Dosimetric Characteristics of FWT-63-02 Radiochromic Film for Quality Assurance in Radiation Processing Industry

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Summary: For a commercially available radiochromic film (FWT-63-02), response functions were determined at the wavelength of maximum absorbance (600 nm) and at several other wavelengths, such as 550, 625, 640 and 650 nm. At 600 nm the dosimeter was found to have a linear response up to 5 kGy. At longer wavelengths (625, 640 and 650 nm), the film can be useful even up to 25 kGy. Post-irradiation stability at different storage temperatures (-10, 7, 25, 40 and 60 °C) for dosimeters irradiated to 2 or 4 kGy was also determined. The response at lower temperature (-10, 7 °C) was stable up to 35 days. At 40 and 60 °C the dosimeter, apart from some initial increase in the response for the first 24 hours showed nearly stable response up to 40 days. Possible use of these radiochromic film dosimeters for quality assurance in radiation processing using gamma rays has been discussed.

Introduction

Radiation processing is an emerging technology with applications in several fields, such as polymer modifications, sterilization of medical products and pharmaceutical, food irradiation, treatment of municipal and industrial wastes, scrubbing of industrial flue gases, curing of plastic coating and inks and production of heat shrinkable plastics. Radiation dosimetry is fundamental to all these industrial processes for routine control and for quality assurance.

Plastic films with dissolved dyes or dye precursors are extensively used as routine dosimeters for a number of radiation applications, such as food irradiation, sterilization of medical products and other radiation processes [1]. These plastic films are conveniently analyzed spectrophotometrically and absorption charges at selected wavelengths are measured as function of absorbed dose. Dosimetric properties of several film dosimeters have already been studied extensively [2-7]. We have studied the dosimetric response and stability of a number of undyed and dyed plastics sheets manufactured commercially in Pakistan as well as several radiochromic films. In this paper we have analyzed the response function at several wavelengths and some other dosimetric characteristics, such as the effects of post-irradiation temperature on stability of response for a commercially available radiochromic film (FWT-63-02). The film is potentially useful for quality control and dosimetric applications in food irradiation, medical products sterilization and other radiation processing applications.

Results and Discussions

The dosimetric film, which is transparent with light blue colour before irradiation develops dark blue colour on gamma irradiation. The

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absorption spectra of the irradiated films (for absorbed doses of 0, 0.1, 0.3, 1.0, 2.0 and 4.0 kGy) show increase in absorbance from 500 nm to 660 nm with absorption maxima at 600 nm as shown in Figure 1. Radiation chemistry of pararosaniline

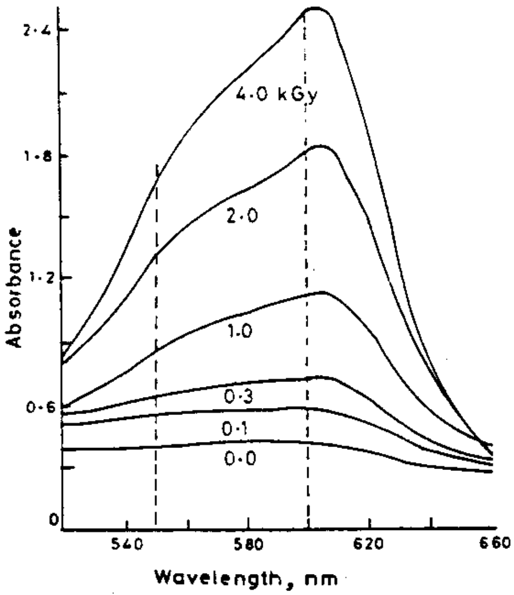

Fig. 1 Absorption spectra of unirradiated and irradiated FWT-63-02 film. The numbers beside the spectra show the absorbed dose in water. The dotted lines show the selected wavelengths for analysis.

cynide dyes in aqueous solutions, organic solutions as well as in form of polymeric films have been previously studied [1-3,5]. On irradiation, scission and elimination of cyanide radical takes place and a board absorption peak in 500-650 nm region due to isomerism of resulting carbonium cation develops. This results in change in absorption at the peak wavelength (around 600 nm region) as well as over all the visible region.

