ENERGY AND ANGULAR DEPENDENCE OF THERMOLUMINESCENT MATERIALS TO BETA MONITORING*

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Abstract **Energy and angular dependences of different thermoluminescent materials were studied with the objective to verify which type of detector would be the most appropriate for beta monitoring of workers. Three types of $CaSO_4$:Dy + teflon pellets were studied. The energy dependence was evaluated using standard beta radiation sources (^{147}Pm, ^{204}Tl and ^{90}Sr + ^{90}Y). For the angular dependence study, the pellets were exposed to beta radiation of the ^{90}Sr + ^{90}Y source, varying the incidence angle between 0° and 90°. In relation to the studied characteristics, the $CaSO_4$:Dy + 10% C dosimeters were the most adequate for use in beta monitoring of workers.**

Key words: Thermoluminescent dosimetry; Beta radiation; Angular dependence; Energy dependence.

Resumo *Dependência energética e angular de materiais termoluminescentes para monitoração beta.*
As dependências energética e angular de diferentes materiais termoluminescentes foram estudadas com o objetivo de verificar que tipo de detector seria o mais adequado para a monitoração de trabalhadores envolvidos com a radiação beta. Três tipos de pastilhas de $CaSO_4$:Dy + teflon foram estudados. A dependência energética foi verificada usando-se fontes padrões de radiação beta (^{147}Pm, ^{204}Tl e ^{90}Sr + ^{90}Y). A dependência angular foi verificada irradiando-se as amostras com feixes de radiação beta, variando-se o ângulo de incidência entre 0° e 90°. Os dosímetros de $CaSO_4$:Dy + teflon + 10% C mostram-se os mais adequados para uso na monitoração de trabalhadores expostos à radiação beta, em relação às características estudadas.

Unitermos: Dosimetria termoluminescente; Radiação beta; Dependência angular; Dependência energética.

INTRODUCTION

The increasing use of (sealed and non-sealed) beta radiation sources in medicine, industry and research implies the necessity of a metrologically reliable dose measurement in workers exposed to this type of radiation.

The value of dose limits to be determined for occupational exposure in beta radiation fields is the equivalent dose on 1 cm² of the evaluated skin, independently from the radiation-exposed area. However, a new denomination is being internationally suggested for this value which would be denominated radiation weighted dose[(1)].

Beta particles with energies of approximately 60 keV may reach a 0.07 mm-depth in the tissue. A detector for radiation beta monitoring must be able to evaluate beta radiation dose with energies higher than 60 keV[(2)].

The determination of extremity doses usually is made by means of thermoluminescent detectors because of their small dimensions. For measuring the equivalent dose in the skin, the detector must be thin, in order to avoid a significant radiation attenuation [(3)]. However, the response in the majority of thermoluminescent dosimeters depends on the radiation energy and the irradiation geometry.

The present study objective was to analyze the energy and angular dependence of different thermoluminescent materials for an appropriate choice of the material to be employed in workers occupationally exposed to beta radiation.

MATERIALS AND METHODS

Three types of $CaSO_4$:Dy + teflon thermoluminescent dosimeters[(4–6)], produced by the Laboratory of Thermoluminescent Materials at Instituto de Pesquisas Energéticas e Nucleares (IPEN) were utilized for radiation detection. Table 1 presents the physical characteristics of the studied $CaSO_4$:Dy + teflon samples. These samples were submitted to a one-hour thermal treatment process at 300°C for reutilization purposes.

The beta radiation secondary standard system of IPEN Laboratory of Instruments Calibration, with Buchler GmbH & Co (Germany) ^{90}Sr+^{90}Y, ^{204}Tl and ^{147}Pm sources, was employed for irradiations (Table 2). These sources calibration is certified by the German primary-standard laboratory Physikalisch-Technische Bundesanstalt (PTB).

The detectors were irradiated in a 15 mm-thick polymethylmethacrylate phantom covered with a 1.20 mg.cm^{-2} superficial density plastic film.

The thermoluminescent reader system employed was the Harshaw Nuclear System 2000A/B model, at a linear heating rate of 10°C.s^{-1} and a 26 s reading cycle with a 4.0 l.min^{-1} N_2 constant flow. The three studied materials presented a dosimetric peak at 220°C. The area under the thermoluminescent curve was integrated into the interval between 140°C and 240°C.

