GENERAL PROPERTIES OF DOMESTIC RADIOCHROMIC FILM ELECTRON DOSIMETER*

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ABSTRACT

The project established a system for routine measurement of electron dose and brought about a complete experimental approach for high-dose dosimetry. The paper reports some general properties of domestic radiochromic pararosaniline cyanide (PR-CN) dye with polyvinyl butyral (PVB)-based film used for measuring electron dose. The optical absorption spectrum, the change in optical density as a function of thickness, distribution of the background optical density and spread of response, long-term stability, linear relationship between the change in optical density per unit thickness and absorbed dose, the minimum detectable limit, effect of environmental factors on background and response after irradiation, effect of light-exposition and the time of establishing complete response have been experimentally investigated.

Keywords: Electron dosimeter High dose dosimetry Film dosimeter Radiation processing

Ⅰ. INTRODUCTION

Measurement of absorbed dose and it's distribution in productions irradiated are quite important for providing reliable quality assurance. Especially, as the limited range, scatter and absorption characteristics of electron beams passing through materials, moreover the definite volume of most common dosimeters and various radiation fields from electron accelerators, this dosimetry becomes a much more complex problem. Among a number of dosimeters the thin film dosimeter containing radiochromic dye is the most suitable for the aim[1], and becomes a common method for routine measurement in radiation processing.

The PR-CN (PVB) film electron dosimeter may have a smaller sensitive volume at the three-dimensions less than the range of electrons and easily satisfies the requirement of the cavity theory.

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II. EXPERIMENTAL METHOD AND EQUIPMENT

Pararosaniline cyanide (PR–CN) is a white crystal synthesized and sensitive to ionizing radiations, melting point of 305°C. The content is 3.2% by weight and the purity is qualified.

For investigating the suitability of the domestic PR–CN (PVB) films used as an electron dosimeter, two kinds of basic conditions have been realized.

(1) Radiation fields with spectral distributions known, adequate constance, uniformity, repeatability, durability and irradiation geometry defined.

(2) A convenient method for routine calibration unified.

Two sorts of the powder–metallurgical radioisotope sources, promethium (^{147}Pm, active area of 12 cm^2 and 10GBq) and strontium+yttrium (^{90}Sr+^{90}Y, active area of 6 cm^2 and 7 GBq), have been used for testing the energy dependence and the spreads of response to the same dose. During irradiaton these sources were rotating with a constant speed. The uniform fields thus have been achieved.

The reference values of electron dose are obtained by an extrapolation ionization chamber made of polystyrene. It is more convenient for calibrating the surface and depth absorbed dose distributions of electron beams, especially in a heterogeneous material or at an interface of widely different materials.

III. RESULTS

Some general characteristics from a series of experimental results are obtained as follows:

(1) After irradiation the optical absorption spectrum in visible region has been remarkably changed. The absorption peak radiation–induced appears at the wavelength about 550 nm as shown in Fig.1. The half–width of the peak is about 76 nm.

(2) The precision is determined by a spread of response, that is defined as one standard deviation for the responses of a group of pieces from the same batch when they are exposed to identical total dose. The range lies from 0.5 to 120 kGy. The results (cf. Fig.2) show that the distribution of spreads follows a lognormal pattern (altogether 130 groups). The median spread is about 2.8%, that is to say 50% groups are less than this figure. The standard deviation is about 6%.

(3) The optical density linearly varies with thickness (0.02–0.11mm) for an identical total absorbed dose as shown in figure 3. As the response is directly proportional to the thickness the thick films can be used to reduce the minimum

detectable limit.