Response curve and useful dose-range:

Response curves for the dosimeter were determined at wavelength of maximum absorbance (600 nm) as well as at several other wavelengths (550, 625, 640 and 650 nm). The change in absorbance per unit thickness (DA/mm) was plotted against absorbed dose. At 600 nm the dosimeter shows linear response up to 4 kGy whereas at 550 nm the response was found to be linear up to 6 kGy (Figure 2). However, the response determined at longer wavelengths (i.e. 625, 640 and 650 nm) were found to be linear for a wider absorbed dose range as shown in Figure 3. The response function at 640 nm is linear up to 15 kGy and at 650 nm up to 25 kGy and, therefore, analysis of response at this wavelength is useful for high dose determination, such as in sterilization and food irradiation. The useful absorbed dose range of 10 kGy reported by us earlier [3] for analysis at 600 nm can thus be

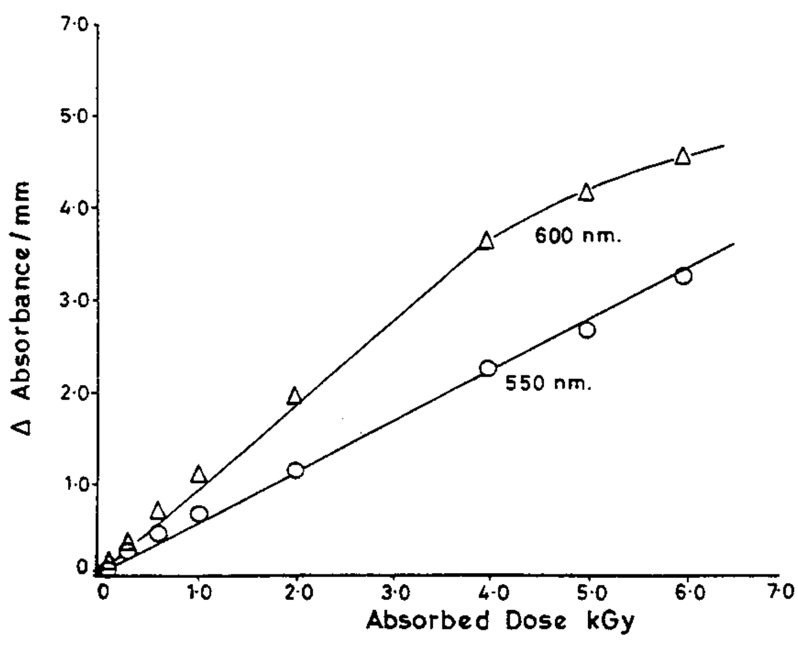

Fig. 2. Response of FWT-63-02 film at 550 and 600 nm.

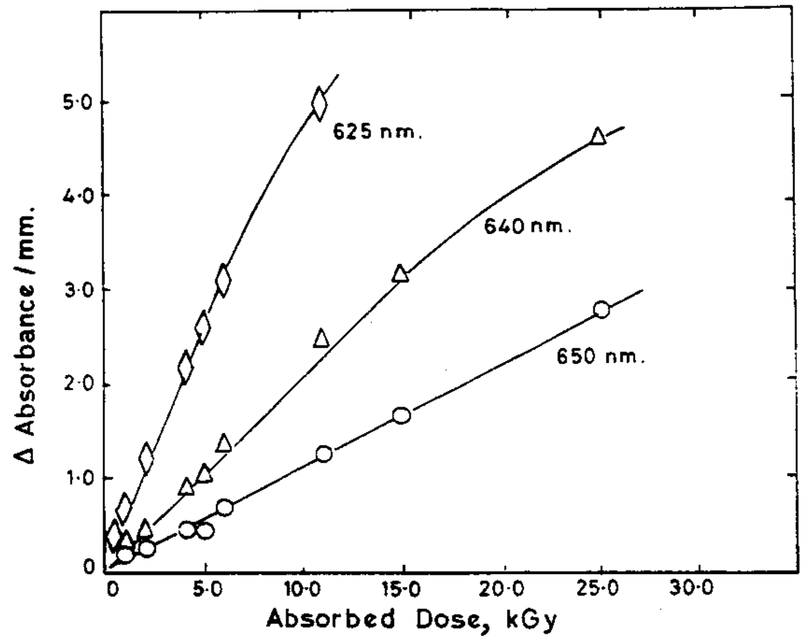

Fig. 3. Response of FWT-63-02 film at 625, 640 and 650 nm.

increased to 25 kGy if absorbance is measured at longer wavelengths. While the 0.05 mm thin film dosimeter analyzed by Buenfil-Burgos and coworkers [8] shows higher dose range, expected for thin film dosimeter, the thick film dosimeter analyzed in the present study shows better sensitivity. At 600 nm, the sensitivity of the film (i.e. increase in absorbance per unit of absorbed dose) is about 2.5 times more than for thin FWT-63-02 film [8].

