Thermoluminescent Dosimetric Properties of Descalvado Sand

Maria Inês Teixeira and Linda V. E. Caldas
Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear,
São Paulo, Brazil
miteixei@ipen.br; lcaldas@ipen.br

Abstract

Sand samples proceeding from Descalvado, São Paulo, were studied with regard to their dosimetric properties using the thermoluminescence technique (TL) for high doses. These sand samples present steady physical and chemical characteristics to the end items, and they are used in the glass industry and for casting. The TL curves of the samples were obtained after an irradiation at the Gamma-Cell system (^{60}Co), of IPEN. The glow curves present two peaks at 80ºC and 220ºC approximately. Calibration curves were obtained for doses between 50 Gy and 5 kGy. The results indicate that the sand samples can be used for high-doses dosimetry in several areas of applications of ionizing radiation.

1. INTRODUCTION

The dosimetric characteristics of sand samples have been studied in relation to high-dose dosimetry as well as their application as routine dosimeters [1-4]. Sand is a material found in the nature in great amounts; in the decade of nineties this material awakened interest in its dosimetric properties. Sand presents the phenomenon of thermoluminescence (TL), because it is basically constituted of quartz and feldspar. Sand also contains some other elements in lesser amounts [1,2]. The group of silicates represents the materials of great amount and importance in the world. Vaijapurkar and Bhatnagar [2] studied sand proceeding from Rajasthan, India; it presented two TL peaks at 80ºC and 220 ºC. In this work the sand samples were tested as thermoluminescent dosimeters for gamma radiation and X-rays up to 20 Gy.

At the Calibration Laboratory of IPEN, Brazil, sand samples from different Brazilian beaches (Barra do Sahy Beach, São Paulo, Santinho Beach, Santa Catarina and Ponta Negra Beach, Rio Grande do Norte) have been tested for the possibility of use in gamma dosimetry with the thermoluninescent technique (TL) [3] and electronic paramagnetic resonance technique (EPR) [4]. The TL curves of these samples were obtained after an irradiation with gamma doses of 5 Gy up to 80kGy, and they presented two peaks at about 110ºC and 170ºC, approximately. The following dosimetric properties of sand samples were studied: reproducibility, batch uniformity, detection range and dose response; they presented satisfactory results for high-dose dosimetry. Two Descalvado sand samples were used in this work proceeding from São Paulo interior, one for glass industry (silicates and ceramic) and another for casting. The particular interest in sand samples is due to the fact that they present small size (when in pellets), good rigidity and easy handling, and they present possibility of use for high-dose dosimetry in the main radiation

processes of disinfection, sterilization, pasteurization [5,6]. On the other hand, sand samples present the disadvantage of the initial fast thermal decay in the first twenty-four hours after irradiation. This effect can be avoided taking the measurements after the same interval of time after each irradiation, or by using special post-irradiation thermal treatments of the sand samples [7].

The objective of this work was to determine the thermoluminescent properties of sand samples with high purity, to compare them with sand samples proceeding from Brazilian beaches, and to verify the possibility of their use for high-dose dosimetry.

2. MATERIALS AND METHODS

Sand samples from Descalvado were acquired in the natural from at São Paulo State, Brazil, for the present work. Two types of sand are manufactured: one for the glass industry and another for the casting market. Sand samples for the glass industry present steady physical and chemical characteristics, in compliance with the requirements in the area for the manufacture of glasses, silicates and ceramics.

Samples for the casting market are produced by special equipment that confers steady physical characteristics to the end items, surpassing the very demanding specifications of the casting market and presented in different grain sizes. These sand samples were called in this work DSG (**D**escalvado **S**and for **G**lass industry) and DSC (**D**escalvado **S**and for **C**asting), respectively.

