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TL RESPONSE OF CITRINE SAMPLES FOR HIGH-DOSE DOSIMETERY

Maria Ines Teixeira[1,2] and Linda V.E. Caldas[1]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN – SP)
Av. Professor Lineu Prestes, 2242
05508-000 São Paulo, SP
miteixeira@ipen.br lcaldas@ipen.br

[2] Associação Educacional Nove de Julho (UNINOVE – SP)
R. Diamantina, 302
02117-010 São Paulo, SP

ABSTRACT

The possibility of using samples of Brazilian stones as quartz, amethyst, topaz, etc. for high-dose dosimetry has been studied in recent years at IPEN, using the thermoluminescence technique (TL). In this work, the TL properties of citrine samples were studied. They were exposed to different doses of gamma radiation (^{60}Co). The natural citrine stone was extracted from a mine in Minas Gerais state, Brazil; it is a tectossilicate ranked as one of three-dimensional structure, showing clear yellow to golden brown color. The natural citrine stone is classified as quartz (SiO_2), and it has a lower symmetry and more compact reticulum. The citrine stone samples were powdered, and the selected grains were mixed with Teflon in the proportion 2 (Teflon):1 (Citrine). The mixture was pressed and sintered for production of Citrine -Teflon pellets of 50 mg. The TL emission curve showed two peaks at 160ºC and 220^{o}C. To remove the TL peak (160^{o}C) of the sintered citrine pellet glow curves, different thermal treatments were tested during several time intervals. The TL dose-response curve between 50 Gy and 100 kGy, the reproducibility of TL response and the lower detection dose were obtained. The preliminary results show that citrine may be useful for high-dose dosimetry.

1. INTRODUCTION

High-doses have been used in industrial processes such as material sterilization, food tuber germination treatments, grain and seed growing, water purification, among other possibilities [1,2].

The Calibration Laboratory of IPEN has tested samples of commercial, national and imported glasses [3,4,5] using the techniques of Optical Absorption (OA), Thermoluminescence (TL) and Electron Paramagnetic Resonance (EPR) for high-dose dosimetry. Brazilian beach sand samples [6] and from the city of Descalvado [7] were studied in IPEN, and showed favorable use in high-dose dosimetry.

The possibility of using samples from natural mines at Minas Gerais state, Brazil, such as topaz [8], amethyst [9], jasper [10], and jade from other parts of the world [11], were studied and tested also at IPEN, using the technique of thermoluminescence.

In this work, preliminary results on the dosimetric characterization of citrine samples was obtained by the thermoluminescence technique.

2. MATERIALS AND METHODS

The natural citrine stone studied in this work is a tectossilicate with a three-dimensional structure, with a color from golden yellow to light brown, and it was extracted from a mine in Minas Gerais state, Brazil. It is classified as quartz (SiO_2), and occurs naturally in clusters of pyramids on a geode base. This kind of material is trigonal, a less symmetrical subset of the hexagonal system with four crystallographic axes.

The stones were first washed, broken and powdered in grains with diameter between 0.075 and 0.180 mm. Samples of citrine powder were subjected to an initial thermal treatment at 300°C for one hour. This treatment was chosen for reutilization too.

To simplify the sample handling, sintered citrine pellets (50 mg) were prepared at the Laboratory for Production of Dosimetric Materials, IPEN, using Teflon as binder in a ratio of 2 (Teflon): 1 (citrine). The samples were irradiated using a Gamma-Cell-220 system (^{60}Co, dose rate 2.18 $kGyh^{-1}$, Nov 2010), of the Center for Radiation Technology, IPEN, between doses of 50 Gy and 100 kGy. The irradiations were made at ambient temperature, and the citrine samples were fixed between 3 mm thick polymethyl methacrylate plates (Lucite), to guarantee the occurrence of electronic equilibrium during the irradiations.

