

PRELIMINARY STUDY OF RHODONITE FOR X-RADIATION DOSIMETRY

Adeilson P. de Melo^{1,3}, Mario E. G. Valerio² and Linda V. E. Caldas³

¹ Centro Federal de Educação Tecnológica de Sergipe
Av. gentil Tavares da Motta, 1166
49055-260, Aracaju, SE
adeilson_pessoa_melo@yahoo.com.br

² Universidade Federal de Sergipe (UFS)
Av. Marechal Rondon, s/n
49055-260, Aracaju, SE
mvalerio@fisica.ufs.br

³ Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
lcaldas@ipen.br

ABSTRACT

Several materials as fluorides, oxides, borates, sulphates and silicates have been investigated in relation to their thermoluminescent properties for radiation dosimetry, as in applications that involve high doses of gamma radiation. However, almost all radiation dosimeters for high doses present some limitations. The research of new materials has been necessary to eliminate those limitations. Samples of natural rhodonite (MnSiO_3) were studied in this work. The main dosimetric characteristics of composites of rhodonite-Teflon (in pellets) for gamma dosimetry were studied: TL emission curves, calibration curves and energy dependence of the TL response for X radiation. These results suggest a potential use of composites of rhodonite-Teflon as radiation dosimeters or as radiation detectors for X radiation.

1. INTRODUCTION

X-rays are used in diverse fields of science and technology. In science the structural study of crystalline and amorphous materials has led to the development of new materials. In medicine they have contributed to the cure of illnesses, in agriculture to the increase of food production, and in the industry for the safety in the verification of the quality of sewings in weldings.

These activities demand absorbed doses between milligrays and kilograys. In these cases, the dosimetry of X radiation beams is very important to guarantee safety and quality. In the case of solid state systems for dosimetric purposes, diverse materials as fluorides, oxides, borates, sulphates and silicates have been investigated in relation to their thermoluminescent (TL) properties for high dose dosimetry. However, almost all systems have some type of limitation for use in radiation dosimetry [1].

Many of the thermoluminescent dosimeters (TLD) utilized in Brazil are imported and of relatively high economic cost. The search for TLDs of low cost has motivated the research with new synthetic and natural materials. The silicates are abundant and represent 92% of the

percentile volume of minerals of the earth crust [2]. In recent years, some silicates as commercial glasses [3], quartz [4], topaz [5] and jade [6] have been studied in relation to their properties applied to radiation dosimetry.

In the present work, the dosimetric characteristics of rhodonite-Teflon pellets were studied : TL glow curves, reproducibility, calibration curves and energy dependence of the TL response in X radiation beams.

2. MATERIALS AND METHODS

The rhodonite is a silicate of pink color with triclinic, tabular crystallography and hardness between 5.5 and 6.5 in the scale of Mohs. About 95.86g of natural rhodonite of chemical composition MnSiO_3 , with inclusion of calcite (CaCO_3), proceeding from Carnaíba, Brazil (Figure 1), was acquired and cleaned mechanically and chemically.



Figure 1. Natural rhodonite used for the production of rhodonite-Teflon pellets.

The sample was initially cleaned with a brush of nylon bristles and isopropilic alcohol. After that, the sample was broken using a geological hammer.

The selected rhodonite pieces were immersed in a solution of intent HCl to dissolve the calcite, according to the reaction: $2\text{HCl}(\text{aq}) + \text{CaCO}_3(\text{s}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$. After 24h, the rhodonite was collected and washed with distilled water. This process was repeated three times until the total removal of all calcite.

After drying in a heater at 50°C for 1h, the rhodonite was sprayed and the powder between 0.074 and 0.177mm was selected and mixed manually in proportion: 1 (rhodonite): 2 (Teflon). This mixture was cooled with liquid nitrogen to optimize the homogeneity. After that, the samples were pressed for the production of pellets of 50mg with 2mm of thickness and 6 mm of diameter. In the sintering process, the pellets were thermally treated at 300°C for 30min and then at 400°C for 1h and 30min.

The cooling of the pellets occurred slowly in the proper oven. Later these pellets received a thermal treatment at 300°C/1h in an open atmosphere oven followed by a fast cooling on a metal plate. This thermal treatment was always realized for re-utilization, and it has the objective of the elimination of spurious thermoluminescent response.

After that, the pellets were exposed to doses of 0.5Gy to 10Gy of low energy X- ray beams (Pantak/Seifert system) between 27 and 41keV (diagnostic radiology qualities) in the Calibration Laboratory of IPEN. The TL evaluation was carried out using a Harshaw 2000 model A/B system of Nuclear Instruments Systems, and the data acquisition was made through a virtual instrument (ADC-212/3 of Pico Technology Ltd.).

3. RESULTS

3.1 Glow Curve

The TL emission curve of a rhodonite-Teflon pellet can be seen in Figure 2. It presents three TL peaks at 130°C (peak 1), 226°C (peak 2) and 270°C (peak 3); peak 3 is of limited visibility. The dosimetric study was carried through using peak 2, that is the main dosimetric peak.

