Temperature Effects on the Response of a Radiochromic Film Dosimeter

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Summary: The dosimetric characteristics of a commercially available radiochromic thin plastic film (Gafchromic) dosimeter have been evaluated spectrophotometrically. The response curves at longer wavelengths (596 and 650 nm) show a linear response up to an absorbed doses of 2 kGy, whereas the response curves at shorter wavelengths (350, 375, 400, 450, 500 nm) are linear up to 5 kGy. If stored at room temperature (ca. 25 °C) in dark, the pre-irradiation shelf-life of the film is more than 30 months. The dosimetric film also shows stable behaviour up to 40 days during post irradiation storage at room temperature in dark. The response is stable at lower temperature (-10 and 7 °C) at 596 nm but shows some variations at 650 nm at higher doses, while at higher temperature (40 °C) the response is unstable. The response shows increase in absorbance as the radiation chamber temperature i increased from 0 to 46 °C.

Introduction

Radiochromic plastic films sheets have widely been used as radiation monitors for routine determination of absorbed dose in radiation processing [1-3]. These film dosimeters are preferred as routine dosimeters owing to their useful properties like low cost, long shelf life and post-irradiation stability. These film dosimeters are rugged, can be handled and transported easily and can be conveniently analysed spectrophotometrically. We have analysed some commercially available radiochromic films as well as some PMMA sheets as radiation dosimeters [4-7]. In the present paper we are reporting some of the dosimetric characteristics of commercially available Gafchromic plastic films as high-dose radiation dosimeter and effects of temperature on the response of these dosimeters.

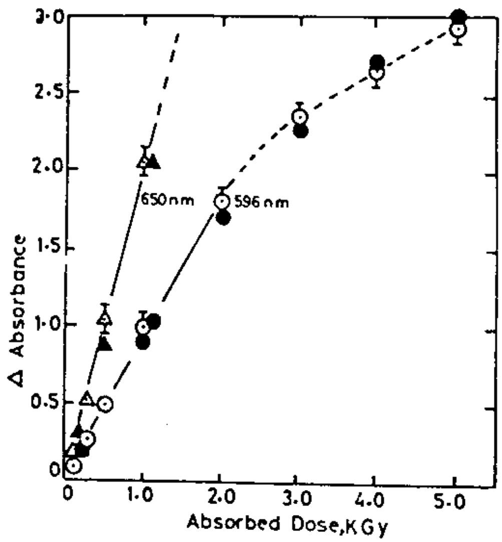

Fig.1: Response curves for Gafchromic plastic film at 596 and 650 nm. Filled and open symbols represent the results recorded before and after pre-irradiation storage period of 30 months.

Results and Discussion

Response curves and useful dose range

The dosimetric film is transparent and shows no pre-irradiation absorption property, but develops blue colour when exposed to ionization radiation with two absorption maxima around 600 and 650 nm, which shifts to somewhat shorter wavelengths at higher doses. For response curves, the change in optical density as a function of absorbed dose was plotted at two selected wavelengths *i.e.* at 596 and 650 nm as shown in Figure 1. The response curves show linearity up to an absorbed dose of 2 kGy at 596 nm and up to 1 kGy at 650 nm. Therefore, useful dose range for the dosimetric film is up to 2 kGy, however with proper calibration, this useful range can be increased to 5 kGy (Fig. 1). This range makes the use of this film dosimeter suitable for application in food irradiation and other radiation processing.

Response curves at other wavelengths (350, 375, 400, 450 and 500 nm) were also drawn for the dosimeter, as presented in Figure 2. The curves show linear response up to an absorbed dose of 5 kGy at all these wavelengths. Therefore for higher doses (0.5 - 5 kGy), the response should be measured at shorter wavelengths, such as 500 or 450 nm, as compared to 596 and 650 nm.