Effect of temperature during post-irradiation storage:

In order to study post-irradiation temperature effects on the response, the dosimeter were irradiated for absorbed dose of 2 or 4 kGy and were stored in the dark at desired temperatures (i.e. -10, 7, 25, 40 and 60 °C). The response of the dosimeter was measured spectrophotometrically at 550, 600, 625, 640 and 650 nm at different intervals of time during post-irradiation storage. The results for lower temperatures (i.e. -10 and 7 °C) showed almost stable response up to 35 days at all the wavelengths of analysis as shown in Figure 4 for -10 °C. This was followed by a small decrease in the response till 55 days. It was found earlier that at 25 °C for 550 and 600 nm, the dosimeter shows a stable response at least up to 44 days [3]. However, at longer wavelengths (625, 640 and 650 nm), some initial decrease in the response was observed for the first few days which was followed by a stable response up to a storage period of 44 days, as shown in Figure 5. The effects of post-irradiation storage at 40 and 60 °C on the response of FWT-63-02 dosimeter showed a rapid increase in response for the first 24 hours followed by almost stable response till 46 days, as shown in Figure 6 for 40 °C. The magnitude of initial increase in the response is higher at higher doses and at higher storage temperatures. As mentioned above, the post-irradiation behaviour of the dosimetric system during the first 24 hours is somewhat different than reported earlier [3] and this may be due to very long pre-irradiation storage of film at room temperature. Stable dosimetric response during post-irradiation storage of seven weeks at temperatures from -5 to 30 °C for PVB based film containing pararosaniline leuco dye has been reported by Buenfil-Burgos *et al.* [8]. Under similar conditions of temperature, apart from a slight increase of response at 40 °C within first day of irradiation, the system shows a similar behaviour from -10 to 40 °C. Contrary to gradual increase in the response for post-irradiation storage at 60 °C

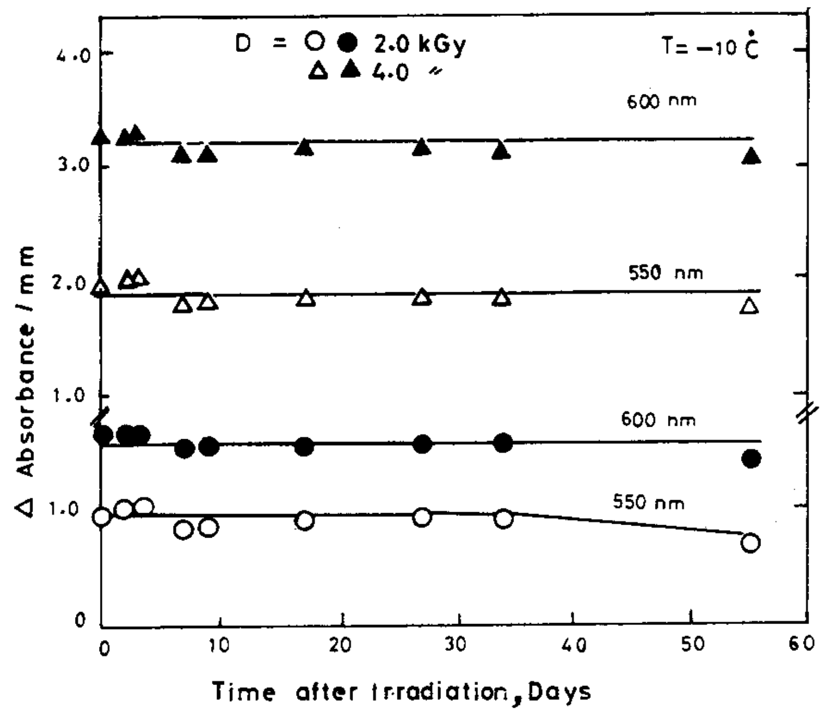

Fig. 4. Effect of post-irradiation storage temperature (-10 °C) on the response of FWT-63-02 film.