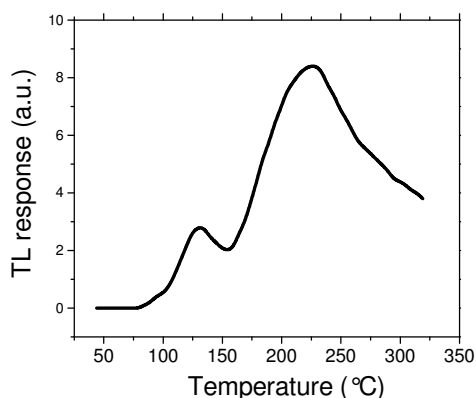


Figure 2. TL emission curve of a rhodonite-Teflon pellet submitted to the thermal treatment of 300°C/1h followed by an absorbed dose of 1Gy of X radiation (33keV)

3.2 Reproducibility

A set of ten numbered pellets of rhodonite-Teflon was exposed ten times to the same procedure of thermal treatment of 300°C/1h (defined for re-utilization) followed of irradiation (10Gy) and TL evaluation. The reproducibility experiment resulted in a maximum coefficient of variation of 5.4%.

3.3 Calibration Curve

The rhodonite-Teflon pellets were irradiated to doses between 0.5Gy and 10Gy; the TL response was integrated between 50°C and 300°C, and it was represented in function of the absorbed dose. The calibration curve of the pellets can be seen in Figure 3. The curve suggests a linear behavior in the studied dose interval for the X-ray beams (33keV).

3.4 Energy Dependence

Figure 4 shows the energy dependence of the TL response between 27keV and 41keV for absorbed doses of 1Gy. The ratio between the maximum and minimum values of the TL response, integrated in the interval between 50°C and 300°C, resulted in a maximum energy dependence of 27.3%

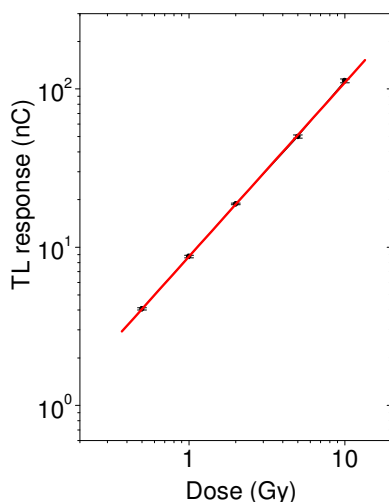


Figure 3. Calibration curve of the rhodonite-Teflon pellets in X radiation beams (33keV)

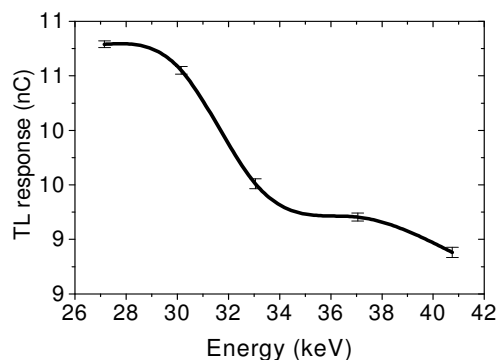


Figure 4. Energy dependence of the TL response of the rhodonite-Teflon between 27keV and 41keV of X radiation (1Gy)

4. CONCLUSIONS

The TL emission curve of rhodonite-Teflon pellets presents three peaks at 130°, 226°C and 270°C. The main and dosimetric peak occurs at 226°C. The reproducibility experiment showed a maximum coefficient of variation 5.4%. The calibration curve suggests a linear behavior. The energy dependence of the TL response obtained between 27keV and 41keV for an absorbed dose of 1Gy was 27.3%. These preliminary results using X-rays show that the pellets of rhodonite-Teflon present application possibilities for dosimetry.

ACKNOWLEDGMENTS

The authors are thankful to the Institute of Geociências, Universidade de São Paulo, for the natural rhodonite sample, to the Laboratory for Dosimetric Materials, for the production of the pellets, and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação de Apoio à Pesquisa do Estado de São Paulo (FAPESP), Brazil, for partial financial support.

REFERENCES

1. S. W. S. McKeever, M. Moscovitch, P. D. Townsend. *Thermoluminescence Dosimetry Materials: Properties and Uses*. Nuclear Technology Publishing, Kent, 1995.
2. C. Klein. *Mineral Science*. 22nd. John Wiley & Sons, New York, 2002.
3. M.I. Teixeira; L.V.E. Caldas. Dosimetric properties of various colored commercial glasses. *Appl. Radiat. Isot.*, **57**, 407-413, 2002.
4. V. Correcher, J. Garcia-Guinea , L. Sanchez-Munoz , A. Delgado. Effect of dopants in the luminescent properties of synthetic quartz for dosimetric purposes. *J. Mat. Process. Techn.*, **143**, 871-874, 2003.
5. D. N. Souza, J.F. Lima, M.E.G.Valerio and L.V.E. Caldas. Performance of pellets and composites of natural coloured topaz as radiation dosimeters. *Radiat. Prot. Dosim.*, **100** (1-4), 413-416, 2002.
6. A.P. Melo, M.E.G Valerio and L.V.E. Caldas. Thermoluminescent characteristics of mineral samples acquired as Jade. *Nucl. Instrum. Meth. B* **218**, 198-201, 2004.