Sand samples were bolted, and grains were obtained with diameter between 0.180 mm and 0.075mm. The organic impurities of the sand samples were eliminated by washing them with a cloridric acid solution 1N (1 molar); after that, distilled water was used to remove the HCl [2]. The sand samples were dried using an electric oven, Formitex, with variation of 5ºC, at 150ºC/50 min. The magnetic particles (mainly iron) were removed from the sand samples using a magnetic separator S.G. Frantz Com. Ind. - Isodynamic, model.L-1. For easy handling, sintered sand pellets were prepared at the Laboratory for Production of Dosimetric Materials, IPEN, using as binder, PVA (Poliacetato of vinila [-$CH_2CH(O_2CCH_3)$-n], Teflon). The sand pellets were made using a Schulz press with maximum pressure of 15.0 ton/cm^2, and they were cold compacted. The matrix used for the confection of the sand pellets has a diameter of 7.0 mm, and the maximum pressure for the compacting process was 1.0 ton/cm^2. The sand pellets present diameter of 5.5 mm and a thickness less that 1.0 mm. The samples were packed in aluminum foils and in black plastic bags for the irradiations.

All irradiations were performed in air (room temperature) with doses between 50 Gy and 1 kGy, using a Panoramic Yoshizawa Kiko Co Ltd. System (^{60}Co), of the Center of Radiation Technology, IPEN, with an absorbed dose rate of 0.3346 kGy/h, at a distance of 40 cm (May/2005). The samples were fixed between 3 mm thick polymethyl melt-acrylate plates (Lucite), to guarantee the occurrence of electronic equilibrium during the irradiations. The thermal treatment for reutilization of the material was 300ºC for 1h [3].

The evaluation of the sintered sand pellets was carried out using a thermoluninescent reader (Harshaw Chemical Co., model 2000 A/B) with a heating rate of 10ºC/s. All TL measurements

were integrated between 50 and 300ºC. The glow curves were obtained using a PicoLog program (PLW32). All TL measurements were taken from the ambient temperature up to 300 ºC, using a constant flow of N_2 of 4 L/min. Due to the thermal fading of the TL response of the sand samples, all measurements in this work were taken exactly one hour after the irradiation.

3. RESULTS

The dosimetric properties were studied in this work for the verification of the possibility of use of sand pellets for high-dose dosimetry. Figures 1 and 2 show the thermoluminescent glow curves of the DSG and DSC sand pellets, irradiated with doses of 0.1kGy, 0.5 kGy and 1.0 kGy. The curves present two peaks: 80ºC and 220ºC for both sand samples. The first peak is not considered for dosimetry due to its fast fading nature.

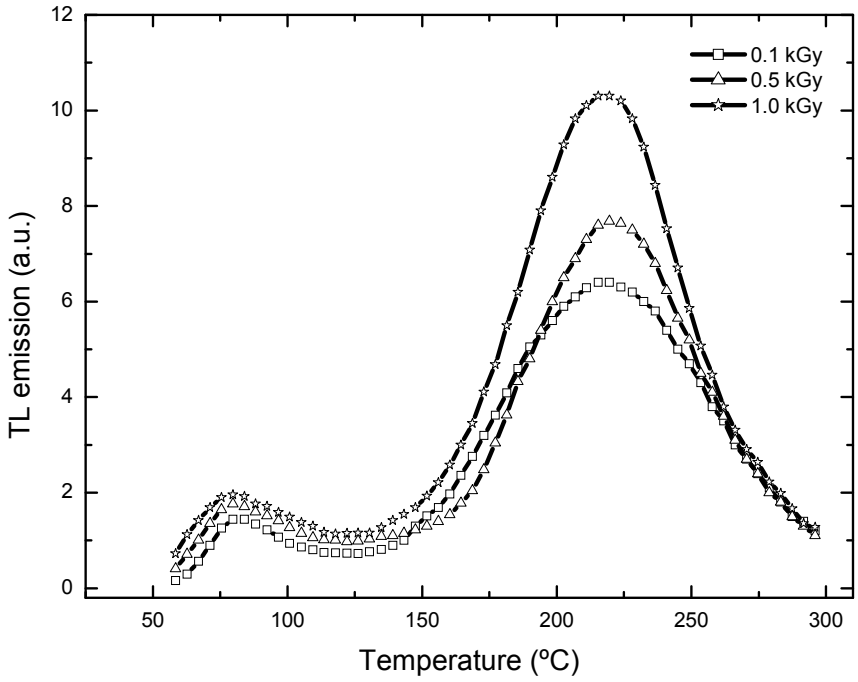

Figure 1. TL glow curve of the sintered DSG sand pellets irradiated with ^{60}Co.

