Radiation detector with spodumene

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Abstract. In this work, β-spodumene potentiality as a radiation detector was evaluated by making use of thermoluminescence (TL) and thermally stimulated exoelectron emission (TSEE) techniques. The pellets were obtained from the β-spodumene powder mixed with Teflon followed by a sinterization process of thermal treatments of 300 °C/30 min and 400 °C/1.5 h. The samples were irradiated in standard gamma radiation beams with doses between 5 Gy and 10 kGy. The TL emission curve showed a prominent peak at 160 °C and in the case of TSEE a prominent peak at 145 °C approximately. Initial results show that the material is promising for high-dose dosimetry.

1 Introduction

The main purpose of radiological protection is to protect man and his environment from harmful effects of ionizing radiation and radioactive substances [1]. As there are no explicit signs of the presence and intensity of ionizing radiation, it is necessary to take steps to monitor the areas and individuals to ensure that the doses received are within safe limits. The dosimetry of ionizing radiation is important so that procedures can be taken in order to maximize the benefits it can offer to society and minimize the damage resulting therefrom. Thus, detectors of different materials detectors have been proposed in the literature for environmental and personal monitoring. Thermoluminescent detectors (TLDs) are the oldest dosimeters. This work includes the study of polycrystalline $LiAlSi_2O_6$ known as spodumene, produced by the process of devitrification, for use in radiation detection systems in the form of pellets bonded with Teflon ®. Samples of β-spodumene have been produced and there is a vast literature on the subject [2-4] but few studies have been performed by means of thermoluminescence and no work by thermally stimulated exoelectron emission with this type of pellet, in this research.

In this respect, thermoluminescence (TL) is the light emitted by certain crystals, when heated, previously exposed to ionizing radiation [5]. The emission of low energy electrons, which occurs on the surface of many insulating solids at temperatures below those at which the thermionic emission is caused by mechanical deformation, phase changes, chemical reactions or exposure to ionizing radiation, is called thermally stimulated exoelectron emission (TSEE) [6]. The objective of the present work was to assess the potentiality of β-spodumene as a radiation detector by making use of TL and TSEE techniques. Factors such as sensitivity and ease of production of dosimeters used in TL and TSEE are very important, and in monitoring programs the "cost" represents a large factor for the best decision in choosing the dosimeter.

2 Materials and Methods

2.1 Samples

The material studied in this work was produced using reagents in powder form in the following proportions: 5.75% SiO_2, 24.50% Al_2O_3 and 17.75% of Li_2CO_3. They were mixed and melted in a platinum crucible in a furnace mounted in the Laboratory of Ionic Crystals, Thin Films and Dating (LACIFID) of Institute of Physics of University of São Paulo. The polycrystals, were crushed in a mortar with the aid of a pestle, both of agate, and grains between 0.180 mm and 0.075 mm were obtained. The grains were selected and mixed by hand with Teflon® powder in a ratio of 1:2, β-spodumene and Teflon® respectively. The mixture was placed in an alumina crucible, taking care of optimizing the stirring until homogenization. Then the mixture was pressed at 1.6 x $10^{11}/m^2$ to obtain 20 mg pellets, with 0,2 mm in thickness and 6,0 mm in diameter. They were then sintered, at 300 ° C/30 min and 400 ° C/1.5 h in a microwave oven, CEM Corporation, USA.

2.2 Equipments

In this paper the technique of X-ray Diffraction (XRD) was used in order to verify the crystalline structure of polycrystal obtained corresponding to the crystalline structure of β-spodumene standard.

The spectrum of X-ray diffraction powder was obtained from the Federal University of Ceará with a powder diffractometer Panalytical (Xpert Pro MPD) with CoKα radiation (λ = 1.7889 Å), with the tube operating at 40 mA kV/30, at room temperature. To identify the constituent phases of the samples, the result obtained was compared to the available pattern in the database of crystallographic PDF2 (Power Diffraction File). The refinement of the data was obtained by the Rietveld method, using the software X'Pert Plus NEW HighScore and DBWS.

