

# Performance of thermoluminescent materials for high dose dosimetry

Maria Inês Teixeira<sup>a,c\*</sup>, Sonia G. P. Cecatti<sup>a,b</sup> and Linda V. E. Caldas<sup>a</sup>

<sup>a</sup> Instituto de Pesquisas Energéticas e Nucleares, IPEN-CNEN/SP, Av. Prof. Lineu Prestes 2242, 05508-000, São Paulo, SP, Brazil.

<sup>b</sup> Fundacentro, Ministério do Trabalho, Rua Capote Valente 710, 05422-970, São Paulo, SP, Brazil.

<sup>c</sup> Associação Educacional Nove de Julho S/C – UNINOVE/SP, Rua Vergueiro 235, 04272-300, São Paulo, SP, Brazil.

**Abstract.** Cases involving high-doses of ionizing radiation are becoming increasingly common. The objective of this work was to characterize thermoluminescent materials for the dosimetry of workers exposed to high doses. Samples of TLD-200, TLD-400 and TLD-800 pellets from Thermo Electron Corporation were studied in gamma high-doses. Dose-response curves were obtained for doses between 100 mGy and 100 Gy. The reproducibility, the lower detection limits and dose-response curves were obtained for all three materials. The different kinds of detectors show usefulness for dosimetry of workers exposed accidentally to high doses.

**KEYWORDS:** *High dose dosimetry, thermoluminescent dosimetry, gamma radiation.*

## 1. Introduction

The process of irradiation by high doses presents several advantages such as sterilization of medical and pharmaceutical products, food and flower preservation, treatment of electrical cables and treatment of different materials [1].

Radiological accidents may be characterized by uncontrolled release of large quantities of radioactive material, involving exposure or contamination of humans or environment, and causing serious injuries or death.

Accidents involving humans may occur due to external irradiation, contamination or a combination of these both procedures. These kinds of accidents may occur in radiological installations, hospitals, industries and due to failure in the radioactive material transport system, caused for instance by a damaged packaging.

At the Calibration Laboratory of IPEN, glass samples [2], sand samples from different Brazilian beaches [3], Descalvado sand samples [4] have already been tested for the possibility of their use in gamma high-dose dosimetry, with the techniques of thermoluminescence (TL) and electronic paramagnetic resonance (EPR).

The thermoluminescent properties of calcium sulphate, doped with Thulium or Copper, prepared according to Kása et al. [5] method were studied in the dose range of 0.5 Gy to 125.0 kGy. This material seems to present an excellent dose response, simple glow curve and a dose linearity from 1 $\mu$ Gy to 2 kGy.

Velbeck et al.[6] studied the dosimetric properties of Harshaw TLD-700H (7LiF:Mg,Cu,P) pellets. This material has an useable linear dose range up to 20 Gy and linearity at much higher doses than the LiF:Mg,Ti material.

---

\* Presenting author, e-mail: miteixei@ipen.br

The objective of the present paper was to study samples of TLD-200, TLD-400 and TLD-800 from Thermo Electron Corporation for dosimetry of workers exposed accidentally to gamma high doses.

## 2. Materials and Methods

This study was performed using CaF<sub>2</sub>: Dy (TLD-200), CaF<sub>2</sub>: Mn (TLD-400) and Li<sub>2</sub>B<sub>4</sub>O<sub>7</sub>: Mn (TLD-800) from Thermo Electron Corporation (Table 1). These samples were in the dimensions of 3.2 x 3.2 x 0.89 mm<sup>3</sup>, each one with a mean mass of 0.220g. For the establishment of the dosimetric characteristics, these thermoluminescent dosimeters were exposed to a gamma source, using a Panoramic Yoshizawa Kiko Do Ltd. System (<sup>60</sup>Co) of the Center for Radiation Tecnology, IPEN. The TL detectors were irradiated at the distances of 10 and 40 cm from the source in the dose interval of 0.1 Gy to 100 Gy.

