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DOSIMETRIC EVALUATION OF A NEWLY DEVELOPED RADIOCHROMIC FILM FOR RADIATION PROCESSING*

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Abstract – In order to improve the performance of a newly developed radiochromic film, GIC-79, some dosimetric characteristics of this film have been studied based on relevant standard practice. The present study describes some parameters that may affect the dosimeter response before, during, and after irradiation. The effect of absorbed dose rate on dosimeter response was determined by irradiating dosimeters at low absorbed dose rates with gamma rays. Calibration irradiations of dosimeters were performed with both gamma rays and also electrons to determine the effect of large difference absorbed dose rates on dosimeter response. In addition, post irradiation stability was obtained and also the temperature and humidity effects on the dosimeter response during the storage time prior to irradiation and post irradiation have been investigated.

Keywords – Dosimetry, film dosimeter, radiochromic film, gamma radiation, electron beam

1. INTRODUCTION

Radiochromic film dosimeters are useful tools for routine dosimetry which have been recently used for various applications of radiation processing. Several plastic films containing certain lucocyanides or lucomethoxides of thriphenylmethane dyes have been successfully developed and used as routine dosimeters in gamma as well as electron beam radiation processing [1, 2, 3].

The preparation of a new polyholostyrene film and its response to Gamma rays have been reported in our previous work [4]. In this paper we are presenting some of the characterization tests that are carried out to determine the optimal conditions for the accurate measurement of dosimeter response.

2. EXPERIMENTAL

The film was prepared in square sheets and cut into small pieces of 1×1 cm and 1×3 cm. The mean thickness of the dosimeters was ~ 50 ± 10 μm which was measured by a Mitotuyo micrometer with 0.001 mm precision. The Gamma irradiation was performed in a Fricke calibrated Gammacell-220 manufactured by Nordion Canada limited, with a dose rate of 52.6 Gy/min in the center of the irradiation chamber. Electron beam irradiation was performed using a Rhodotron TT200 (Belgium) with a maximum energy of 10 MeV calibrated by a calorimeter. The induced absorbances were read after 24h at the major absorption band with a wavelength of 630 nm with a Pye Unicam spectrophotometer (PU-8800) manufactured by the Philips company.

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3. RESULT AND DISCUSSION

Preliminary performance characterization tests were implemented during the development of our dosimeter to determine the optimal conditions for the dosimeter manufacture and for the measurement of the dosimeter response. These tests include those that may affect the dosimeter before, during, or after the irradiation, and also during the dosimeter analysis.

a) Pre-irradiation stability

Pre-irradiation stability of the films was investigated at different storage temperatures and relative humidites. In order to study the temperature effect, the background absorbance of the films were measured and were kept for a period of one month at 25, 30, and 37 °C at room relative humidity, ~50 %. In the same way, for measuring relative humidity effect, the background absorbance of the films were measured and were then kept for a period of one month at 12, 35, 75, and 95% relative humidity at ambient temperature. Measured absorbance results after one month indicated that there are no remarkable spectral changes relative to humidity and temperature variations for one month prior to irradiation**.**

b) Dose rate effect

The effect of the absorbed dose rate on the dosimeter response was studied by irradiating sets of dosimeters in the center of Gammacell-220 at low dose rates, 52.6, 16.9, and 5 Gy/min. The dose rate of 52.6 Gy/min was reduced to 16.9 and 5 by insertion of 1.65-cm and 4-cm lead liners in the outside periphery of the Gammacell chamber. The dose rate dependance curve shows the response of the film increases with the decreasing dose rate (Fig. 1). This may occur due to the low activity of our gamma cell, and consequently, very long irradiation times, resulting in interfering chemical effects in the formation of dye carbonium ions.

