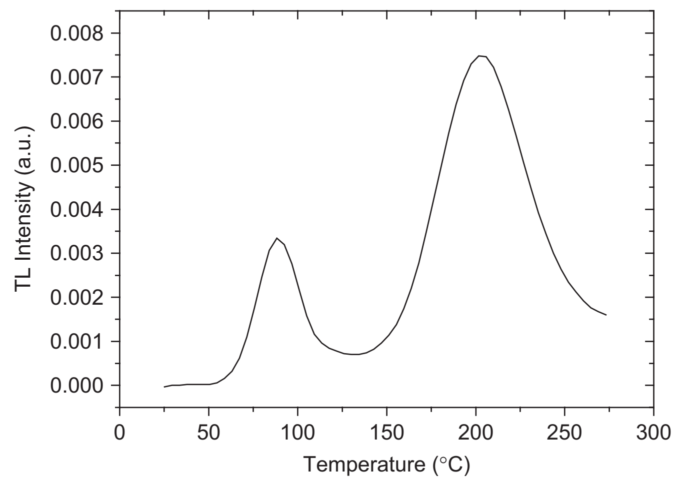

Fig. 1. TL glow curve of a Wollastonite–Teflon pellet X-irradiated (37.05 keV–1.5 Gy).

The TSEE signal was registered using a system with a 2π windowless gas-flow proportional counter, with hemispherical volume [5]. The heating was linear at a rate of 10 °C/s from room temperature up to 300 °C.

The samples were heated for 60 min at 300 °C before each irradiation.

3. Results

Fig. 1 shows the TL glow curve of a Wollastonite–Teflon pellet irradiated to 1.5 Gy with X-rays (37.05 keV). The TL curve exhibits two very well defined peaks around 100 and 200 °C. The second TL peak at 200 °C was assumed as a dosimetric peak.

In Fig. 2 the TSSE curve emission of a pellet, irradiated under the same conditions, shows a single peak at 250 °C. The signal before this peak is not significant. The uncertainty level in the TSEE measurements was higher than in TL measurements, probably because the degree of reproducibility of the TSEE response is very dependent of the superficial characteristics of the sample. Small imperfections on the pellet surface may cause variation in the results. However, in both analyses the confidence level considered was 1σ.

The TL and TSEE responses of the pellets were plotted as a function of the absorbed dose of X-rays in Figs. 3 and 4, respectively. The dose response is defined as the functional dependence of the intensity of the measured TL

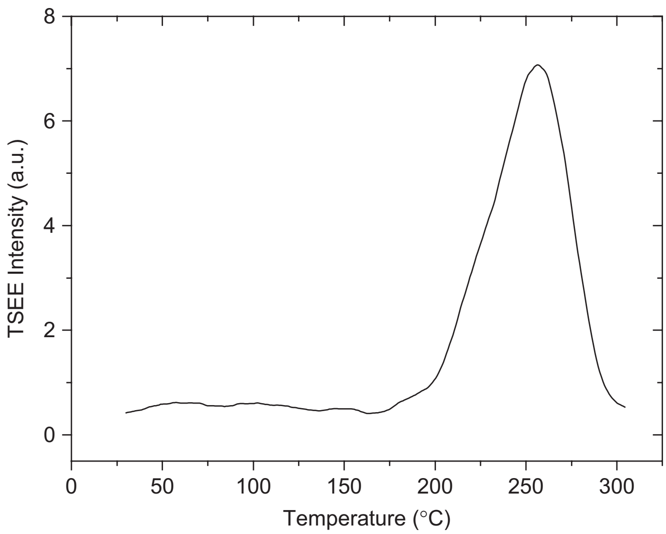

Fig. 2. TSEE emission of a Wollastonite–Teflon pellet X-irradiated (37.05 keV–1.5 Gy).

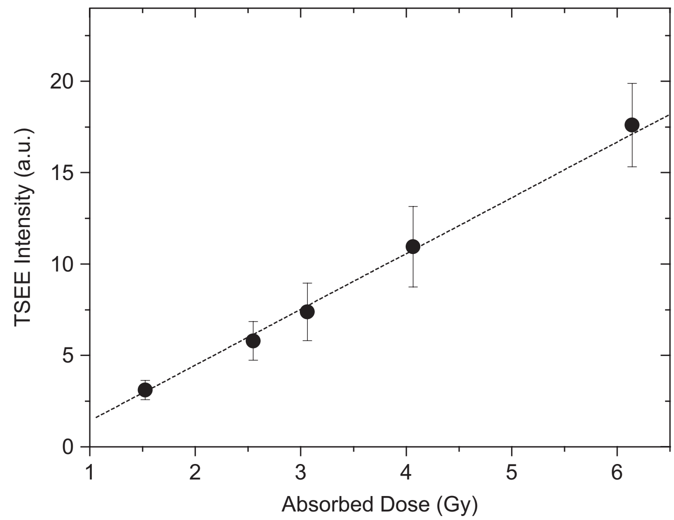

Fig. 4. TSEE response of Wollastonite–Teflon pellets as a function of the absorbed dose of medium-energy of X-radiation (37.05 keV).