Thermal treatments during 1 hour at 400 °C were applied to the TLD-200 and TLD-400 samples and 1 hour at 300 °C to the TLD-800 samples for reutilization. Due to the thermal fading the sample were treated during 15 minutes at 115 °C after gamma irradiation.

The TL evaluation of the detector samples was realized by using a Harshaw Chem. Co. thermoluminescence reader, model 2000 A/B (heating rate of 10 °C/s).

**Table 1:** Characteristics of the TL materials.

TL Detector	Material	Effective Atomic Number
TLD-200	CaF <sub>2</sub> : Dy	16.3
TLD-400	CaF <sub>2</sub> : Mn	16.3
TLD-800	Li <sub>2</sub> B <sub>4</sub> O <sub>7</sub> : Mn	7.4

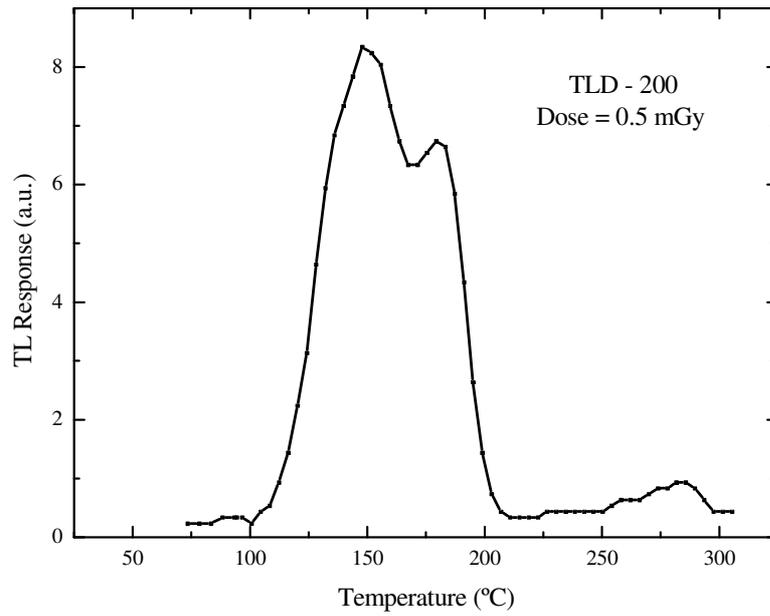
## 3. Results

The main dosimetric properties of TL detectors studied in this work were reproducibility, lower detection limits and dose-response curves.

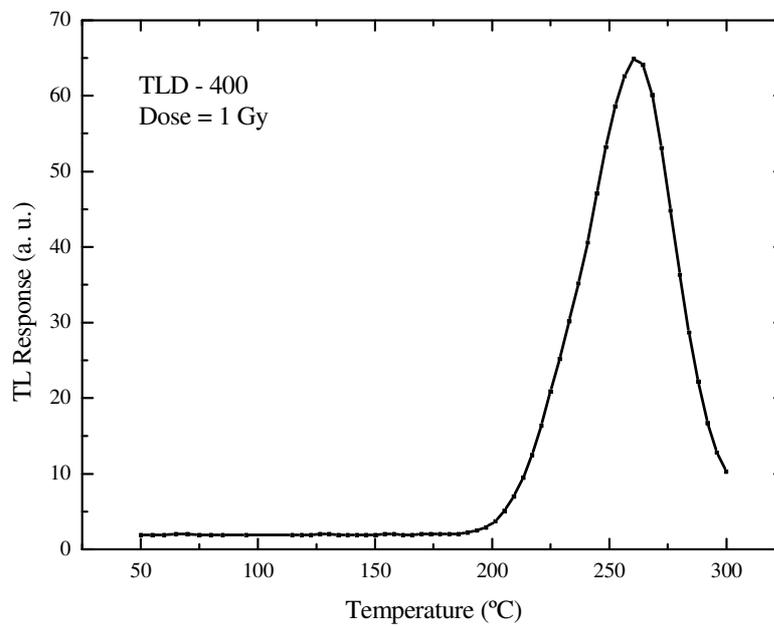
### 3.1 Glow Curve

Figures 1, 2 and 3 show the thermoluminescent glow curves of TLD-200, TLD-400 and TLD-800 samples, irradiated with 0.5 Gy, 1 Gy and 10 Gy of <sup>60</sup>Co, respectively.