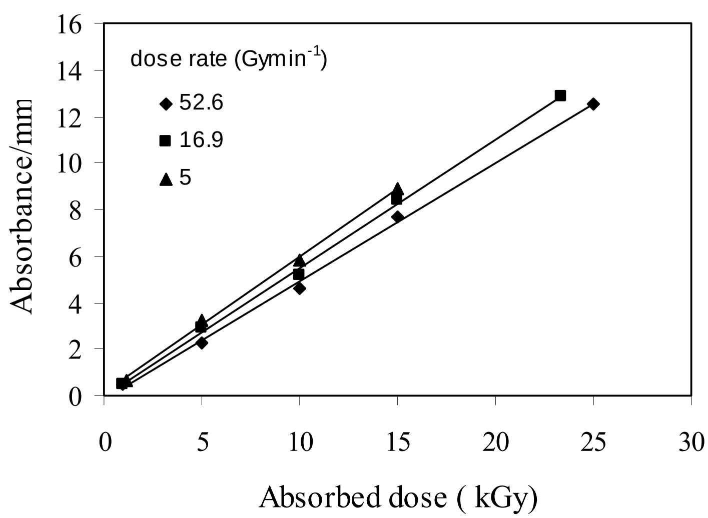

Fig. 1. Effect of dose rates variations on the response of the dosimeter

In order to study the effect of large differences in absorbed dose rates, the dosimeter was calibrated with both gamma rays and electrons in the same conditions. Figure 2 shows that there is minimal dose rate dependence of response between continous long-term gamma irradiation and short-term irradiation with an electron beam. The combined uncertainties of the absorbed-dose evaluations at a 95 percent confidence level by the films were lower than ±5 percent.

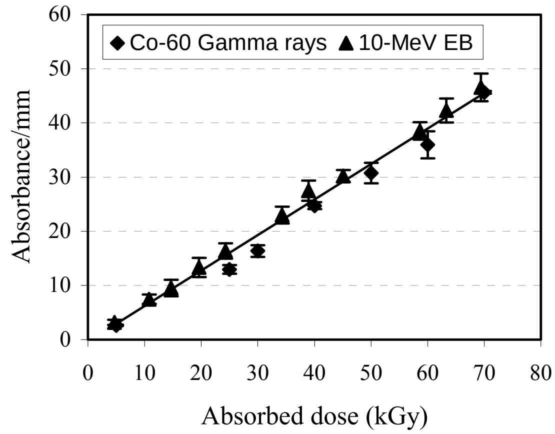

Fig. 2. Gamma ray and electron beam response curves for GIC-79 at 630 nm. The vertical bars represent estimated random uncertainty at 95% confidence level

c) Post irradiation stability

Post irradiation response of the dosimeter was checked at room conditions (25°C, ~ 50% relative humidity). They were irradiated at 5 different absorbed doses and the stability of the responses was measured for a period of about one month after irradiation. Figure 3 indicates that all films follow the same post irradiation coloration effect within the first 24 h; the negative coloration effect in 10 kGy is probably a statistical error. After 24 h the dosimeter response was almost stable up to one month for all absorbed doses.

d) Temperature effect on Post-irradiation stability

The dosimeters were irradiated in environmental conditions (25°C, ~ 50% relative humidity) at the applied doses of 5 and 25 kGy. They were stored for a period of one month at 25, 30, and 37 °C at the background relative humidity; ~50 % and their response were compared with those stored at room temperature. Post irradiation measurements in Fig. 4 show that the greatest increase is about 15%, which occurred at the highest storage temperature in both 5 and 25 kGy, however, the response of the dosimeters for all temperatures, even at 37 °C, are stable over the storage period.

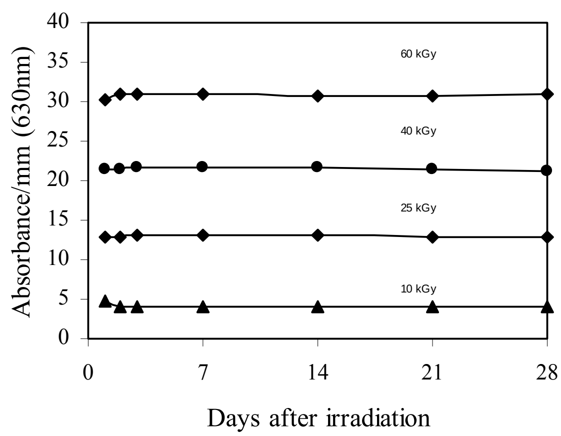

Fig. 3. Post-irradiation stability of the film stored in the dark at room temperature