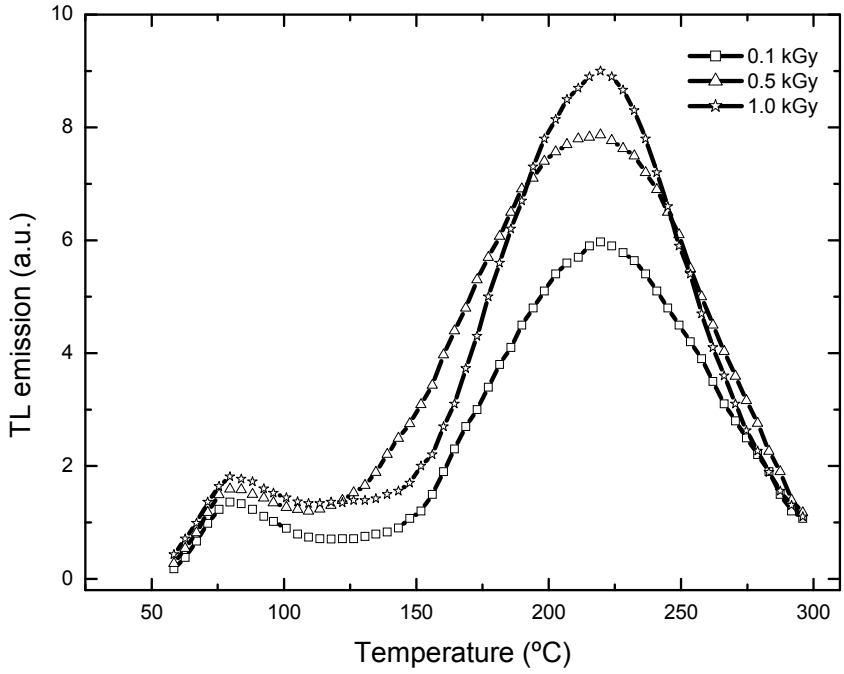

Figure 2. TL glow curve of the DSC sintered sand pellets irradiated with ^{60}Co.

Sand pellets were irradiated in ^{60}Co beams from 50 Gy to 1.0 kGy. Figure 3 presents the calibration curve of the two types of sand samples. It can be observed that the response to the absorbed dose increases conveniently for high-dose dosimetry for both sand samples. It is also possible to observe in Figure 3 that the TL response above 1.0 kGy tends to saturation in both cases. It must be taken into account that the sand samples present thermal decay at room temperature [3,7]. The results are exclusively for the studied sand samples, being necessary to obtain a calibration curve for each type of sand sample to be used. The maximum standard deviations of these measurements were 2.5% and 3.8% for DSG and DSC sand samples, respectively.

Five sets of both types of sand pellets were submitted five times to the same procedure of thermal treatments at 300ºC for 1h (defined for the reutilization), and irradiation (0.5kGy), in order to study their response reproducibility. The maximum standard deviations obtained were approximately 1.7% and 2.4% for DSG and DSC sand samples, respectively.

The lower detection limits were obtained taking three times the values of the standard deviation of ten measurements of three non-irradiated sand samples of each sand type, expressed in units of absorbed dose. Using the TL reader, the values of 0.5 Gy and 0.7 Gy were obtained for the DSG and DSC sand samples, respectively.