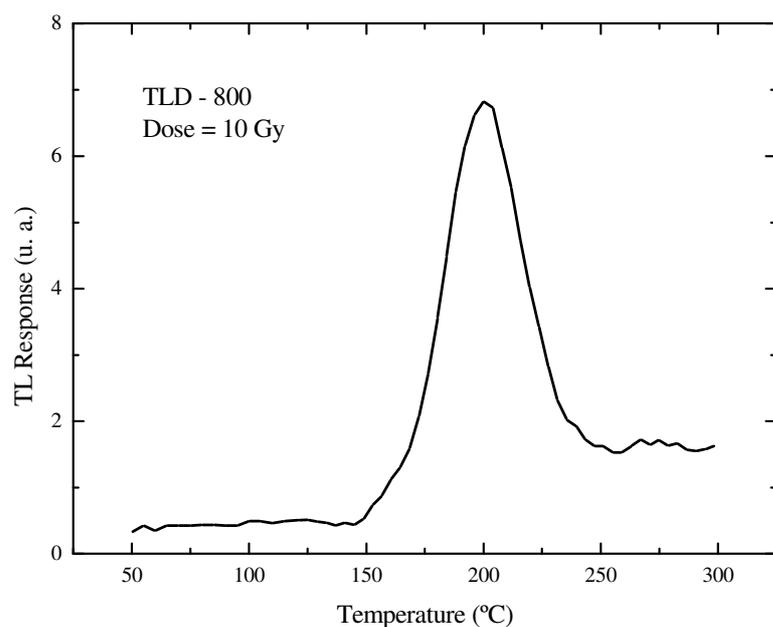
The curves present dosimetric peaks at 180, 260 and 200 °C, for the TLD-200, TLD-400 and TLD-800 samples, respectively.



**Figure 1:** TL glow curve of a TLD-200 pellet, irradiated with 0.5 mGy of  $^{60}\text{Co}$ .



**Figure 2:** TL glow curve of a TLD-400 pellet, irradiated with 1 Gy of  $^{60}\text{Co}$ .



**Figure 3:** TL glow curve of a TLD-800 pellet, irradiated with 10 Gy of  $^{60}\text{Co}$ .

### 3.2 Reproducibility

The reproducibility of the TL response of the three materials was obtained by their TL evaluation for each dosimeter type after successive procedures of standard thermal treatments and irradiation with the  $^{60}\text{Co}$  source. The individual reproducibility (coefficient of variation) obtained for the TL detectors irradiated with 3 Gy ( $^{60}\text{Co}$ ) are presented in Table 2.

**Table 2:** Reproducibility of TL response.

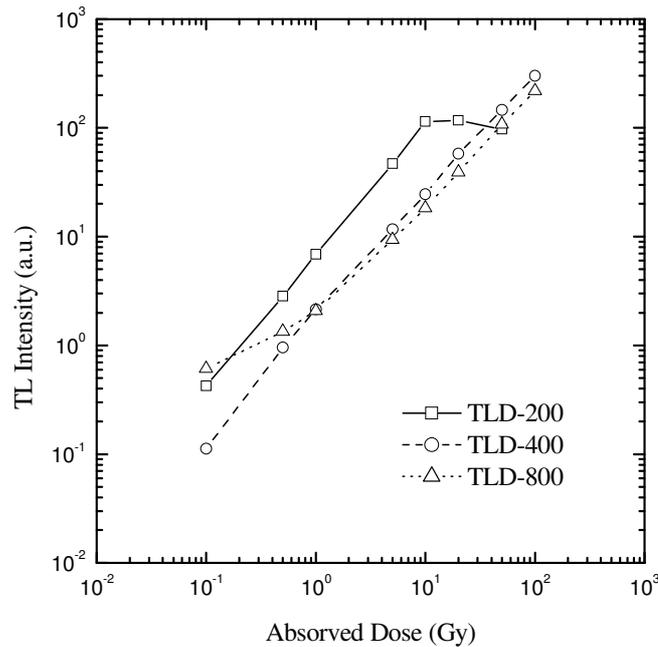
<b>TL Detector</b>	<b>Coefficient of variation (%)</b>
TLD-200	2.15
TLD-400	3.14
TLD-800	3.34

