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Determination of transmission factors for beta radiation using Al_2O_3:C commercial OSL dosimeters

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ABSTRACT

In recent years, the optically stimulated luminescence (OSL) technique has been used in personal dosimetry, and aluminum oxide (Al_2O_3:C) has become a very useful material for this technique. The objective of this work was the determination of the transmission factors for beta radiation using Al_2O_3:C commercial dosimeters and the OSL method. The obtained results were similar to the transmission factors reported in the beta source calibration certificates.

1. Introduction

The optically stimulated luminescence technique (OSL) has become a popular procedure for the determination of environmental radiation doses absorbed by archaeological and geological materials [1,2]. However, various authors have already reported the use of OSL as a personal dosimetry technique [1,2,3]. Al_2O_3:C has become a material of choice for OSL dosimetry, because it has excellent dosimetric properties such as high sensitivity and low effective atomic number [4,5], but this material is extremely sensitive to light. The fading is among the most important dosimetric characteristics of Al_2O_3:C. The existence of light-induced fading in Al_2O_3:C due to exposure to light may result in loss of dose information [6,7].

In addition, the main requirement of a personal dosimeter for the monitoring of beta radiation doses is the capability of measuring the ICRU quantity of Hp (0.07) with satisfactory accuracy, independently of the angle of incidence of the radiation and the beta radiation energy [8]. Dosimeters with a finite thickness present the dose averaged over the dosimeter thickness, as result [9].

When workers handle radioactive materials they may expose their extremities to doses significantly greater than the whole body doses. Beta radiation may cause damage to the workers in these cases, and then extremity dosimeters become extremely important [9]. The Al_2O_3:C commercial OSL detectors have been tested in order to develop a hand dosimeter for beta radiation which takes into consideration the dose variation at different parts of the body.

Previous studies of the group showed that the maximum deviation of the reproducibility of the OSL response of Al_2O_3:C Landauer dot detectors for beta radiation is only 2.5%. The dose response curve presented a linear response in the low dose range 0.1–10 mGy, but the detectors presented high energy dependence [10].

However, the detectors have to be covered with filters to avoid their exposure to light and the consequent fading effect. The covered detectors characterization includes the determination of the transmission factors for beta radiation. Transmission factors are defined as the ratios between the OSL response obtained with an attenuator and the OSL response extrapolated to absorber null thickness.

The objective of this work was the determination of the transmission factors for beta radiation using Al_2O_3:C detectors and the OSL method.

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 can be seen in Table 1.

The OSL measurements were obtained using single dot dosimeters of Al_2O_3:C from the InLight Systems, Landauer, and the MicroStar portable reader, Landauer. This dosimeter is a layer of Al_2O_3:C sandwiched between two layers of polyester, with a total thickness of 0.3 mm and diameter of 0.7 mm [11]. The

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detectors were covered with Mylar filters with superficial density between 1.27 and 60.86 mg cm^{-2}.

For the irradiations, each OSL detector was positioned on a polymethylmethacrylate (PMMA) phantom (120 mm × 120 mm × 15 mm). The dosimeters were irradiated at the phantom surface–source distance of 30 cm in the cases of $^{90}Sr+^{90}Y$ and ^{85}Kr, and at 20 cm in the case of ^{147}Pm, 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 26×10^3 lux during 1 h prior to each reutilization. A Delta OHM radiometer, model D09721, with a LUXLP9021PHOT sensor, was utilized for the light level determinations [7].

3. Results

The OSL detectors were irradiated with absorbed doses in air of 2 mGy for $^{90}Sr+^{90}Y$, 6 mGy for ^{85}Kr and 25 mGy for ^{147}Pm, using the Mylar filters. In order to determine the transmission factors, it was necessary to extrapolate the attenuation curves to zero thickness. Figs. 1–3 show the extrapolation procedure, respectively, for $^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm radiations. The curves were obtained using the Origin software "B-spline" curves correction to link the experimental points.

The OSL response for $^{90}Sr+^{90}Y$ presents an initial increase, between 0 and 10 mg cm^{-2}, and then a decreasing behavior can be observed. The OSL response for the ^{85}Kr and ^{147}Pm sources decreases monotonically as the tissue superficial density increases. The behavior of the transmission factors for the three tested energies is similar to the obtained by Caldas [12], using the termoluminescent technique.

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

Source	^{147}Pm	^{85}Kr	$^{90}Sr+^{90}Y$
Nominal activity (MBq)	3700	3700	460
Mean beta energy (MeV)	0.06	0.14	0.80
Absorbed dose rate in air (μGy 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

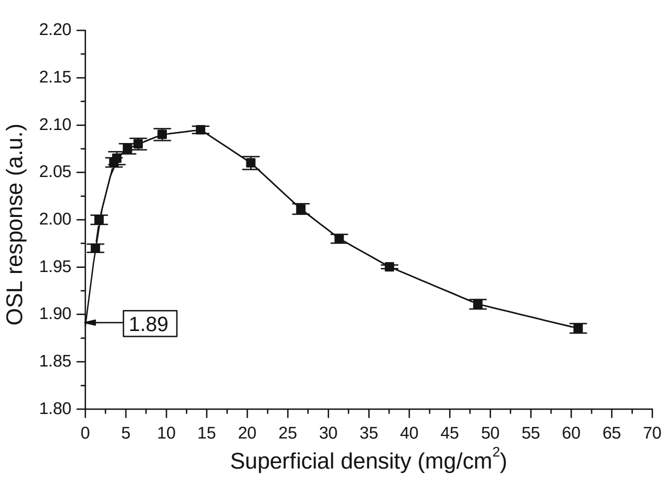

Fig. 1. Attenuation of the OSL response of Al_2O_3:C detectors for $^{90}Sr+^{90}Y$ radiation.

