Available online at www.sciencedirect.com
ScienceDirect
Applied Radiation and Isotopes 66 (2008) 346–352
Applied Radiation and Isotopes
www.elsevier.com/locate/apradiso

A comparison of the performance characteristics of four film dosimeters in a 10-MeV electron beam

Zofia Peimel-Stuglik*, Sławomir Fabisiak

Institute of Nuclear Chemistry and Technology, Laboratory for Measurements of Technological Doses, ul. Dorodna 16, 03-195 Warsaw, Poland

Received 8 January 2007; received in revised form 20 February 2007; accepted 30 March 2007

Abstract

Performance characteristics of four routine film dosimeters (CTA, B-3, PVC and LiF (Sunna)) in a 10-MeV electron beam were investigated. Dose response curves for the range 5–40 kGy are presented. The dose response curve is linear for the CTA film, supralinear for the LiF (Sunna) film and sublinear for the B-3 and PVC films. The low sensitivity of the CTA film to ionizing radiation restricts its use to high doses, while the supralinear response curve of the LiF (Sunna) dosimeter allows this film to be used only in measurements of low doses. The optical absorption temperature coefficients for the CTA, B-3 and LiF (Sunna) films were found to be at the level of $\pm 0.1\%/^{\circ}C$. The temperature coefficient for the PVC film decreased from $+0.35\%/^{\circ}C$ immediately after irradiation to $+0.04\%/^{\circ}C$ three months later. Because of the significant time dependence of the PVC film signal, a careful standardization of the heating regimen and of the time between the irradiations and measurements is necessary.

Keywords: Film dosimeters; Electron beam; CTA; PVC; B-3; LiF; Sunna

1. Introduction

Thin film dosimeters (0.25–0.01-mm thick) play an important role in routine dosimetry for electron beams. They allow to measure dose distributions with a negligible distortion of the radiation field. Most of the dosimetry with films is based on optical signal measurements (ISO/ASTM 51275:2004(E); ISO/ASTM 51650:2005(E); ASTM E 2304-03; Bułhak, 1975); however, electron paramagnetic resonance (EPR) detection systems are also used (Janovský et al., 1988; Lin et al., 2005; ISO/ASTM 51607:2004(E)). An advantage of the optical absorption measurements is the high spatial resolution (Niromand-Rad et al., 1998) unattainable with the EPR detection. Moreover, UV/VIS spectrophotometers are cheaper and more widespread than EPR spectrometers.

The aim of the work was to compare the performance characteristics of four routine film dosimeters, namely, CTA, B-3, LiF (Sunna), and PVC, used with optical signal detection. CTA and B-3 are films widely used in dosimetry (ISO/ASTM 51275:2004(E); ISO/ASTM 51650:2005(E)). LiF in a polymer was introduced into practice a few years ago (ASTM E 2304-03). The technical PVC film had been used as a routine dosimeter at the sterilization plant of the Institute of Nuclear Chemistry and Technology (INCT) for many years (Bułhak, 1975; Peimel-Stuglik and Fabisiak 2005a,b).

The film dosimeters were irradiated with 10-MeV electron beams from an industrial 10-kW linear accelerator under identical conditions. The absorbed doses were measured with standard alanine dosimeters from the National Physical Laboratory (NPL, Teddington, UK) irradiated simultaneously with the investigated films.

2. Experimental

The 10-MeV linear accelerator Elektronika (TORIJ, Russia, 1993) at the INCT Sterilization Plant emitted 6-μs pulses of electrons with the frequency of 350 Hz. The beam scanning frequency was 5 Hz. The mean electron energy measured by the wedge method was in the range 9.6–9.8 MeV. The interrelation between the electron beam

*Corresponding author. Tel.: +48 22 5041053; fax: +48 22 8111532.
E-mail address: stuglik@ichtj.waw.pl (Z. Peimel-Stuglik).

0969-8043/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apradiso.2007.03.020

flux and the speed of the conveyor delivering dosimeters under the beam allowed keeping the dose at the specified level.

The absorbed doses were quantified with standard alanine EPR dosimeters from NPL in terms of dose to water. Both the test and reference dosimeters were irradiated in the polystyrene phantoms produced at the High Dose Radiation Laboratory (HDRL), Riso, Denmark (Fig. 1) and described in ISO/ASTM 51631:2003(E). A short distance of 5 cm between the reference and test dosimeters reduced uncertainty from conceivable instability of electron beam flux. The overall uncertainty of the dose absorbed by irradiated films was estimated to be ±3.4% (U; $k = 2$). The measured doses were traceable to the NPL primary standard. Four strips of each film were irradiated in parallel at each dose point.