### 3.3 Lower detection limits

Taking three times the standard deviation of 10 measurements of 6 not irradiated detectors of the three materials, TLD-200, TLD-400 and TLD-800 samples, expressed in terms of absorbed dose, it was possible to obtain the following results of 0.1 mGy, 0.15 mGy and 1.0 mGy respectively.

### 3.4 Dose-Response Curve

The TL dose-response curves of the detectors were obtained as a function of the absorbed doses of gamma radiation ( $^{60}\text{Co}$ ) from 0.1 Gy to 100 Gy (Figure 4). The maximum standard deviation for these data was 2.3%. TLD-200 samples presented the highest TL sensitivity of all three kinds of TL detectors. The TL response of TLD-400 and TLD-800 samples present linearity between 1 Gy and 100 Gy, but TLD-200 samples present a supralinear response from 100 mGy up to 10 Gy and then saturation.



**Figure 4:** Dose response curves of TLD-200, TLD-400 and TLD-800 pellets to gamma radiation ( $^{60}\text{Co}$ ). The maximum standard deviation was 2.3%.

### 4. Conclusion

All three TL materials presented usefulness for high-dose dosimetry. The TL glow curves presented the same dosimetric peaks at known temperatures from literature. The lower detection limits were 0.1 mGy, 0.15 mGy and 1 mGy for TLD-200, TLD-400 and TLD-800 respectively. The dose-response curves showed the usefulness of the materials for high gamma doses up to 10 Gy (TLD-200) and 100 Gy (TLD-400 and TLD-800).

### Acknowledgements

The authors acknowledge Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil, for partial financial support.

## REFERENCES

- [1] MCLAUGHLIN, W.L., BOYD, A.W., CHADWICK, K.H., MCDONALD, J.C., MILLER, A., Dosimetry for Radiation Processing. Taylor & Francis, London ISBN 0-85066-740-2 (1989).
- [2] TEIXEIRA, M.I., FERRAZ, G.M., CALDAS, L.V.E., Thermal treatments to minimize fading effects of colored glasses radiation detectors. Nucl.Instrum.Meth. Res. B 263, 67-71, 2007.
- [3] CALDAS, L.V.E., TEIXEIRA, M.I., FERRAZ, G.M., Influence of thermal treatments on the response of sand radiation detectors for high-doss dosimetry. Radiat. Prot. Dosim. v.120, 230-234, 2006.
- [4] TEIXEIRA, M. I., CALDAS, L. V. E. Thermoluminescent dosimetric properties of Descalvado sand. In: First American IRPA Congress, 2006, Acapulco. Proceedings of the First American IRPA Congress, 2006.
- [5] KÁSA, I. CHOBOLA, R., MEILL, P., SZAKÁCS, S., KERÉKES, A. Preparation and investigation of thermoluminescence properties of  $\text{CaSO}_4:\text{Tm,Cu}$ . Radiat. Prot. Dosim. v.123, n.1, 32-35, 2007.
- [6] VELBECK, K.J., LUO, L.Z., RAMLO, M.J., ROTUNDA, J.E. The dose-response of Harshaw TLD700H, Radiat. Prot. Dosim. v.119, 255-258, 2006.