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Application of the OSL technique for beta dosimetry

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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 is to study the dosimetric characterization of Al_2O_3:C for beta radiation detection using the OSL method. 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.

Keywords: Optically stimulated luminescence; Beta radiation; Al_2O_3:C

1. Introduction

When workers handle radioactive materials they may expose their extremities to doses significantly greater than the whole body dose. Beta radiation may cause damage to the workers in these cases, and then extremity dosimeters become extremely important (Durhan et al., 2002).

The main requirement of a personal dosimeter for the monitoring of beta radiation doses is the capability of measuring the ICRU quantity of H_p (0.07) with satisfactory accuracy, independently of the radiation incident angle and the beta radiation energy (Akselrod et al., 1999).

Beta dosimetry presents more difficulties than gamma dosimetry, since skin dose is defined at a single depth in tissue, and the dose deposition from beta particles in tissue is highly non-uniform. Dosimeters with a finite thickness yield the dose averaged over the thickness of the dosimeter (Durham et al., 2002).

In extremity dosimetry the dose should preferably be measured using a very thin dosimeter, particularly for beta dosimetry (Akselrod et al., 1996). Extremity dosimeters have to be produced in very thin layers with sufficient sensitivity to provide accurate dose measurements between 1 mGy and 10 Gy. Various types of thin detectors have been prepared and tested using highly sensitive thermoluminescent (TL) phosphors, e.g. MgB_4O_7:Dy; $CaSO_4$:Dy; Al_2O_3:C and LiF:Mg,Cu,P (Campos and Lima, 1987); (Akselrod et al., 1996).

Aluminum oxide (Al_2O_3:C) was initially developed as a TL material. In recent years, the optically stimulated luminescence (OSL) technique has been used in personal dosimetry, and Al_2O_3:C has become a material of choice for this technique (Akselrod et al., 1999).

The Al_2O_3:C detectors present very good dosimetric properties, and they have become successful personal OSL dosimeters (Akselrod et al., 1990; McKeever et al., 1996; McKeever, 2001). Thin layers of this material can be used to measure different energies of beta radiation, within the limits established in the US by the National Voluntary Laboratory Accreditation Program and the US Department of Energy Laboratory Accreditation Program with acceptable accuracy (Akselrod et al., 1999).

The objective of this work is the dosimetric characterization of Al_2O_3:C for beta radiation detection using the OSL method in order to monitor workers exposed to beta radiation.

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,

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Table 1
Characteristics of the secondary standard system of beta radiation

Source	^{147}Pm	^{85}Kr	^{90}Sr + ^{90}Y
Nominal activity (MBq)	3700	3700	460
Mean beta energy (MeV)	0.06	0.69	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

manufactured by AEA Technology, Germany, and calibrated by the primary standard laboratory, Physikalisch - Technische Bundesanstalt (PTB), Germany. The radiation source characteristics can be seen in Table 1.

The measurements were obtained using OSL dot dosimeters of Al_2O_3:C with 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 (Landauer, 2006).

For the irradiations, each OSL dot dosimeter of Al_2O_3:C was positioned on a polymethylmethacrylate (PMMA) phantom (120 mm × 120 mm × 15 mm). The dots 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 for 1 h prior to being re-utilized. A Delta OHM radiometer, model D09721, LUX LP 9021PHOT sensor, was utilized to determine the light level. (Gronchi et al., 2007).

3. Results

3.1. Reproducibility

The reproducibility of the OSL response of Al_2O_3:C detectors was obtained by taking 10 measurements of each OSL dosimeter, irradiated with an absorbed dose of 0.6 mGy of beta radiation (^{90}Sr + ^{90}Y). The reproducibility obtained of the Al_2O_3:C detectors was 2.5% (1σ).

3.2. Dose–response curve

The OSL dots of Al_2O_3:C were irradiated with ^{90}Sr+^{90}Y in the dose range of 0.1–10 mGy. Ten dots were utilized for each dose level. The dose–response curve presents (Fig. 1) a linear response for low doses, which are more probable to occur in occupational dosimetry. The error bars correspond to 1σ.

