PERFORMANCE TESTS FOR CHARACTERIZATION OF REUTILIZED DOSIMETRIC MATERIAL OF DISPOSABLE EXTREMITY DOSIMETERS

Daniela P. Groppo, *Patrícia L. Antonio and Linda V. E. Caldas*

Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, IPEN – CNEN/SP, São Paulo, Brazil, dpgroppo@ipen.br

Abstract: The extremity dosimeters tested in this work were designed as disposable thermoluminescent dosimeters. The main purpose of this study was the characterization of the reutilized dosimetric material from these extremity dosimeters. Parameters as reproducibility, lower detection limit, dose-response curve and energy dependence were obtained. The satisfactory results show the potential use of this reutilized material.

Key words: radiation dosimetry, extremity dosimeters, thermoluminescence.

1. INTRODUCTION

Thermoluminescent dosimetry is typically recognized as the most versatile technique for the quantitative measurements of X, gamma and beta radiations, specially in individual monitoring.

One of the most important characteristics of thermoluminescent (TL) materials is that they may be reused several times without significant change of their dosimetric properties [1].

The utilization of thermoluminescent dosimeters (TLDs) requires their characterization. Reproducibility, lower detection limit, dose-response curve and energy dependence are very important parameters for radiation dosimetry.

The extremity dosimeters studied in this work were manufactured as disposable thermoluminescent dosimeters. The dosimeters were inside of metal holders; however, for this study they were removed as single pellets.

Small and thin dosimeters are very useful for beta dosimetry, because beta radiation is easily absorbed, and its intensity presents high dependence with the source-detector distance.

Previous studies reported on the performance of various types of TL materials in beta radiation beams [2].

Lithium borate dosimeters may be acquired commercially in several forms, as powder, pellets and chips. They may present different dopants: Mn; Mn,Si; Cu; and Cu,Ag. The main dosimetric peak of $Li_2B_4O_7$ with different dopants occurs in the temperature range of 200ºC to 250ºC. Lithium tetra-borate, doped by manganese, was prepared in 1967 by Schulman et al. [3], when they were investigating thermoluminescent materials with tissue equivalence. Another important parameter is the energy independence; lithium borate presents very low dependence on the photon energy [4].

The objective of this work was to study $Li_2B_4O_7$:Mn pellets adapted from disposable extremity dosimeters in relation to their main characteristics in standard beta radiation beams.

2. MATERIALS AND METHODS

The detectors were selected at random of a large amount of samples. The dosimeters were removed from the original holders and identified one by one. Some pellets can be seen in Figure 1.

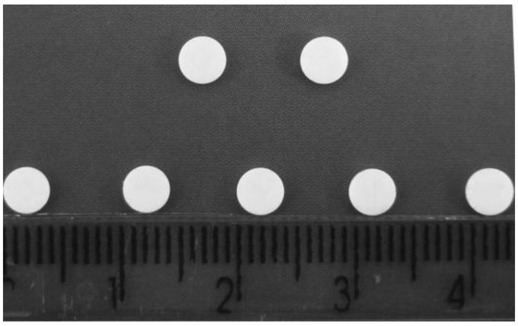

Fig. 1. $Li_2B_4O_7$:Mn dosimeters pellets in relation to a rule scale (cm).

For the reproducibility test, the pellets were exposed to a $^{90}Sr+^{90}Y$ standard source, Buchler GmbH & Co., model BSS1, Germany.

For the irradiations, sixteen pellets were positioned on a polymethylmethacrylate (PMMA) holder (110mm x 110mm x 25mm), as shown in Figure 2.

The reproducibility test consisted of a series of TL measurements after a reproducible procedure: thermal treatment of 400ºC during 1 hour and irradiation of the pellets at a distance of 110mm from the beta radiation source, with a dose of 1 Gy.

The TL measurements were performed immediately after each irradiation, using the Harshaw TLD reader, model 3500, with a linear heating rate of 10ºC.s^{-1} and a constant flux of N_2 of 5.0 $l.min^{-1}$. The light emission was integrated in the temperature interval between 50ºC and 350ºC. After the measurements, the pellets were thermally treated at 400ºC during 1 hour, for subsequent utilization.