Pre-irradiation shelf life

To check the pre-irradiation shelf life of the dosimeter, it was stored in dark at room temperature (ca. 25 °C) for 30 months. The response curve was drawn before storage (filled circles and triangles) and after this storage period (open circles and triangles) as shown in Figure 1. Within experimental errors, the results after storage are the same as obtained before storage. This comparison shows long shelf life of the Gafchromic film dosimeter (more than 30 months) if stored at room temperature in dark.

Post-irradiation storage effect

The stability of response of the dosimeter during post-irradiation storage in dark is shown in Figure 3. This film dosimeter was irradiated to absorbed dose of 0.5 or 1.0 kGy. The response of dosimeter was measured at 596 and 650 nm as a function of storage time in days. The results show an almost stable response at both the wavelength up to a storage period of 40 days. For sample irradiated to 0.5 kGy a small decrease in the response is observed for first two days at both the wavelengths. This is followed by a stable response up to 40 days. This initial decrease in response of dosimeter may be due to its characteristically unstable behaviour at low absorbed doses of irradiation.

Effects of temperature during post-irradiation storage

The effect of temperature on the response of dosimeter were studied very carefully since in several countries, like Pakistan, the temperature fluctuations at different times of the year and at different locations, where radiation sources are located, are quite wide. In addition, there are certain foods which are essentially irradiated in frozen state or stored in frozen state after irradiation, so it was considered necessary to study the effects of different temperatures on the response.

In order to evaluate the effect of temperature during post-irradiation storage on the response of film dosimeters, the films were irradiated at room temperature to 0.5 to 1.0 kGy. The irradiated films

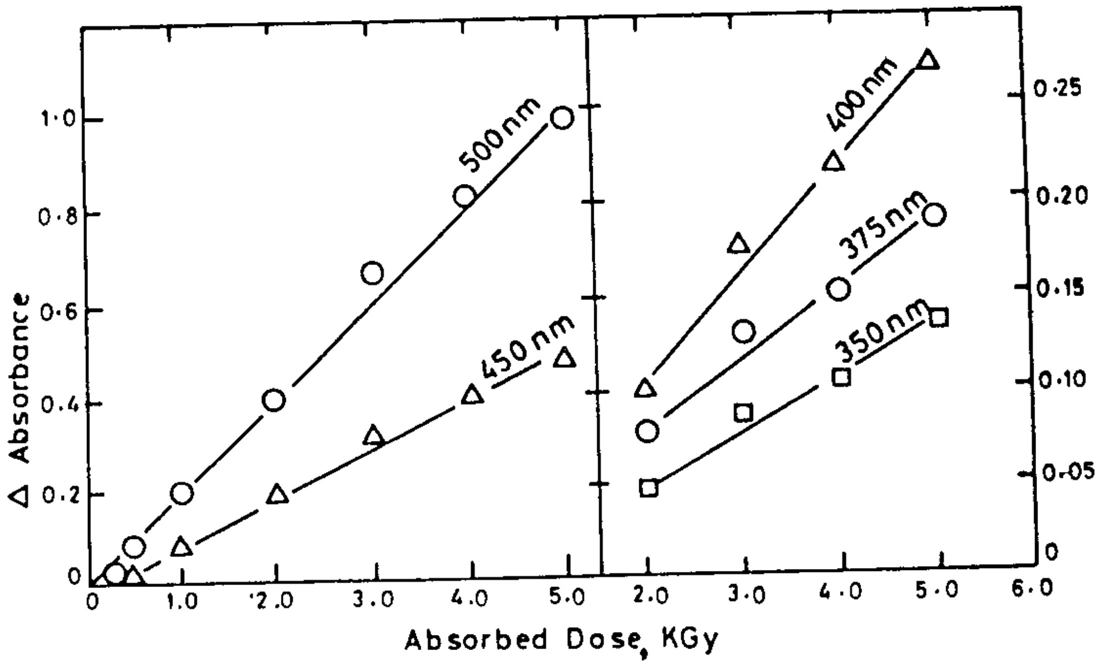

Fig. 2: Response curves for Gafchromic plastic film at 350, 400, 450 and 500 nm.