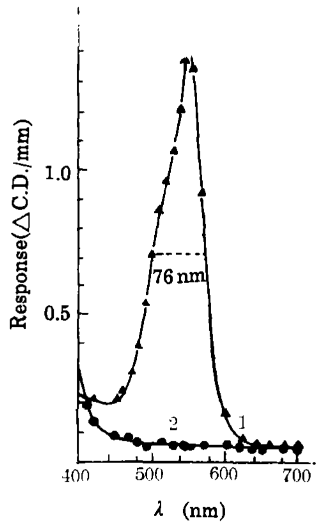

Fig.1 Absorption spectra of domestic PR– CN (PVB) film irradiated with 34.5 kGy (curve 1) and back–ground (curve 2)

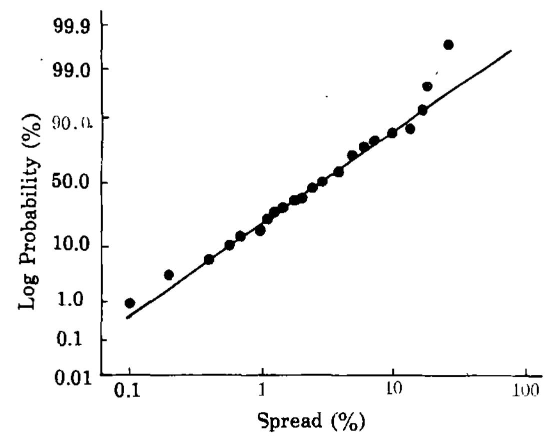

Fig.2 Distributions of spread for domestic PR– CN (PVB) film dosimeters irradiated with identical electron doses (0.5– 120 kGy)

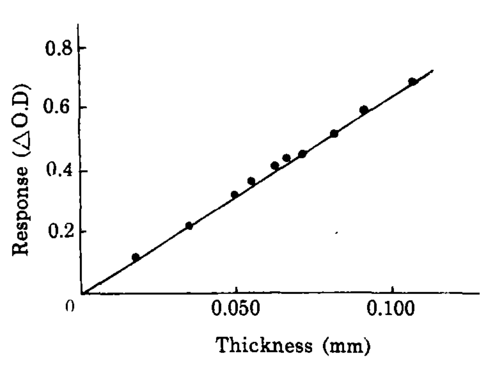

Fig.3 Linear function between the change in optical density and thickness for the domestic PR—CN (PVB) dosimeter

D=10.3 kGy n=10 r=0.994

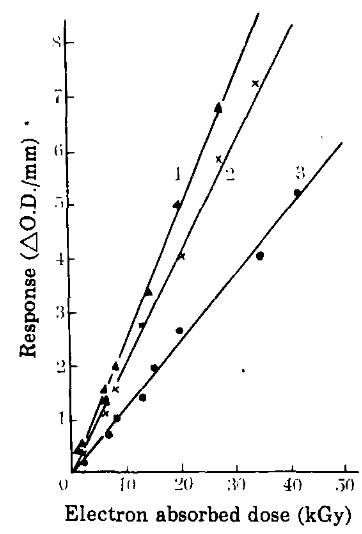

Fig.4 Optical density at different wavelengths as a function of electron absorbed dose

1– 550 nm 2– 540 nm 3– 580 nm

(4) Fig.4 shows that a good linearity exists between the change in optical density

per unit thickness at three wavelengths 550, 540 and 580 nm and electron absorbed dose.

(5) The distributions of background optical density per unit thickness for 202 pieces of the films in storage time of 1–3 months after preparation in a desiccator at room temperature follow a lognomal distribution as shown in Fig.5. The median reading is 0.52 O.D./mm and standard deviation is about 0.18 O.D./mm. The background may be primarily due to reflection of the light beams from a spectrometer or due to exposition to U.V. light component. In general the background is less than that of Nylon–based film depending on the storage conditions.

(6) The distribution of backgrounds has decided the lowest detectable limit of decades Gy estimated for electron absorbed dose. The influence of the change in background measured on the reading is less than 1%.