All measurements were taken at room temperature, and the pellets were sandwiched in Lucite plates with 3,5 mm thickness to guarantee the electronic equilibrium during the irradiation. The TL measurements were taken using a Harshaw TL reader model 2000 A/B in the range from 50 to 300 °C and linear heating rates of 10 °C/s in nitrogen flux. The TSEE measurements were taken using a home-made system developed at Centre for Radiation Metrology in the range from 30 to 300 °C and linear heating rate of 5 °C/s in P10 gas flux. The time interval between the end of each irradiation and the beginning of each TL and TSEE measurement was kept constant, approximately 0.5 h.

The heat treatment at 300 ° C/1 h was established for the reuse of samples using the TL and TSEE techniques.

2 Results

Before starting the luminescent measurements to confirm the type of crystals that were obtained from the sample preparation, they were tested by the X-ray diffraction technique. The XRD spectrum obtained with the polycrystal of spodumene is shown in Fig. 1, together with the spectrum calculated by the Rietveld method. The experimental XRD patterns were analyzed using the parameters of the reference card Inorganic Crystal Struture Database (ICSD) 14235, β-spodumene, which was the one that best fitted the experimental data. The phase identification as single (100%) was confirmed by Rietveld refinement. The β-spodumene obtained belongs to the tetragonal crystal system and space group P43212. The crystallographic parameters are
a = 7.5392 Å, b = 7.5392 Å, c = 9.1489 Å, α = 90 °, β = γ = 90 ° and 90 °.

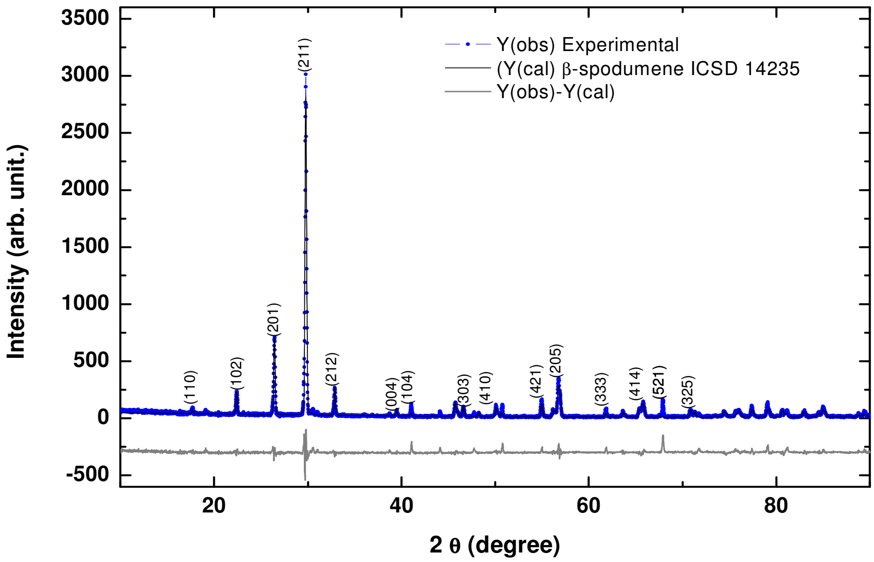

Fig. 1. *X-ray diffraction pattern of a powder sample of pure synthetic spodumene Y(obs) compared with the calculated spectrum by the Rietveld method Y(cal). The result of refinement is shown by the difference Y(obs) - Y(cal)*

The dose-response curves of the pellets irradiated at doses of 5 Gy to 10 kGy were obtained by the TL and TSEE techniques. Figure 2 shows the curves of the emission characteristics of TL (Fig.2a) and TSEE (Fig.2b) for the sample irradiated with 50 Gy. Both show intense peaks at approximately 160 ° C (TL) and 145 ° C (TSEE), and other less intense. The emission curves showed reproducibility and intensity of the peaks increased with the absorbed dose of 5 Gy and 200 kGy.

The most intense peaks were chosen to obtain the dose-response curve of the β-spodumene-Teflon® pellets. Fig 3a and 3b show the TL and TSEE dose-response curves respectively.