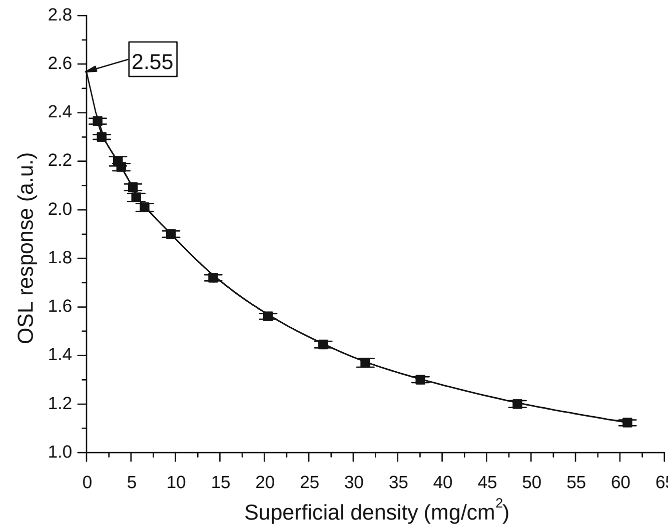

Fig. 2. Attenuation of the OSL response of Al_2O_3:C detectors for ^{85}Kr radiation.

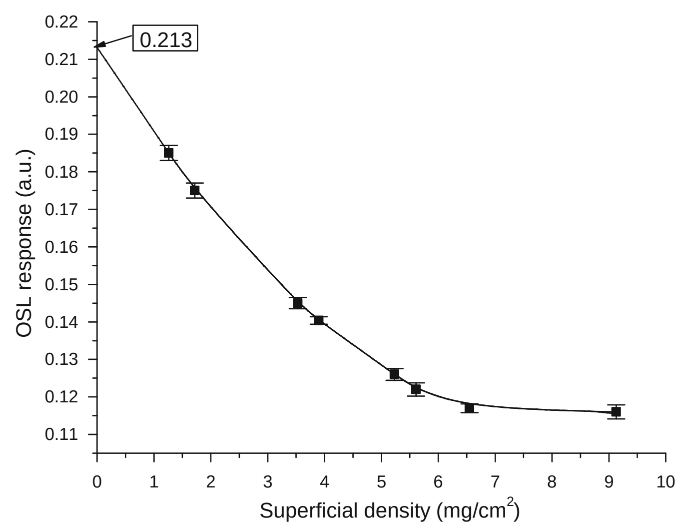

Fig. 3. Attenuation of the OSL response of Al_2O_3:C detectors for ^{147}Pm radiation.

Table 2
Transmission factors for $^{90}Sr+^{90}Y$ beta radiation using OSL detectors.

Tissue thickness (mm)	Tissue superficial density (mg cm^{-2})	Transmission factors	
		Calibration certificate	Obtained results
0.00	0	0.93 ± 0.01	0.909 ± 0.01
0.02	2	0.96 ± 0.01	0.968 ± 0.01
0.04	4	0.98 ± 0.01	0.992 ± 0.01
0.05	5	0.99 ± 0.01	0.998 ± 0.01
0.07	7	1.00	1.000
0.10	10	1.02 ± 0.01	1.005 ± 0.01
0.20	20	1.07 ± 0.01	0.997 ± 0.01

Tables 2–4 present the transmission factors in tissue for $^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm radiations, respectively, in comparison to the data presented in the calibration certificates of the sources. The data were normalized to 0.07 mm tissue thickness, as in the calibration certificates.

Table 3
Transmission factors for ^{85}Kr beta radiation using OSL detectors.

Tissue thickness (mm)	Tissue superficial density ($mg\,cm^{-2}$)	Transmission factors	
		Calibration certificate	Obtained results
0.00	0	1.05 ± 0.01	1.110 ± 0.01
0.02	2	1.04 ± 0.01	1.111 ± 0.02
0.04	4	1.03 ± 0.01	1.062 ± 0.01
0.05	5	1.02 ± 0.01	1.044 ± 0.02
0.07	7	1.00	1.000
0.10	10	0.96 ± 0.01	0.946 ± 0.01
0.20	20	0.78 ± 0.01	0.816 ± 0.01

Table 4
Transmission factors for ^{147}Pm beta radiation using OSL detectors.

Tissue thickness (mm)	Tissue superficial density ($mg\,cm^{-2}$)	Transmission factors	
		Calibration certificate	Obtained results
0.00	0	4.84 ± 0.05	5.000 ± 0.06
0.02	2	3.12 ± 0.03	3.421 ± 0.04
0.04	4	2.00 ± 0.02	2.250 ± 0.05
0.05	5	1.59 ± 0.02	1.800 ± 0.03
0.07	7	1.00	1.000

The maximum variation between the obtained transmission factors and the data presented in the calibration certificates of the sources for $^{90}Sr+^{90}Y$ and ^{85}Kr was 6.8% (for both sources) for 20 and 2 $mg\,cm^{-2}$ of tissue superficial density respectively. In the case of ^{147}Pm, the maximum variation was 13.2%, for 5 $mg\,cm^{-2}$ of tissue superficial density.

4. Conclusion

Transmission factors were obtained in tissue for $^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm radiations. They are similar to those informed in the calibration certificates of the beta sources. The transmission factors of the ^{147}Pm source presented the highest variation. These results show that the OSL dosimeters are useful for beta radiation detection.

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