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EFFECT OF THE IRRADIATION TEMPERATURE AND RELATIVE HUMIDITY ON PVG DOSIFILM*

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Abstract

The effect of environmental factors, such as irradiation temperature and relative humidity, on the PVG dosifilm irradiated by EB was tested. Experiments show that the temperature coefficient of irradiated PVG dosifilm was 0.008 °C $^{-1}$ from 20 °C to 55 °C, and the humidity coefficient was 0.006 per r.h. (%) from r.h.0% to 76 %. The PVG dosifilm can be used as a routine dosimeter for dose measurement for low-energy EB processing. The absorbed dose values for various irradiation temperature and humidity can be corrected based on experimental data.

1. INTRODUCTION

The environmental factors affected the measurement accuracy of the dosifilm, which was used for quality control of irradiation processing. For example, the relative humidity below r.h. 20 % has less effect on the response of undyed PMMA dosimeter, but the response decreased significantly above r.h. 80 % [1, 2, 3]. During irradiation temperature below 30 °C, the response of the PMMA dosimeter seemed independent of temperature, however, above 30 °C, the response decreased[4]. For other dosifilms, such as CTA, radiochromic dosifilm, alanine dosimeter, the dose response was also affected by irradiation environment [5-9]. For these reasons, the effects of temperature and relative humidity during irradiation on PVG dosifilm were investigated.

2. EXPERIMENTAL

A water jacket for sample irradiation, with recycle water from a thermostat for keeping a given constant temperature during irradiation, was used to examine the effect of irradiation temperature (see Fig. 1). The temperature values were read out from both thermometers (1 and 2) which were put in the inlet and outlet of water jacket, respectively. In front of the dosifilm, the thickness of the wall material (plastic) of the water jacket plus the thickness of the water layer was 10 mm. The temperature difference between both thermometers for each given temperature was less than 0.5 °C during irradiation.

Several plastic vials with various relative humidity for PVG dosifilms irradiation were prepared as Fig.2. The relative humidity was 0 %, 33.6 %, 54.9 % or 75.7 % in each vial. Three PVG dosifilms were placed in each vial with a given relative humidity at least one day before irradiation.

Irradiations were performed by LINAC model BF-5 with electron energy of 4 MeV (±5%), and the current intensity of 100 μA. Dose was calibrated by calorimeter and dichromate dosimeters.

Absorbance on PVG dosifilms was measured by DMS-300 spectrophotometer, Varian Ltd. USA at least one day after irradiation.

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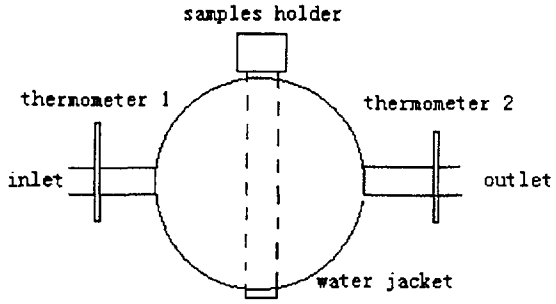

FIG. 1. Temperature controllable water jacket with thermometers and recycle water from thermostat.

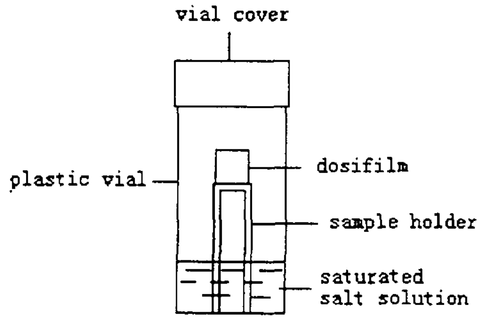

FIG.2. Plastic vial for PVG dosifilm irradiation with a given relative humidity at various doses.

3.RESULTS AND DISCUSSION

3.1. Temperature effect on EB irradiated PVG dosifilm

PVG dosifilms were irradiated with dose from 1 kGy to 55 kGy at a given temperature in the water jacket. Absorbed dose was calibrated by dichromate dosimeter and calorimeter. As shown in Fig.3, the relationship between the absorbed dose and the specific net absorbance (ΔA/Thickness (mm^{-1})) depends on the irradiation temperature. At 20 °C (curve with symbol ■), this relationship can be expressed as shown in Eq. (1):

$$\Delta A/\text{Thickness}_{(20°C)}\ (mm^{-1}) = 0.49 + 0.79 \bullet D - 0.002 \bullet D^2 \quad (1)$$

where, D is the absorbed dose (kGy).