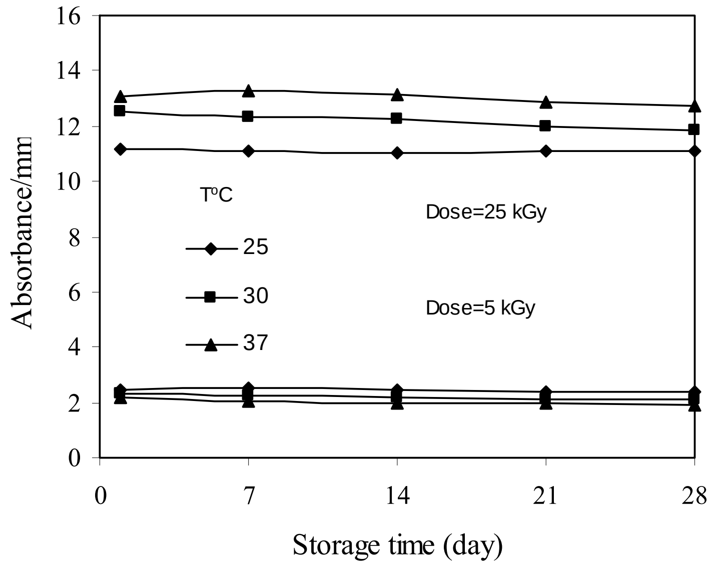

Fig. 4. Change in effective response at different relative temperatures with storage time after irradiation

e) Humidity effect on Post-irradiation stability

The films were irradiated in environmental conditions (25°C, ~ 50% relative humidity) at 5 and 25 kGy doses. They were stored for a period of one month at 12, 35, 75, and 95% relative humidity at ambient temperature and their responses were compared with those stored at room relative humidity (~50%). Figure 5 shows the results of the humidity effect on dosimeter response during the storage period after irradiation. The relative response variation is lower than 6%, except for the lowest humidity datum at 5 kGy where it was about 12 % higher than that stored at room relative humidity.

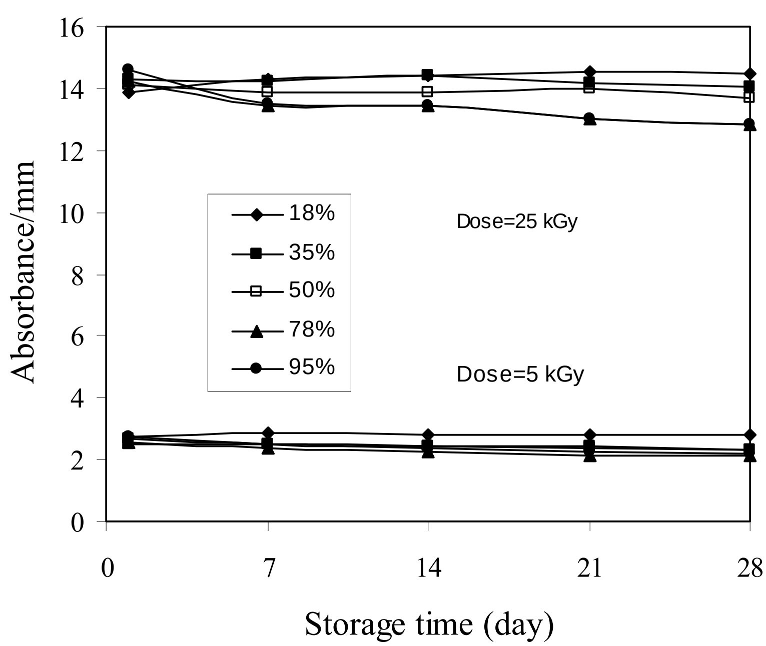

Fig. 5. Change in effective response at different relative humidities with storage time after irradiation

4. CONCLUSIONS

The results of this study confirm that GIC-79 radiochromic film can be a useful dosimeter for quality control in radiation processing work, both for gamma and electron irradiation systems. Like other kinds of routine dosimeters, it is necessary to calibrate the film against a reference standard dosimeter under the same conditions and check all parameters for each batch of the produced GIC-79 films. The dosimeter can be stored in air at room temperature for at least four weeks. Storage of these films under wide variations of temperature and relative humidity is not recommended. Further work is underway to upgrade or increase the sensitivity of the film response at a lower range of applied doses.

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