In the case of TL (Fig. 3a), the curve is initially linear between 5 and 100 Gy. In the second interval, between 100 and 1000 Gy it becomes supralinear. After 1 kGy, begins the saturation. Thus, the region most appropriate for use in dosimetry is the range between 5 Gy and 1 kGy, but with careful evaluation of the different dose intervals.

In the case of TSEE (Fig. 3b) the signal shows a large variation in range for doses below 700 Gy, not interesting for dosimetry. However, between 700 Gy and 10 kGy, the curve shows a sublinear growth. Therefore, in this dose range it would be possible to use this material for dosimetry. Both preliminary results demonstrate the feasibility of using this crystal for high-dose dosimetry using TL emission and/or TSEE. However, further studies on the characteristics of this material are necessary.

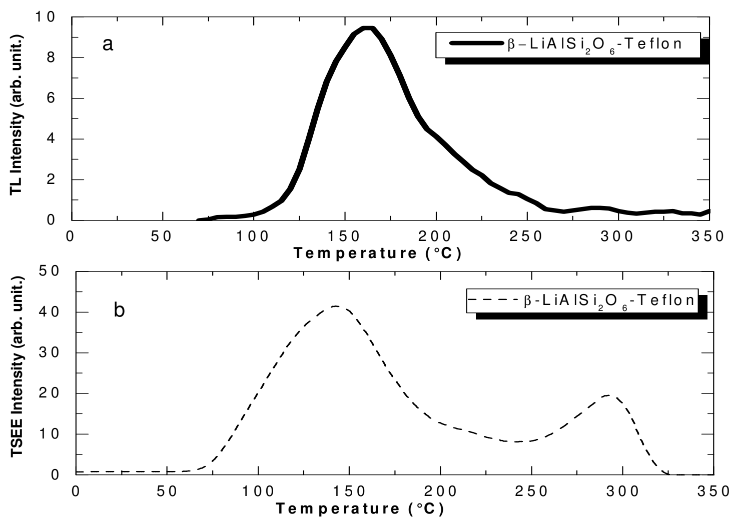

Fig. 2. *TL (a) and TSEE (b) emission curves of β-spodumene-Teflon® pellets irradiated with 50 Gy (^{60}Co source) at room temperature.*

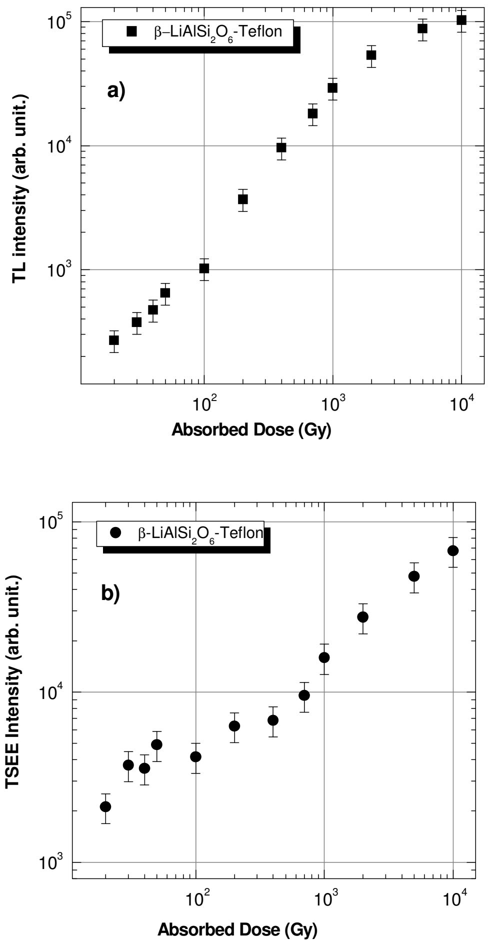

Fig. 3. *TL (a) and TSEE (b) dose-response curves of β-spodumene-Teflon® pellets irradiated with the ^{60}Co source.*

3 Conclusions

It was possible to obtain the β-spodumene- Teflon® pellets through applied techniques. Preliminary results are promising for high-dose dosimetry using TL emission and/or TSEE, the material is easily prepared, and it is of relatively low cost.

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