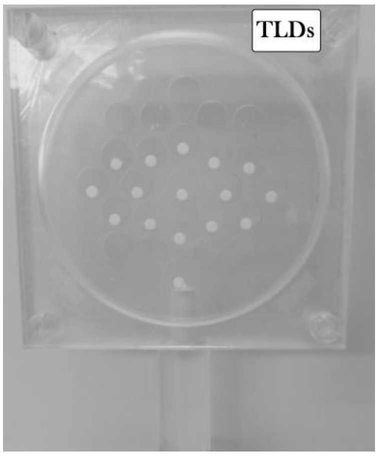

Fig. 2. Irradiation holder of the TL dosimeters.

The characteristics of the beta sources of the BSS1 and BSS2 systems, utilized in all tests, are shown in Table 1.

The dose-response curve was obtained by irradiating the TL samples with a $^{90}Sr+^{90}Y$ source (BSS1 system) with various absorbed doses: 0.1, 0.2, 0.5, 1.0, 4.0, 10.0 and 20.0 mGy. This test was undertaken at the distance of 500 mm from the source.

In another experiment, the TL detectors were exposed to doses of beta radiation: 5 mGy for $^{90}Sr+^{90}Y$ source, 15 mGy for ^{85}Kr source and 50 mGy for ^{147}Pm source, in order to obtain their calibration factors and to study the energy dependence of their response. In this case the BSS2 secondary standard system was utilized.

Table 1. Characteristics of the beta radiation sources

Source		Reference date	Nominal activity	Mean beta energy	Source-detector distance	Absorbed dose rate in air
			(MBq)	(MeV)	(mm)	($\mu Gy.s^{-1}$)
BSS1	$^{90}Sr+^{90}Y$	04/12/1981	1580	0.80	110	518.4±5.2
					500	25,2±0.2
BSS2	^{147}Pm	19/11/2004	3700	0.06	200	2.35±0.05
	^{85}Kr	30/11/2004	3700	0.14	300	39.70±0.50
	$^{90}Sr+^{90}Y$	08/12/2004	460	0.80	300	16.46±0.22

The results were normalized to those obtained with the $^{90}Sr+^{90}Y$ source and divided by each absorbed dose. The exposure of the detectors to $^{90}Sr+^{90}Y$ and ^{85}Kr sources was at the distance of 300 mm. The ^{147}Pm source was positioned at a distance of 200 mm.

The sources of both BSS1 and BSS2 systems were calibrated at the primary standard laboratory, Physikalisch-Technishe Bundesanstalt (PTB), Germany.

Before and after each set of dosimeter readings, the internal light source was measured ten times, to assure control of the adequate reader behavior. The TL value of non-irradiated samples was subtracted from the readings.

3. RESULTS

The main dosimetric characteristics are presented.

3.1. Glow curve

The thermoluminescent glow curve of the dosimetric material is shown in Figure 3. The curve presents a main dosimetric peak at 200ºC, approximately.

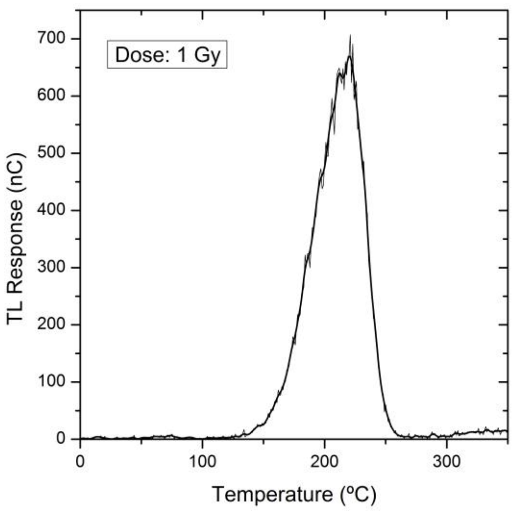

Fig. 3. TL glow curve of a $Li_2B_4O_7$:Mn pellet irradiated with 1 Gy of $^{90}Sr+^{90}Y$ (BSS1).

3.2. Reproducibility

The pellets were submitted five times to the same procedure of thermal treatment at 400ºC for 1h, irradiation (1 Gy) and TL measurement, in order to determine the response reproducibility. The relative standard deviation obtained was 3.6%, and the associated uncertainty was equal to 5.5%.

3.3. Lower detection limit

By measuring the TL response of non-irradiated samples, it was possible to obtain the lower detection limit: 0.551 mGy.

3.4. Dose-response curve

The TL samples were irradiated with various absorbed doses in air in the interval between 0.1mGy and 20mGy. A linear behavior may be observed from 1mGy up to 20mGy (Figure 4). The relative standard deviation of the responses was 9.8%. The associated uncertainty was 8.4%. These detectors present a good interval of response linearity.