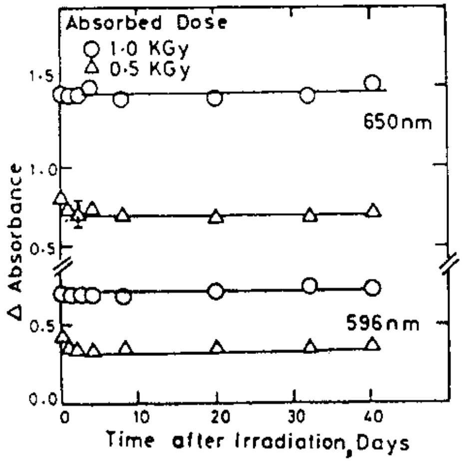

Fig. 3: Post-irradiation stability of response of Gafchromic plastic film dosimeter in dark at room temperature. Absorbed doses 1.0 and 0.5 kGy.

were stored at constant temperature conditions (-10, 7 and 40 °C). The response was measured at selected time intervals for a time period of 41 days at two wavelengths. The response as function of storage time in days was plotted as shown in Figures 4 and 5 for storage temperatures of -10 and 40 °C, respectively. The Figure 4 shows the response of dosimeter irradiated to the absorbed doses of 1.0 kGy or 0.5 kGy at storage temperature of -10 °C. At 596 nm, the response is stable for both the doses till 41 days. The response of dosimeter recorded at 650 nm behaves differently for two absorbed doses. For the absorbed dose of 1.0 kGy there is initial increase of response followed by a gradual decrease in response with time, while at lower absorbed dose of 0.5 kGy, the dosimeter shows some initial increase of response for the first two days followed by stable response behavior throughout the remaining storage period of 41 days.

The results for storage at 7 °C were similar to those mentioned above for storage at -10 °C except that the increase at 650 nm were less prominent. Effects of post-irradiation storage at room temperature (ca. 25 °C) has been reported in the earlier section (see Figure 3). The response of dosimeter for storage at 25 °C is quite stable throughout the entire storage period of 40 days except some decrease during first two days at lower absorbed dose (0.5 kGy). Figure 5 shows the effect of post-irradiation storage of dosimeter at 40 °C on the

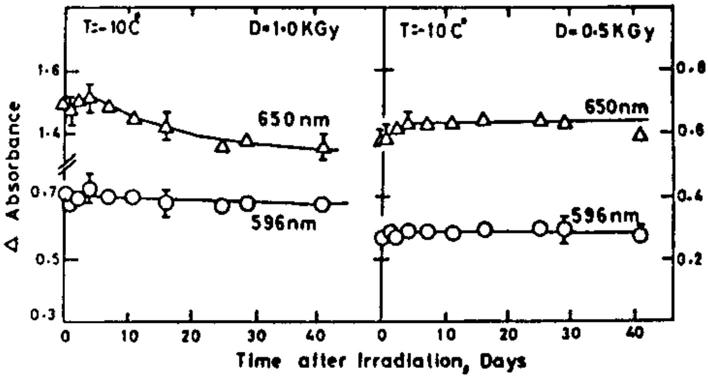

Fig. 4: Post-irradiation stability of response of film dosimeter at -10 °C. Absorbance doses 1.0 and 0.5 kGy.

response of the dosimeter. The response was measured for two absorbed doses of 0.5 and 1.0 kGy at both the wavelengths of analysis. The response of dosimeter is not stable at 40 °C. The results show sharp increase in response during first few days of irradiation followed by slow and continuous increase in response at both the wavelengths for remaining storage period of 41 days.

Effect of temperature during irradiation

The dosimeter film strips after conditioning to various temeprature (-20, 0, 23, 40 and 46 °C) were exposed to gamma irradiation at the respective temperature to an absorbed dose of 1.0 kGy. The irradiated films were brought to room temperature before measurements of optical response at both the wavelenths of analysis. The response as a function of irradiation chamber temperature is shown in Figure 6. It is apparent that the response of dosimeter is dependent on the temperature during irradiation. The results show a fairly constant response at 596 nm between temperature range of -20 to 0 °C which is followed by a sharp increased in response from 23 to 46 °C. The response of dosimeter at 650 nm shows a continuous increase right from -20 to 46 °C. The temperature dependent behaviour of the film dosimeter limits its applications to a small temperature range.

