

Energy dependence of OSL detectors in standard beta radiation beams

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Abstract. Sometimes it is necessary to measure the absorbed doses at extremities (hands) due to beta radiation. The optically stimulated luminescence technique has become a successful dosimetry method in the past ten years. For beta radiation dosimetry, the $\text{Al}_2\text{O}_3:\text{C}$ detectors present energy dependence. The aim of this work was to investigate the energy dependence to beta radiation of $\text{Al}_2\text{O}_3:\text{C}$ detectors when filters are utilized. Different thicknesses of aluminized polyethylene terephthalate polyester film (Mylar) filters were used. The beta radiation attenuation in Mylar filters was determined.

1. Introduction

There are special radiation situations, with occurrence of superficial exposure, e.g. workers handling beta sources. In this case, it is necessary to measure the absorbed dose of extremities (hands) due to beta radiation [1]. The doses of beta radiation that workers are exposed to during their working hours are mostly not reflected adequately with the dosimeters used up to now [2]. Beta dosimetry presents difficulties. According to ICRP [3-4], the measurements should be taken at 0.07 mm depth, demanding thin dosimeters [5].

In Brazil, the occupational dosimetry has been performed using photographic and thermoluminescence (TL) techniques. However, the optically stimulated luminescence (OSL) technique has become a successful dosimetry method in other countries [6]. The OSL technique has advantages over TL: it requires no heating of the sample, the sample can be read several times, and OSL measurements are relatively cheaper than TL measurements [7].

The $\text{Al}_2\text{O}_3:\text{C}$ detector has become the main OSL material and a successful personal dosimeter [8]; some authors [5] consider that a extremity dosimeter based on OSL readout of aluminium oxide shows great promise for improving the capabilities of extremity dosimeters. However, for beta radiation dosimetry, the $\text{Al}_2\text{O}_3:\text{C}$ detectors present a very high energy dependence without the use of filters [9-10].

The aim of this work was to investigate the energy dependence to beta radiation of $\text{Al}_2\text{O}_3:\text{C}$ when filters are used with the detectors. Different superficial densities of aluminized polyester film (Mylar) filters were used.

2. Material and methods

The beta irradiations of the OSL detectors were performed using the beta secondary standard system of the Calibration Laboratory at IPEN, with $^{90}\text{Sr} + ^{90}\text{Y}$, ^{85}Kr and ^{147}Pm sources, manufactured by AEA Technology, Germany, model B1 S/N 233 and calibrated by the primary standard laboratory, Physikalisch - Technische Bundesanstalt (PTB), Germany. The radiation source characteristics can be seen at Table 1.

Table 1: Characteristics of the secondary standard system of beta radiation, AEA Technology, model B1 S/N 233, sources calibrated at PTB

Source	¹⁴⁷ Pm	⁸⁵ Kr	⁹⁰ Sr+ ⁹⁰ Y
Nominal activity (MBq)	3700	3700	460
Beta mean energy (MeV)	0.06	0.25	0.80
Absorbed dose rate in air ($\mu\text{Gy}\cdot\text{s}^{-1}$)	2.35 \pm 0.05	39.7 \pm 0.5	16.46 \pm 0.22
Calibration distance (cm)	20	30	30
Reference date	19/11/2004	30/11/2004	08/12/2004

The measurements were obtained using OSL dosimeters of Al₂O₃:C evaluated with the Landauer microStar reader and software. This detector is a layer of Al₂O₃:C sandwiched between two layers of polyester for a total thickness of 0.3 mm and diameter of 0.7 mm [11].

For the irradiations, each detector was positioned on a polymethylmethacrylate (PMMA) phantom (120 mm x 120 mm x 15 mm) and covered with aluminized polyethylene terephthalate polyester film (Mylar) filters with superficial densities of 1.27 mg.cm⁻², 1.72 mg.cm⁻², 2.54 mg.cm⁻², 3.81 mg.cm⁻², 5.08 mg.cm⁻², 5.18 mg.cm⁻² and 6.35 mg.cm⁻².

The dosimeters were irradiated at the phantom surface-source distance of 30 cm in the cases of ⁹⁰Sr + ⁹⁰Y and ⁸⁵Kr, and at 20 cm in the case of ¹⁴⁷Pm, because the absorbed dose rates were determined at those distances by the PTB laboratory.

The measurements were always taken immediately after irradiation. The detectors were optically treated at 26 x 10³ lux during one hour prior to each reutilization. A Delta OHM radiometer, model D09721, LUX LP 9021PHOT sensor, was utilized for the light level determination [12].