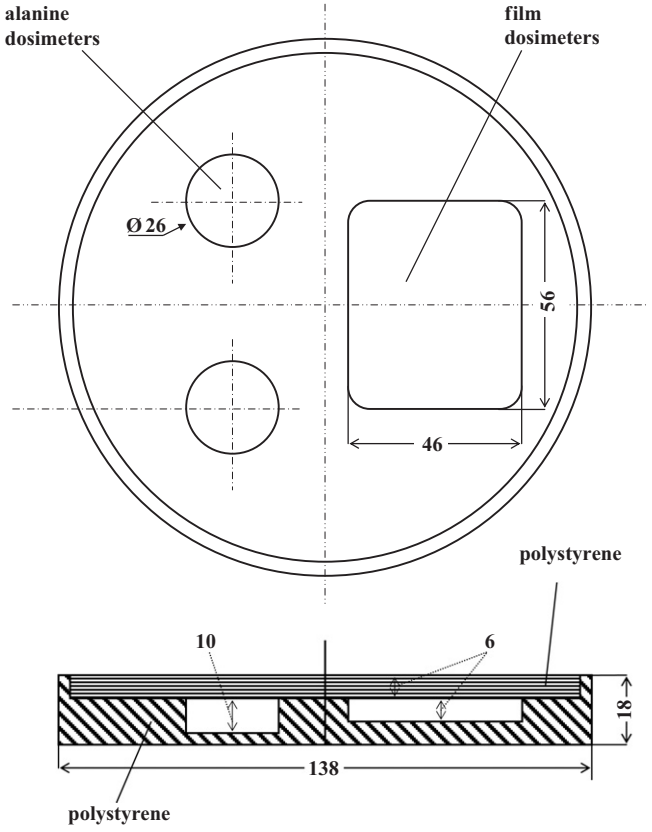

Fig. 1. Polystyrene phantom with cavities for alanine and film dosimeters.

The mean temperature of irradiation was calculated as the average of temperatures before and after the irradiation, which were measured with a calibrated thermistor mounted in a polystyrene calorimetric dosimeter irradiated in the same experiment.

Table 1 provides a summary of the performance characteristics of the investigated dosimeters. Radiation-induced increments of the absorbance values at 280, 245, and 396 nm were used as dosimetric signals for the CTA, LiF (Sunna) and PVC films, respectively. For the B-3 films, the dosimetric signal was defined as the total optical absorbance of the irradiated film at 556 nm. (That was because of the limited accuracy of the spectrophotometer, discussed below, which precluded sufficiently precise measurements of the low absorbance of unirradiated B-3 films.)

All optical measurements were performed using a Cintra-40 UV/VIS spectrophotometer (GBC, Australia) with two Littrow monochromators in a Czerny-Turner arrangement. Its resolution and very low stray light allowed for precise optical absorption measurements up to 4.5 AU. The photometric uncertainty was at the level of ±0.001 AU below 0.5 AU and ±0.002 AU above that value. A Peltier-effect thermocell was used for temperature coefficient measurements. The spectrophotometer was maintained according to a quality control system consistent with the ISO/IEC 17025:2005 standard.

Table 1
Characteristics of the investigated film dosimeters

Dosimeter	CTA FTR-125	Radiochromic B-3	LiF (Sunna)	PVC
Composition[a]	H, C, O, P	H, C, N	Li, F	H, C, Cl
Thickness (mm)	0.127	0.020	0.245	0.260
λ (nm)[b]	280	556	245	396
Transparency	High	High	Low	High
Post-irradiation thermal treatment	None	5 min, 60 °C	None	30 min, 70 °C
Price (USD)[c]	0.20	0.08	0.35	<0.001
Batch number	4481207	9711 Ba 1-1	1 F 11	IV[d]
Manufacturer	Fuji Film, Japan	Beiersdorf AG, Germany	SUNNA Systems Corporation, USA	Germany
Provider	AERIAL, France	HDRL, Riso, Denmark	SUNNA Systems Corporation, USA	Germany
Measurement standard used	ISO/ASTM 51650	ISO/ASTM 51275	ASTM E2304	None

[a]Elements in the radiation-sensitive compounds.
[b]Wavelength of the absorbance measurement.
[c]Price of one piece (2 cm^2).
[d]Number assigned at the Institute of Nuclear Chemistry and Technology (INCT).