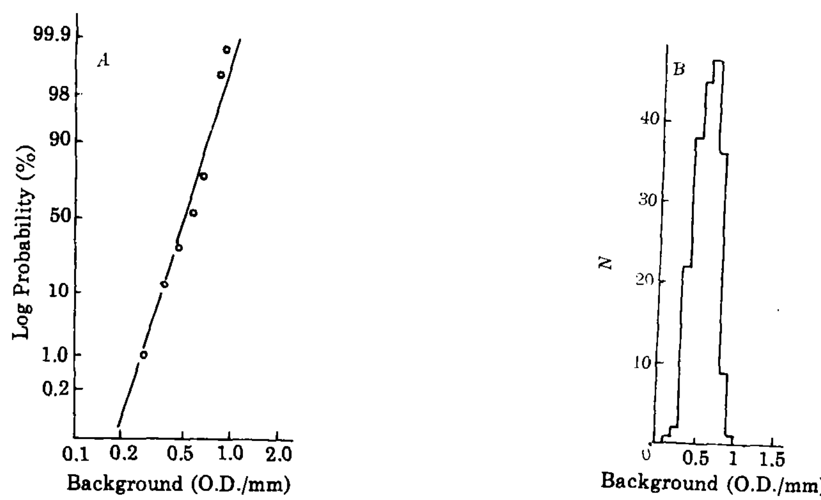

Fig.5 Distributions of background optical density per unit thickness for domestic PR– CN(PVB) electron dosimeter

A. Probability distributions *B*. Histogram

(7) Among the environmental factors the influence of temperature during irradiation on optical density of the thin film dosimeter is the one of important factors in radiation processing with electron beams. During irradiation the temperature can rise to decades degree centigrade and depends on the heat capacity of material irradiated. Those materials with a small heat capacity will experience greater temperature increase. The effect can't be avoided or controlled but can be taken into account. In order to make suitable correction for the temperature dependence a digital thermocouple meter was used. It is shown that a linear increase in optical densities with irradiation temperature can be characterised by a positive temperature coefficient of about +0.5% per degree centigrade in the range of 5–50°C, as shown in

Fig.6.

(8) There is no effect of indoor storage conditions on the background and response of the dosimeters irradiated if they are wrapped in a sealed plastic package and stored in a desiccator as shown in Fig.7.

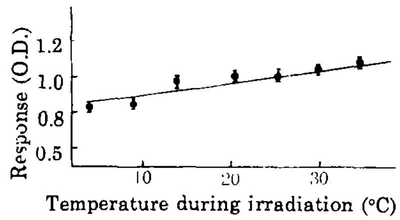

Fig.6 Effect of temperature during irradiation on reseponse of domestic PR– CN (PVB) electron dosimeter

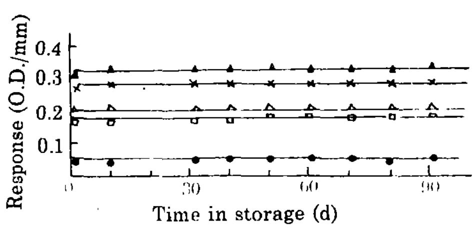

Fig.7 Stability of optical density for background and response of PR– CN (PVB) electron dosimeter placed in a desiccator at room temperature
Symbols represent different dose–level

(9) Time of establishing complete response: If the measurements were made immediately after irradiation then the complete response wouldn't be established. As a consequence the reading was unstable and underestimated. The effect can be avoided. After irradiation by heating the dosimeters irradiated for 10 min at temperature of about 60°C or waiting for several hours the colour centres have arrived at a stable value.

(10) Effect of light exposition: The radiochromic dye film dosimeter is not only sensitive to ionizing radiations, but also to U.V.light. The effect of different lights, such as sunlight, daylight, ultraviolet light, incandescent light and natural light in room, on the background reading has been investigated in more detail. Among these lights the dosimeter is very sensitive to sunlight and U.V.light. The effect can't be corrected but can be controlled. In order to avoid the error, therefore the film dosimeter should only be handled under a low intensity of incandescent light, then carefully be packed with a black paper or placed in dark. The effect and some dosimetric properties will be published separately.

(11) According to the [Recomendation on the Statement of Uncertainties], a evaluated combination of type *A* uncertainties from the radiochromic film dosimeter used for measurement of electron absorbed dose at not too low energy is about 3.1%. The main source of this uncertainty is due to the scattering of response. The relative combined uncertainty in categery *B* is about 3.5%. The source of errors mainly lies in the method of calibration for electron dose.

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