3. Results

The OSL dosimeters were exposed to a dose of 2 mGy of beta radiation of ⁹⁰Sr + ⁹⁰Y, 10 mGy of ⁸⁵Kr, and 25 mGy of ¹⁴⁷Pm. Due to the low radiation energy, in the case of the ¹⁴⁷Pm source, the absorbed dose rate was corrected for the environmental standard conditions of 20°C, 101.3 kPa and 50% relative humidity.

Ten measurements were taken for each detector, and the results are presented using the average readouts and standard deviations (1 σ) as error bars. The results were normalized to the zero superficial density and to the ⁹⁰Sr + ⁹⁰Y mean energy, and divided by the absorbed doses (Table 2). Figure 1 shows the results for four different superficial densities of Mylar filters. A very strong energy dependence can be observed.

Table 2 - Energy dependence of OSL response of Al₂O₃:C dosimeters covered with Mylar filters of different superficial densities to beta radiation

Beta mean energy (MeV)	Superficial density (mg/cm ²)					
	0	1.27	2.54	3.81	5.08	6.35
0.060	0.0071	0.0057	0.0063	0.0048	0.0059	0.0046
0.240	0.3697	0.3609	0.3509	0.3311	0.3237	0.3119
0.800	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

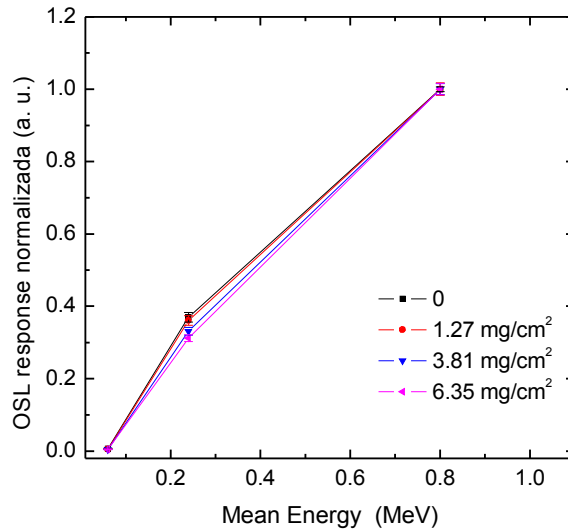


Figure 1 - Energy dependence of OSL response of $\text{Al}_2\text{O}_3:\text{C}$ dosimeters covered with Mylar filters of different superficial densities to beta radiation

The beta radiation attenuation was determined after the irradiation of the OSL dosimeters exposed to doses of 2 mGy of $^{90}\text{Sr} + ^{90}\text{Y}$, 10 mGy of ^{85}Kr , and 25 mGy of ^{147}Pm . Ten measurements were taken and the results are presented using the average readouts and standard deviations (1σ) as error bars. The results were normalized to the $^{90}\text{Sr} + ^{90}\text{Y}$ mean energy and divided by the absorbed doses (Figure 2). Strong attenuation curves can be observed for ^{85}Kr and ^{147}Pm sources.

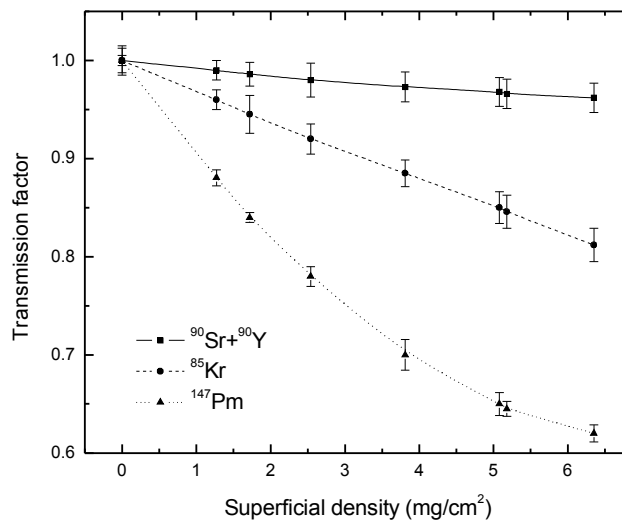


Figure 2: Beta radiation attenuation due to different superficial densities of Mylar filters covering the OSL detectors of $\text{Al}_2\text{O}_3:\text{C}$.

4. Conclusions

The OSL response of Al₂O₃:C detectors, covered by Mylar filters of different thicknesses, presented a very strong energy dependence to beta radiation, indicating that these detectors may be useful as monitors only in known specific radiation fields. Attenuation curves in Mylar were obtained for the three standard beta sources.

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