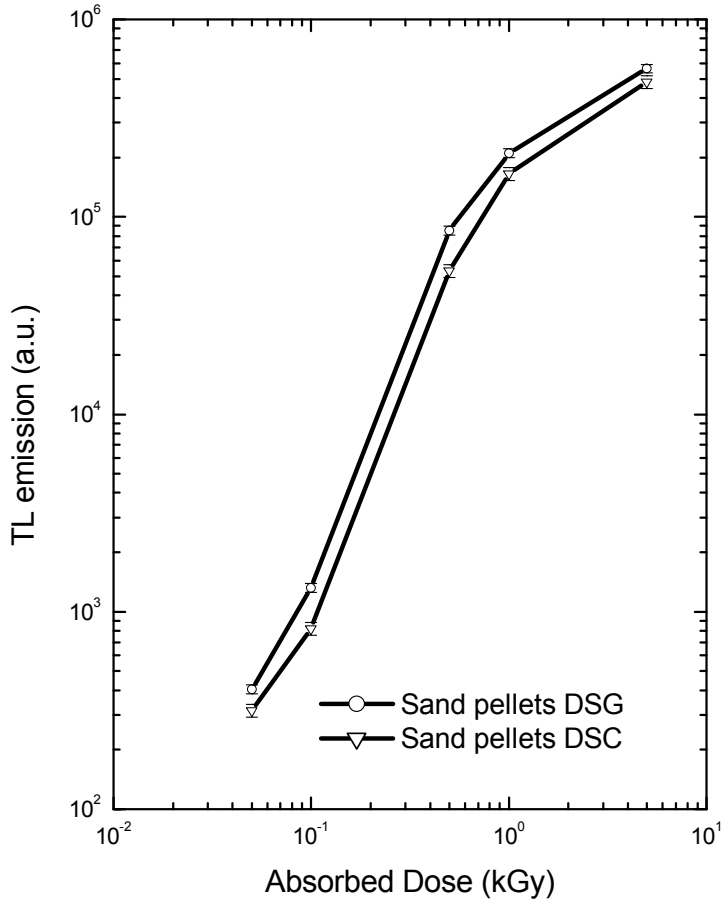

Figura 3. Calibration curves of sintered sand pellets (DSG and DSC) irradiated with ^{60}Co. Measurements were taken 1h after the irradiations

4. CONCLUSION

The main dosimetric properties (possibility of reutilization, response reproducibility, absorbed dose response, lower detection limits), studied in this work, show that the Descalvado sand samples can be used for high-dose dosimetry, taking into account their thermal decay at room temperature. The advantages of the use of this kind of samples for high-dose dosimetry are their very low cost and easy handling. The calibration curves obtained show that these sand samples can be used for different application areas of radiation dosimetry, between 1.0 Gy and 5.0 kGy (pasteurization, processes of water purification, sterilization and desinfestation of products, among others).

ACKNOWLEDGEMENTS

The authors thank Mr. Manoel Jacomo Bonilha Cordova, of the Mineração Jundú Ltda., Descalvado, São Paulo, Brazil, for providing the sand samples, and to Dr. L.C. Campos for the pellets preparation, and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil, for partial financial support.

REFERENCES

1. Vaijapurkar, S.G., Raman, R., Bhatnagar, P.K. "Sand-a high gamma dose thermoluminescence dosimeter". *Radiat. Meas*., **29 (2)**, p. 223-226 (1998).

2. Vaijapurkar, S.G., Bhatnagar, P.K. "Low cost thermoluminescence (TL) gamma dosimeter for radiotherapy". *Nucl.Tracks Radiat.Measur*., **21 (2)**, p. 267-269 (1993).

3. Teixeira, M.I., Caldas, L.V.E. "Sintered sand pellets for high-dose dosimetry". *Nucl. Inst. Meth. Phys. Rer. B*, **218**, p.194-197 (2004).

4. Teixeira, M.I., Ferraz, G.M., Caldas, L.V.E. "Sand for high-dose dosimeter using the EPR technique". *Appl.Radiat.Isot*., **62**, p.359-363 (2005).

5. Farrar,H. "Dosimetry standards for radiation processing". *Proceedings of Symposium Techniques for High Dose Dosimetry in Industry, Agriculture and Medicine*, Vienna, November, *IEA-TEC DOC–1070*, 307-11 (1998).

6. McLaughlin, W.L., BOYD, A.W., Chadwick, K.H., McDonald, J.C., Miller, A. *Dosimetry for radiation processing.* Taylor & Francis Ltd., London, ISBN 0-85066-740-2 (1998).

7. Caldas, L.V.E., Teixeira, M.I., Ferraz, G.M. "Influence of Thermal Treatments on the Response of Sand Radiation Detectors for High Dose Dosimetry". *Radiat. Prot. Dosim.* **10**, in press, (2006).