Experimental

The polyester based plastic film was manufactured by GAF Chemical Corporation, USA. It is 100 μm thick, colourless transparent film with a

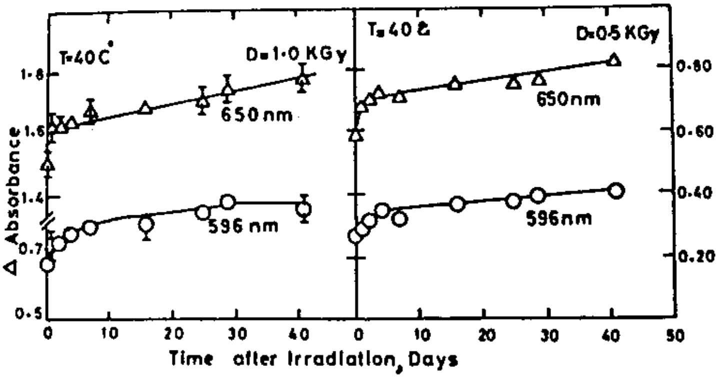

Fig. 5: Post-irradiation stability of response of film dosimeter at 40 °C. Absorbed doses 1.0 and 0.5 kGy.

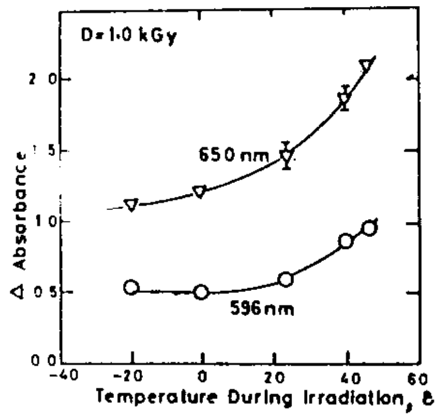

Fig. 6: Effect of temperature of radiation chamber on the response of Gafchromic plastic film. Absorbed dose 1.0 kGy.

radiochromic imaging layer coated uniformly on one side of the film. The radiation sensitive layers is made up of microcrystals of radiation sensitive monomer. When these microcrystals are exposed to ionizing radiation, polymerization occurs and the film develops a very fine grain blue colour which can be measured spectrophotometrically. The film sheet was cut into small square pieces of 1 x 1 cm^2 dimensions for dosimetric analysis. Each of these pieces could be easily placed in a specially designed film holder, which was fitted to the sample holder of Varian DMS-200 spectrophotometer. The optical absorbance of each irradiated film with reference to unirradiated film was measured at the selected wavelengths. A set of four to six dosimeters was irradiated at a time to a predetermined absorbed dose, using Co-60 gamma-ray source (Issledovatel, USSR) available at the Nuclear Institute for Food and Agricultural (NIFA), Peshawar. In order to maintain electronic equilibrium, the dosimeter film strips were sandwitched between two 5 mm thick polystyrene blocks. This whole assembly was then sealed in thin black plyethene envelops to ensure the protection of the dosimeters from light. The dosimeters were stored in the dark at room temperature (ca. 25 °C) before and after irradiation, unless otherwise stated. The ionizing radiation source used in the present study was calibrated using ferrous sulphate (Fricke) dosimeter solutions [8].

To check the stability of the response during post-irradiation storage at different temperatures, the dosimetric strips after irradiation were stored in dark at the desired temperature until photometeric analysis. To investigate the effects of temperature during irradiation, sets of sealed dosimeters were pre-treated by immersing in constant temperature liquid bath in double walled Dewar flask for about one hour and then irradiated at the same temperature in the Dewar flask.

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