RESULTS

The energy dependence of all the $CaSO_4$:Dy + teflon samples was analyzed by means of standard ^{90}Sr+^{90}Y (3.5 mGy),

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Table 1 $CaSO_4$:Dy + teflon samples physical characteristics.

Thermoluminescent material	Dimension		
	Mass (mg)	Diameter (mm)	Thickness (mm)
$CaSO_4$:Dy (50mg)	50	6.0	0.80
$CaSO_4$:Dy (20mg)	20	6.0	0.35
$CaSO_4$:Dy + 10% C	20	6.0	0.35

Table 2 Characteristics of beta radiation secondary standard system.

Radionuclide	^{147}Pm	^{204}Tl	^{90}Sr+^{90}Y	^{90}Sr+^{90}Y
Nominal activity (MBq)	518	18.5	74	1,850
Mean beta radiation energy (MeV)	0.06	0.24	0.80	0.80
Absorbed dose to air rate (µGy.s^{-1})	0.366	0.412	1.707	518.4 70.6 25.23
Absorbed dose to tissue rate (µGy.s^{-1})	0.411	0.462	1.896	575.9 78.4 28.03
Calibration distance (cm)	20	30	30	11 30 50
Reference date	25/5/1990	9/6/1990	12/1/1981	4/2/1981

^{240}Tl (1.8 mGy) and ^{147}Pm (8.5 mGy) beta radiation sources. Thermoluminescent responses were normalized for the ^{90}Sr+^{90}Y radiation response. Additionally, the measures were normalized for a same absorbed dose (3.5 mGy).

Figure 1 shows the three $CaSO_4$:Dy detectors energy dependence. The results are presented in terms of thermoluminescent response/unit of beta dose in the tissue related to the ^{90}Sr+^{90}Y beta radiation.

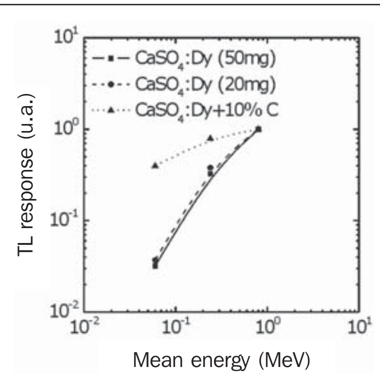

Figure 1. $CaSO_4$:Dy + teflon samples energy dependence for beta radiation.

The $CaSO_4$:Dy + teflon (50 mg) and $CaSO_4$:Dy + teflon (20 mg) samples presented practically the same high energy dependence, while the $CaSO_4$:Dy + teflon + 10% C samples presented a 60% energy dependence in the studied energy interval. The results compare to those obtained for $CaSO_4$:Tm (60 µm) and $CaSO_4$:Tm (70 µm) by Caldas[7], and for LiF (0.9 mm), LiF (0.4 mm), MgB_4O_7:Dy and LiF (Vinten), by Christensen and Prokié[8].

The angular dependence of the three types of $CaSO_4$:Dy + teflon dosimeters was analyzed for three different incidence angles between 0° and 90°, in ^{90}Sr + ^{90}Y (3.5 mGy) beta radiation fields. The Figure 2 presents the three detectors thermoluminescent response as a function of the radiation incidence angle.

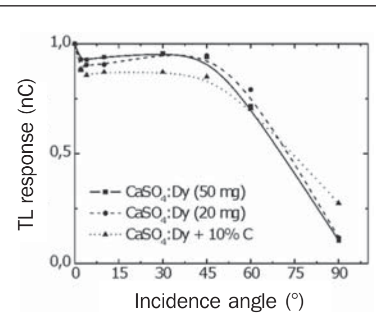

Figure 2. $CaSO_4$:Dy + teflon pellets angular dependence for beta radiation (^{90}Sr+^{90}Y).

The thermoluminescent response presented an accentuated angular dependence from 45° for all the types of materials included in the present study. This is the expected behavior for the majority of thermoluminescent dosimeters. The $CaSO_4$:Dy + 10% C pellets have shown more sensitivity than the other two materials.

CONCLUSION

Energy and angular dependence results obtained for different thermoluminescent dosimeters exposed to beta radiation emphasize the importance of utilizing thin detectors for determination of the beta radiation dose in the skin.

$CaSO_4$:Dy + 10% C pellets have presented better energy and angular dependence results for beta radiation monitoring.

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