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CHARACTERIZATION OF OSL COMMERCIAL DOSIMETERS USING A HAND PHANTOM, IN STANDARD BETA RADIATION BEAMS

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ABSTRACT

In this study, a hand phantom was developed and tested with Al_2O_3:C detectors (nanodots, Landauer) and the optically stimulated luminescence (OSL) technique. This paper shows the results of a characterization study of Al_2O_3:C detectors at the hand phantom, to simulate operations at a nuclear medicine service. The OSL detectors were exposed to standard beta radiation beans of the beta secondary standard system of the Calibration Laboratory at IPEN, with ^{90}Sr + ^{90}Y, ^{85}Kr and ^{147}Pm sources. The detectors were optically treated prior each re-utilization. The results obtained show that for monitoring of workers exposed to beta radiation, the technique and the material are useful, but the energy dependence of the OSL response of Al_2O_3: C has to be taken into consideration.

1. INTRODUCTION

Beta radiation dosimetry demands special methodologies, in order to consider the different doses. In this case, it is necessary to measure the absorbed doses 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 by the dosimeters used up to now [2]

In the last ten years, the optically stimulated luminescence (OSL) technique has become a successful dosimetry technique, in particular using Al_2O_3:C as dosimeters. Commercial dosimeters of Al_2O_3:C have been developed and tested, however, mostly in gamma beams [3-4]. Some authors [5] consider that an extremity dosimeter based on OSL readout of aluminium oxide shows great possibility for improving the capabilities of extremity dosimeters. The OSL technique has advantages over the thermoluminescent technique (TL): it requires no sample heating, the detector can be read several times, and OSL measurements are relatively cheaper than TL measurements [6].

This paper shows the results of a preliminary characterization study of Al_2O_3:C detectors at a developed hand phantom, to simulate operations at a nuclear medicine service. Further studies are needed for the practical use of the detectors as beta dosimeters.

2. MATERIALS AND METHODS

The beta irradiations of the OSL detectors were performed using the beta secondary standard system of the Calibration Laboratory at IPEN, with $^{90}Sr + ^{90}Y$, ^{85}Kr and ^{147}Pm sources, manufactured by AEA Technology, Germany, model BSS2 and calibrated by the primary standard laboratory, Physikalisch - Technische Bundesanstalt (PTB), Germany. The radiation source characteristics are presented at Table 1.

Table 1. Characteristics of the beta secondary standard system, model BSS2, with sources calibrated at PTB

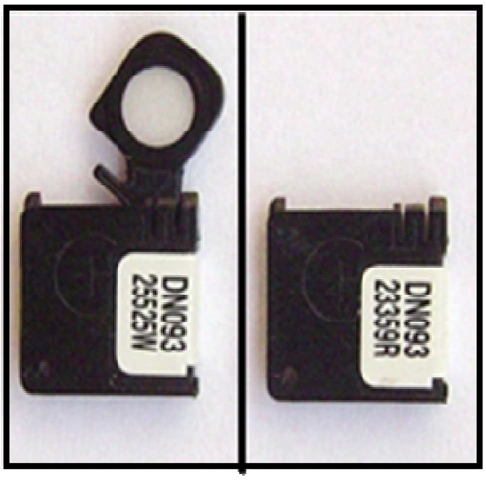
Source	**^{147}Pm**	**^{85}Kr**	**^{90}Sr+^{90}Y**
Nominal activity (MBq)	3700	3700	460
Beta mean energy (MeV)	0.06	0.14	0.80
Absorbed dose rate in air ($\mu Gy.s^{-1}$)	2.35±0.05	39.7±0.5	16.46±0.22
Calibration distance (cm)	20	30	30
Reference date	19/11/2004	30/11/2004	08/12/2004

The measurements were obtained using OSL nanodot dosimeters of Al_2O_3: C (Fig. 1) and a Landauer MicroStar reader and software. This detector is a layer of Al_2O_3:C sandwiched between two layers of polyester for a total thickness of 0.3 mm and diameter of 0.7 mm [7]. The measurements were always taken immediately after irradiation.

Each detector was positioned on a hand phantom for the irradiations (Fig. 2). The numbers in Fig. 2 identify the detector positions at the phantom.

The dosimeters were irradiated open (as shown in Figure 1) at the phantom surface-source calibration distance of 30 cm in the cases of $^{90}Sr + ^{90}Y$ and ^{85}Kr sources, and at 20 cm in the case of ^{147}Pm source.