The evaluation of the citrine pellets was carried out with a thermoluminescent reader (Harshaw Chemical Co., model 2000A/B) using a heating rate of $10°Cs^{-1}$. All TL measurements were integrated between 50°C and 300°C For data acquisition we used a virtual instrument Pico Technology Lts., Model ADC-212, connected to a computer, was utilized.

3. RESULTS

In this work some dosimetric properties of citrine samples were studied: TL emission curve, the thermal treatment to eliminate the first TL peak, TL response reproducibility, the minimum detectable dose, and the dose-response curve for gamma radiation.

Figure 1 shows a TL emission curve of a citrine sample irradiated with 10 kGy, one hour after its irradiation. Two TL peaks at 160°C and 220ºC can be observed.

The first TL peak at 160°C of citrine pellets was eliminated through thermal treatments at 130°C for different time intervals (5 - 60 minutes), as shown in Figure 2. The most appropriate thermal treatment to remove this TL peak was 130°C during 10 min.

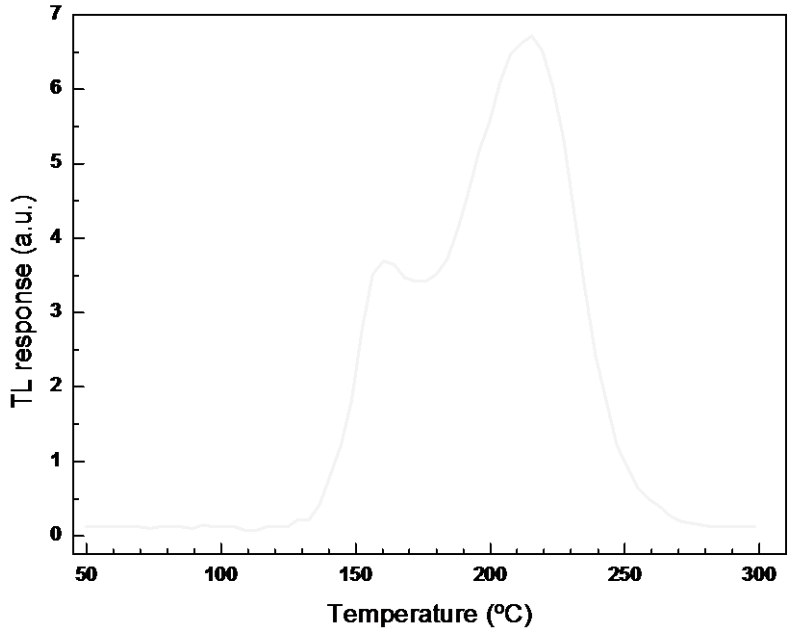

Figure 1: TL glow curves of a citrine sample pellet irradiated with 10 kGy (^{60}Co).

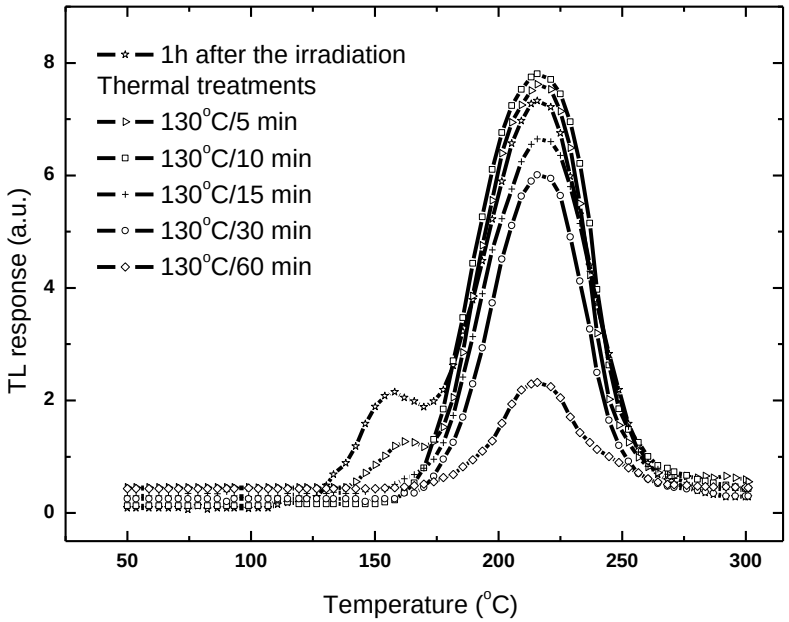

Figure 2: TL glow curves of citrine pellets irradiated with 5 kGy (^{60}Co) and thermally treated at different time intervals after irradiation.