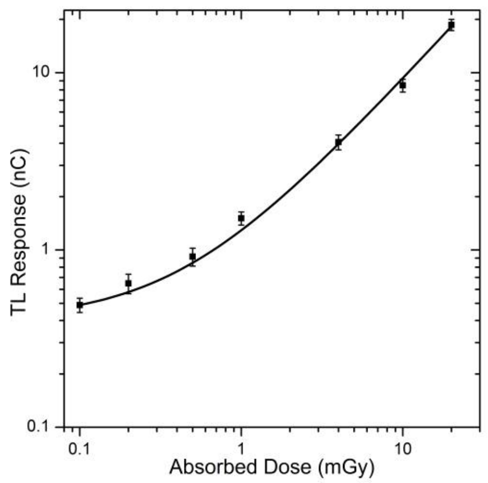

Fig. 4. TL dose-response curve of the detectors exposed to ^{90}Sr+^{90}Y system.

3.5. Calibration Factor and Energy dependence

For the determination of calibration factors and the energy dependence curve, the pellets were irradiated with ^{147}Pm, ^{85}Kr and ^{90}Sr+^{90}Y sources. The calibration factors obtained for different beta sources are shown in Table 2. The TL response is shown in Figure 5 in relation to the beta mean energy. The relative standard deviations of the ^{147}Pm, ^{85}Kr and ^{90}Sr+^{90}Y responses were 9.3%, 9.3% and 6.3%, respectively.

The dosimeters present a high energy dependence. The ideal dosimetric material should preferentially show a low energy dependence, but in the case of beta radiation only a few studies have been conducted; therefore, the knowledge of their energy dependence properties allows the determination of correction factors and their application in beta radiation dosimetry [5].

Table 2. Calibration Factor of the detectors exposed to beta radiation sources (BSS2)

Beta source	Beta mean energy (MeV)	Calibration factor (nC / mGy)	Associated uncertainty (%)
^{147}Pm	0.06	0.568	6.1
^{85}Kr	0.14	0.859	6.2
^{90}Sr+^{90}Y	0.80	4.536	5.8

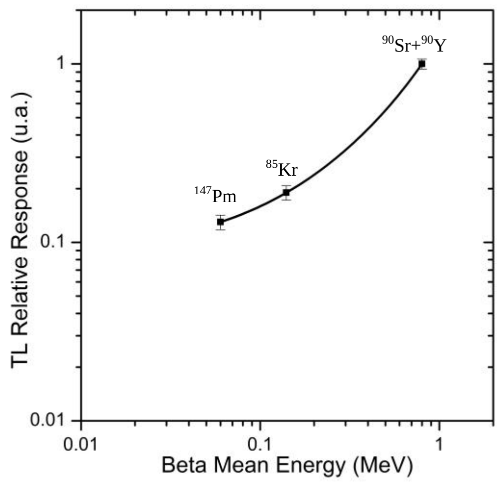

Fig 5. Energy dependence of the detectors exposed to beta radiation sources (BSS2 system).

4. CONCLUSION

The tests performed in this work are necessary for the characterization of the thermoluminescent dosimetric material. The results obtained were satisfactory.

The results show the possibility of the reutilization of the dosimetric material from disposable extremity dosimeters for individual monitoring of workers exposed to beta radiation.

ACKNOWLEDGMENTS

The authors are grateful for partial financial support from the Brazilian agencies: FAPESP, CNPq and CAPES, and Ministry of Science and Technology (Project INCT for Radiation Metrology in Medicine), Brazil.

REFERENCES

[1] L. L. Campos, "*Thermoluminescence of Materials and its Application in Radiation Dosimetry"*, Cerâmica, v. 44, n. 290, pp 244-251, 1998.

[2] M. L. Oliveira and L. V. E. Caldas, "*Performance of Different Thermoluminescence Dosimeters in ^{90}Sr+^{90}Y Radiation Fields*", Radiation Protection Dosimetry, v.111, pp 17-20, 2004.

[3] J. H. Schulman, R. D. Kirk and E. J. West, "*Luminescence dosimetry"*, Proceedings of the International Conference on Luminescence Dosimetry, pp 113-118, California, 1967.

[4] J. R. Cameron, N. Suntharalingam and G. N. Kenney, *Thermoluminescent Dosimetry*, The Colonial Press, London, 1968.

[5] S. W. S. McKeever, M. Moscovitch, P. D. Townsend, *Thermoluminescence Dosimetry Materials: Properties and Uses*, Nuclear Technology Publishing, Ashford, 1995.