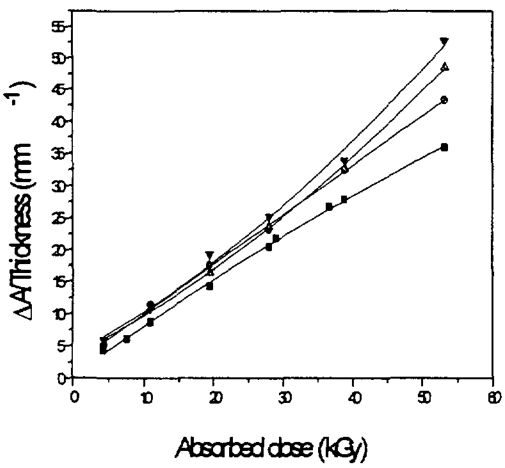

FIG 3. ΔA/Thickness (mm^{-1}) vs. absorbed dose at different irradiation temperature.
■:20℃, ●:35℃, ▲:45℃, ▼: 55℃.

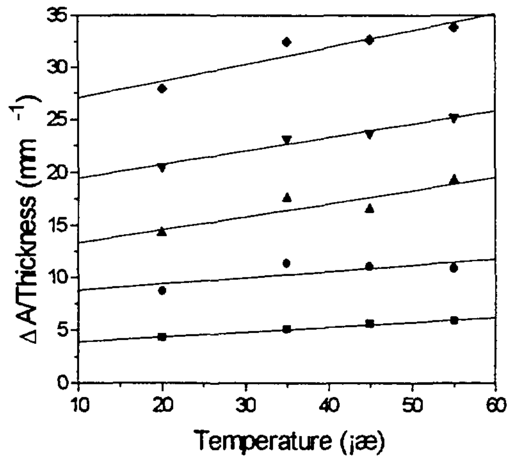

FIG. 4. ΔA/Thickness (mm^{-1}) vs. irradiation temperature at various absorbed dose.
■:4.3 kGy, ●:11 kGy, ▲:19.5 kGy, ▼: 29 kGy
◆:39kGy

TABLE I. THE EXPERIMENTAL VALUE ΔA/Thickness $_{(t°C)}$ (mm^{-1}) OF PVG DOSIFILM AND CALCULATION VALUE BY EQUATION (2) AT VARIOUS TEMPERATURES.

Irradiation	10.9 kGy		19.4 kGy		28 kGy		39 kGy	
temperature °C	ΔA/Thickness (mm^{-1})		ΔA/Thickness (mm^{-1})		ΔA/Thickness (mm^{-1})		ΔA/Thickness (mm^{-1})	
	[1]Exp.	[2]Cal.	[1]Exp.	[2]Cal.	[1]Exp.	[2]Cal.	[1]Exp.	[2]Cal.
20	8.75	[3]8.82	14.26	[3]14.92	20.54	[3]20.83	27.92	[3]27.42
35	11.4	10.06	17.6	16.4	23.2	23.62	32.5	32.11
45	11.1	10.94	16.5	17.82	23.7	25.67	32.7	34.9
55	10.9	11.81	19.3	19.25	25.2	27.73	33.9	37.69

[1]Exp. = experimental values, [2]Cal. = the values calculated by Eq. (2),
[3]data = the values calculated by Eq. (1).

This indicates that the relation of ΔA/Thickness (mm^{-1}) vs. absorbed dose is sublinear. Curves with symbol ●(35°C), ▲(45°C), and ▼(55°C) in Fig. 3 showed that at the same dose the specific net absorbance of the irradiated PVG dosifilm increased with the increasing irradiation temperature. The specific net absorbance of the PVG dosifilm vs. irradiation temperature for various doses are shown as Fig. 4. Experiments showed that the temperature coefficient of the PVG dosifilm from 20 °C to 55 °C was approximately +0.008 $°C^{-1}$. The value of ΔA/Thickness (mm^{-1}) at any temperature can be expressed by Eq. (2):

$$\Delta A/\text{Thickness}_{(t°C)}\ (mm^{-1}) = \Delta A/\text{Thickness}_{(20°C)}\ (mm^{-1})\ [1 + (t\ °C - 20)\times 0.008] \quad (2)$$

where, ΔA/Thickness$_{(t°C)}$ (mm^{-1}) is the specific net absorbance at t°C irradiation temperature.