For the reproducibility study of the TL response, five samples of citrine pellets were submitted five times to the same procedure of thermal treatment at 300°C for 1h (defined for

the reutilization), irradiation (5 kGy), and thermal treatment at 130°C/10 min (to eliminate the first TL peak) and TL reading. The TL reproducibility response obtained was 3.25%.

The dose-response curve was obtained with citrine samples irradiated (^{60}Co) from 50 Gy to 100 kGy and thermally treated at 130°C/10min: Figure 3. Initially a linear behavior can be observed, and after 500 Gy sublinearity occurs. The maximum uncertainty of these measurements was 2.0%.

The lower detection limit of the citrine samples was determined by studying the variability of the TL signal obtained from samples treated at 300°C/1h but not irradiated. Taking three times the standard deviation of these measurements, the lower detection limit, was obtained as 150 mGy.

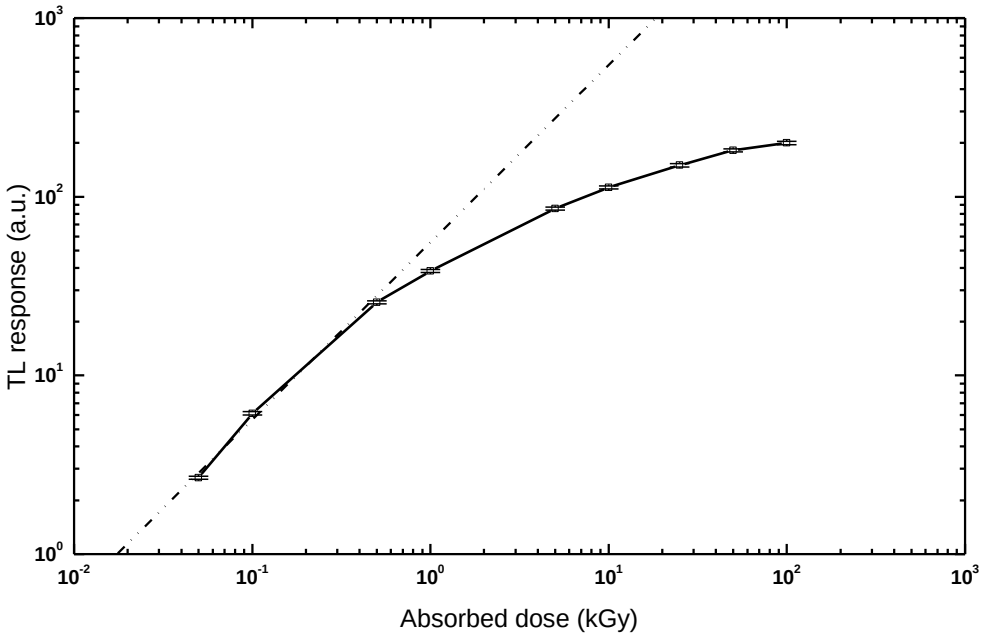

Figure 3: Calibration curve of citrine pellets for ^{60}Co radiation. Measurements were taken after the thermal treatment of 130°C/10 min.

3. CONCLUSIONS

The results of this study show that the citrine samples can be used in high-dose dosimetry. The TL glow curve of citrine samples presented two peaks at ~ 160ºC and 220º C. To remove the first TL peak, a post-irradiation thermal treatment at 130 ºC during 10 min is enough. The citrine material has the advantage of being found in a great quantity in nature so that it presents low cost.

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