3.3. Energy dependence

The OSL dot dosimeters were exposed to a dose of 3 mGy of beta radiation of ^{90}Sr+^{90}Y and ^{85}Kr, and to a dose of 13 mGy of ^{147}Pm. The results were normalized to the ^{90}Sr+^{90}Y mean energy and divided by the absorbed doses (Fig. 2). Due to the low radiation energy, in the case of the ^{147}Pm source, the absorbed dose rate had to be corrected for the environmental standard conditions of 20 °C, 101.3 kPa and 50% relative humidity. The curve was obtained using the Origin software "spline" curve correction to link the three main points. The response is given per unit dose and error bars are 1σ. These materials present a very high dependence of the OSL response on the

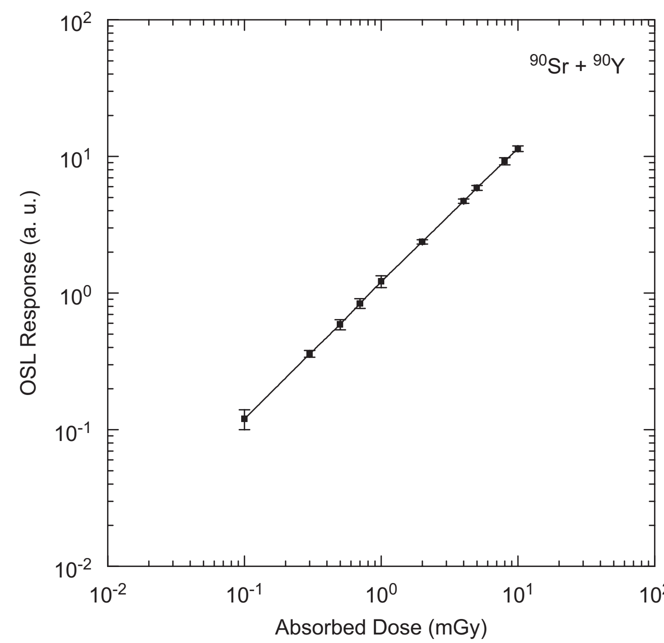

Fig. 1. Dose–response curve of OSL response of Al_2O_3:C dot dosimeters to beta radiation (^{90}Sr + ^{90}Y).

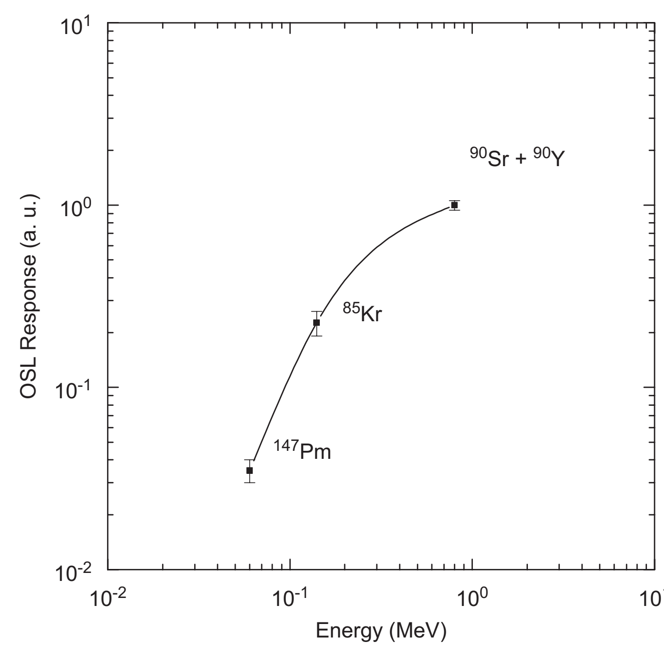

Fig. 2. Energy dependence of OSL response of Al_2O_3:C dot dosimeters to beta radiation.

beta radiation energy, which has to be taken into consideration for beta monitoring. The energy dependence curve obtained for the Al_2O_3:C pellets irradiated with different beta sources is comparable to that presented by Akselrod et al. (1999). The energy response for beta radiation can be flatted by using filters as discussed by Akselrod et al. (1996).

4. Conclusion

Al_2O_3:C dot dosimeters were characterized for beta radiation dosimetry using the OSL technique in this work. The reproducibility of OSL response was 2.5%.

The dose–response curve presents a linear response in the low dose range of 0.1–10 mGy; these doses are more probable to occur in occupational dosimetry.

The material presents a high energy dependence that has to be taken into consideration for beta occupational dosimetry. As discussed by Akselrod et al. (1996), filters may be used to flatten this energy dependence curve.

The results on the main dosimetric characteristics investigated in this paper show that the OSL dot dosimeters may be useful for extremity dosimetry of workers exposed to beta radiation, taking the energy dependence into consideration.

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