The comparison of the experimental values and the calculated values of ΔA/Thickness $_{(t°C)}$ (mm^{-1}) on PVG dosifilm from Eq. (2) and Eq. (1) are listed as Table I. At 20°C, the deviation between [1]Exp and [3]data was around ± 2%. It was determined from the experimental uncertainties i.e. it was the deviation from the regression Eq. (1). Also, the deviation between [1]Exp with [2]Cal values was around ±5 %. This was determined by the experimental and temperature corrections. This value is less than 10 %, i.e. less than the uncertainty of the routine dosimetry. So this [2]Cal. value of ΔA/Thickness $_{(t°C)}$ (mm^{-1}) was adequate for conversion into dose value by Eqs (2) and (1).

3.2. Relative humidity effect on EB irradiated PVG dosifilm

The relationships of ΔA/Thickness (mm^{-1}) vs. dose for various relative humidities are shown in Fig. 5. It indicates that, at the same dose, ΔA/Thickness (mm^{-1}) value increases with relative humidity from r.h.0% to 76%; the humidity coefficient is calculated to be 0.006 per r.h.(%). The change of ΔA/Thickness (mm^{-1}) value for various doses from r.h. 0 % to 33.6 % is less than 4%; therefore, the effect of relative humidity on the irradiated PVG dosifilm can be neglected below r.h.33.6% and below 25 kGy. However, at higher relative humidity the effect cannot be neglected, i.e. the response of the dosifilm must be corrected by the coefficient 0.006. If the dosifilm is kept in a dry container with lower relative humidity before and after irradiation, and irradiated in a sealed package, the correction for relative humidity can be neglected.

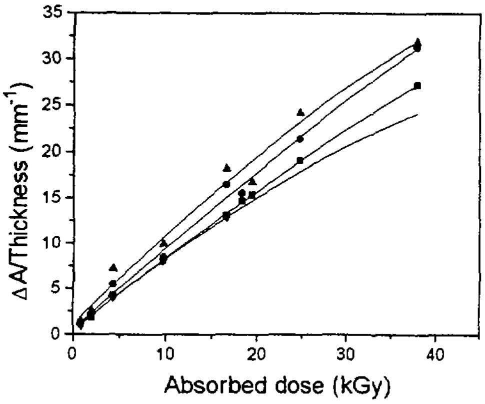

FIG. 5. Specific net absorbance vs. absorbed dose at various relative humidity. ▼: r.h. 0%, ■: r.h. 33.6%, ●: r.h. 54.9%, ▲: r.h. 75.7%.

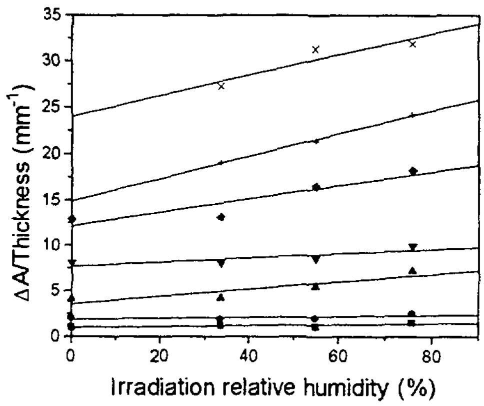

FIG. 6. Specific net absorbance vs. relative humidity at various absorbed dose. ■:0.8kGy, ●:2kGy, ▲:4kGy, ▼: 10kGy, ◆:17kGy, +: 25kGy, ✖:38kGy.

4. CONCLUSION

The influence on the specific net absorbance value for various irradiation temperature or humidity conditions was determined on the EB irradiated PVG dosifilm. At 20 °C, the absorbed dose can be calculated from the specific net absorbance of the irradiated PVG dosifilm by Eq. (1) up to 150 kGy. For other temperatures, the $\Delta A/Thickness_{(20°C)}$ can be calculated from $\Delta A/Thickness_{(t°C)}$ by Eq. (2) using experimental temperature coefficient 0.008 $°C^{-1}$. The relative humidity effect on the irradiated PVG dosifilm can be neglected below r.h.30%, but the correction is necessary at higher relative humidity values by the coefficient 0.006.

Experiments showed that the PVG dosifilm can be used as a routine dosimeter for electron beam irradiation processing.

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