The detectors were optically treated at 26×10^3 lux during one hour prior to each re-utilization. A Delta OHM radiometer, model D09721, with a LUX LP 9021PHOT sensor, was utilized for the light level determination [8].



(a) (b)

Figure 1. Landauer OSL nanodot dosimeters of Al_2O_3: C; open (a) and closed (b)

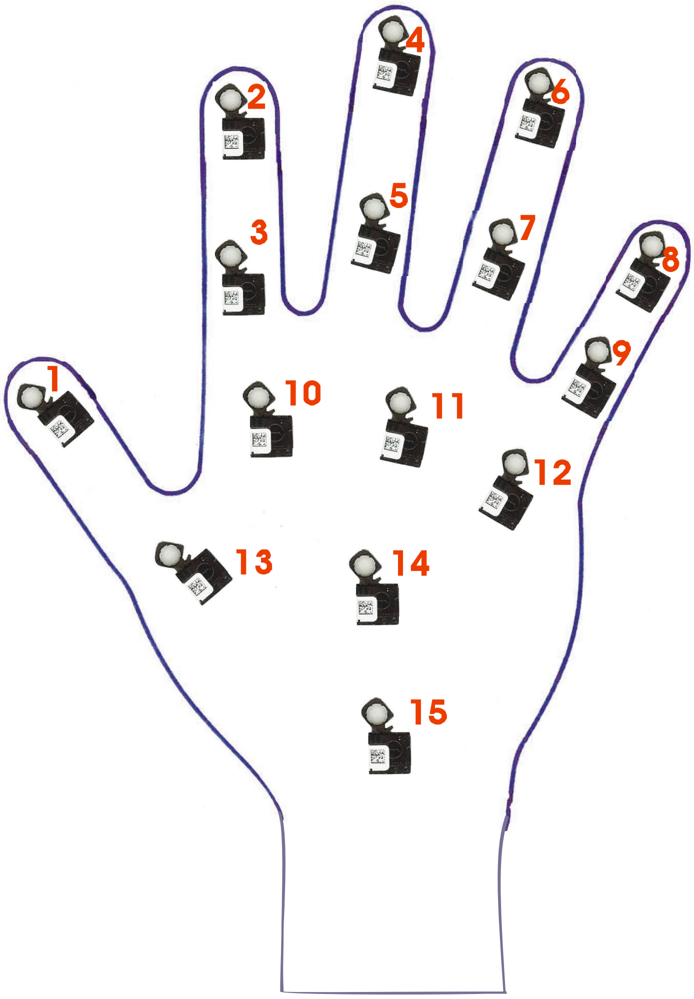


Figure 2. Hand phantom with the Landauer nanodots for beta irradiation

3. RESULTS

3.1. Reproducibility

The reproducibility of the OSL response of Al_2O_3: C detectors was obtained by taking ten measurements of each OSL dosimeter, irradiated with an absorbed dose of 6 mGy of $^{90}Sr + {}^{90}Y$. The OSL reproducibility obtained for the Al_2O_3: C detectors was 4.9 % (1σ).

3.2. Energy Dependence

The OSL dosimeters were exposed to doses of 5 mGy of beta radiation of $^{90}Sr + {}^{90}Y$, 10 mGy of ^{85}Kr, and 25 mGy of ^{147}Pm. Due to the low radiation energy, in the case of the ^{147}Pm source, the absorbed dose rate was corrected for the environmental standard conditions of 20ºC, 101.3 kPa and 50% relative humidity.

Ten measurements were taken for each detector, and the results are presented using the average readout values and standard deviations (1σ). The results were normalized to the $^{90}Sr + {}^{90}Y$ mean energy, and divided by the absorbed doses (Table 2). Figure 4 presents the energy dependence for the detectors D4 and D11 (detectors positions can be observed in Figure 2). The results showed high energy dependence and a similar behavior for all detectors.