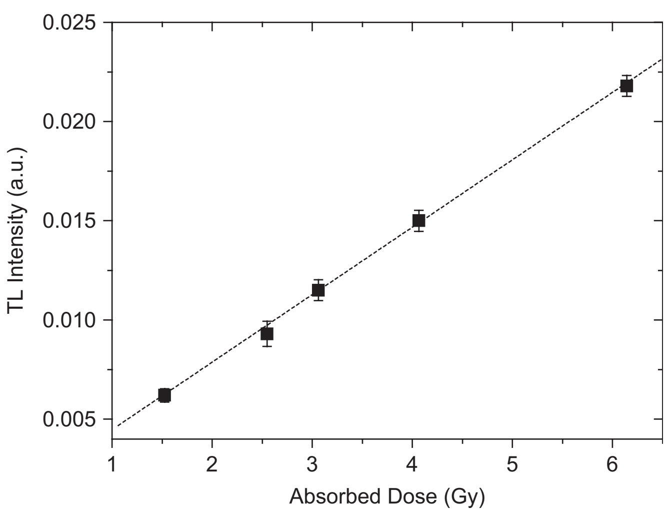

Fig. 3. TL response of Wollastonite–Teflon pellets as a function of the absorbed dose of medium-energy X-radiation (37.05 keV).

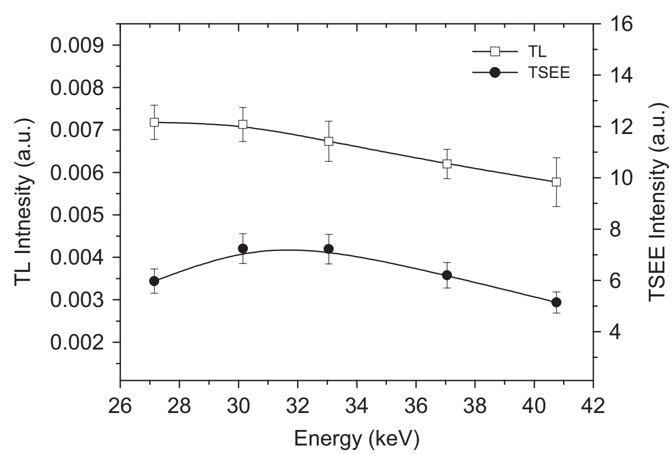

Fig. 5. Dependences of the TL and TSEE response Wollastonite–Teflon pellets on the energy of X-rays. All the samples were irradiated to 1.5 Gy in air. The TL and TSEE uncertainties are within 6% and 15%, respectively.

signal upon the absorbed dose [2]. In both cases, the calibration curves presented responses proportional to absorbed dose between 1.5 Gy and 6.0 Gy for the radiation energy of 37.05 keV; the curves are useful in the whole tested dose range. No dose saturation was observed. The measurement uncertainties in those studies were always below 5%.

The processes governing the energy absorption from the ionizations by Wollastonite–Teflon pellets are energy dependent. Meantime, the dependence of the TL and TSEE response on the energy of X-rays between 27.17 and 40.75 keV (dose of 1.5 Gy) were less than 15% as can be seen in Fig. 5.

The TL fading at the ambient temperature was monitored for 60 days. To this study, the pellets were previously irradiated to 6.0 Gy (37.05 keV), and the samples were stored at room temperature. The TL response of the dosimetric peak faded by about 7% in the first 30 days after irradiation. In the next 30 days, the response faded by only 1.5%, tending to a constant value. The fading of TL signals at room temperature is treated as an isothermal decay. Thus, if the pellets shall be used in routine dosimetry, the fading should be taken into account in determining absorbed doses.

4. Conclusions

The main dosimetric characteristics of Wollastonite–Teflon pellets, such as TL glow curve, response reproducibility, response fading, calibration curves and the energy dependence of the response are properly determined. The results show that this material can be used in dosimetry, provided that fading and energetic dependence of its response are properly taken into account.

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