Table 2. Energy dependence of OSL response of Al_2O_3: C dosimeters, positioned on a hand phantom in beta radiation beams

	Sources		
Detector	**$^{90}Sr+^{90}Y$**	**^{85}Kr**	**^{147}Pm**
Beta mean energy (MeV)			
	0.800	**0.140**	**0.060**
1	1.000 ± 0.042	0.629 ± 0.039	0.021 ± 0.001
2	1.000 ± 0.023	0.576 ± 0.026	0.023 ± 0.001
3	1.000 ± 0.044	0.588 ± 0.084	0.020 ± 0.000
4	1.000 ± 0.078	0.656 ± 0.006	0.022 ± 0.001
5	1.000 ± 0.029	0.536 ± 0.021	0.024 ± 0.000
6	1.000 ± 0.090	0.611 ± 0.090	0.027 ± 0.001
7	1.000 ± 0.039	0.466 ± 0.053	0.023 ± 0.001
8	1.000 ± 0.061	0.549 ± 0.075	0.025 ± 0.001
9	1.000 ± 0.072	0.512 ± 0.096	0.020 ± 0.001
10	1.000 ± 0.035	0.460 ± 0.032	0.021 ± 0.002
11	1.000 ± 0.025	0.442 ± 0.037	0.022 ± 0.001
12	1.000 ± 0.029	0.466 ± 0.082	0.023 ± 0.001
13	1.000 ± 0.045	0.564 ± 0.060	0.025 ± 0.001
14	1.000 ± 0.068	0.545 ± 0.084	0.020 ± 0.001
15	1.000 ± 0.025	0.528 ± 0.081	0.021 ± 0.002

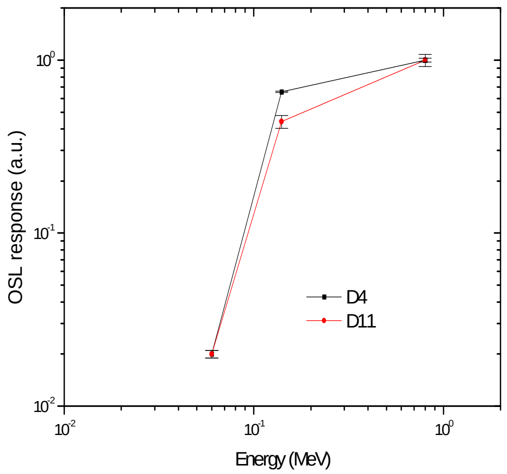


Figure 4. Energy dependence of OSL response of Al_2O_3: C dosimeters D4 and D11, positioned on a hand phantom to beta radiation

3.3. Angular dependence

The angular dependence was determined for the detector D11 (the detector position at the hand phantom can be observed in Figure 2). The OSL dosimeter was exposed to a dose of 2 mGy of beta radiation of $^{90}Sr + ^{90}Y$ and 6 mGy of ^{85}Kr. The obtained results were normalized to frontal incidence radiation (null angle). The irradiation angle was varied between -90^0 and 90^0, using a goniometer. Ten measurements were taken for each incident angle, and the results are presented using the average readout values and standard deviations (1σ) (Figure 3). According to the European Standard Norme [9], the angular dependence should not be greater than ± 40% from 0^0 to 45^0. These Al_2O_3:C commercial detectors present an angular dependence within this recommendation.

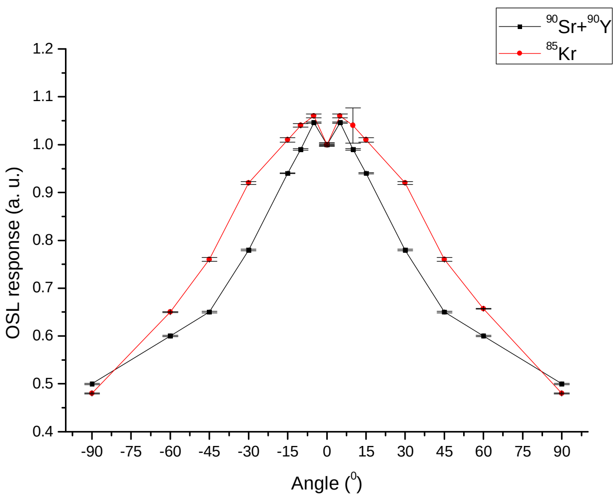


Figure 3. Angular dependence of Al_2O_3:C detectors, in beta radiation beams of $^{90}Sr+^{90}Y$ and ^{85}Kr.

4. CONCLUSIONS

The results on the main dosimetric characteristics obtained of the Al_2O_3:C detectors positioned at the hand phantom show that the OSL nanodot dosimeters may be useful for extremity dosimetry of workers exposed to beta radiation, taking the energy dependence into consideration.

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