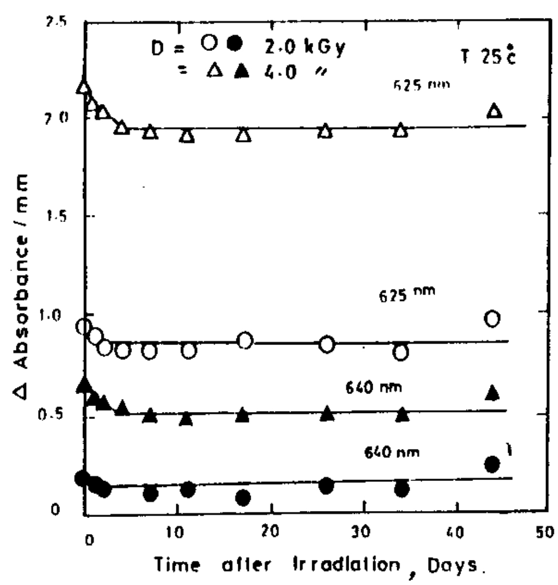

Fig. 5. Effect of post-irradiation storage temperature (25 °C) on the response of FWT-63-02 film.

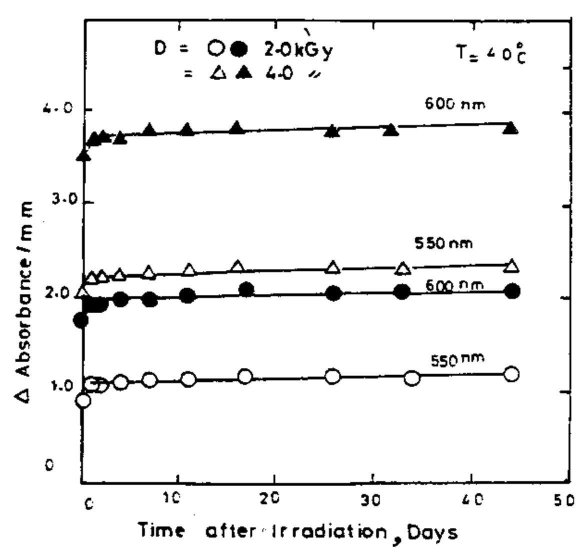

Fig. 6. Effect of post-irradiation storage temperature (40 °C) on the response of FWT-63-02 film.

reported by Buenfil-Burgos *et al.* [8] for PVB based film, our system shows abrupt initial increase in the response within first day of irradiation followed by a gradual and continuous increase throughout the storage period of 46 days. Results for HPR-CN dye in PVB matrix at longer wavelengths (510 and 603 nm) reported by Levine *et al.* [9] are also similar to those reportêd above for the similar wavelengths. At 25 and 60 °C following 24 hours of storage the dosimeter showed a similar behaviour as reported by us on the radiochromic film [3].

Experimental

Commercially available plastic film, FWT-63-02*, was cut into small pieces of 1 x 1 cm square. This is a polyvinyl butyral based film with hexa(hydroxyethyl) pararosaniline cynide dye embedded in it. The thickness of each piece was determined carefully using a micrometer. The thickness varies from 0.50 mm to 0.64 mm with a mean thickness of 0.55$\pm$ 0.01 mm for a large number of samples of 1 x 1 cm pieces.

The optical absorbance of each film strip was determined at several wavelengths of analysis (i.e. 550, 600, 625, 640 and 650 nm). A custom-built film holder fitted to a Varian DMS-200 UV-visible spectrophotometer was used for the measurement of absorbance. The absorbance measurements before and after irradiation were recorded against air as reference. The readings before irradiation, (A_o), and after irradiation, (A_i), were used to find the values of change in absorbance because of irradiation $\Delta A = A_i - A_o$ and ΔA per unit thickness (mm^{-1}) was calculated. A batch of two or three dosimeters were irradiated using gamma-rays from a Co-60 source located at the Nuclear Institute for Food and Agriculture (NIFA) Peshawar. The stack of films were about 5.0 cm from each side of the cylindrical radiation chamber at a hight of about 10 cm from the bottom of the chamber. To maintain electronic equilibrium and to avoid light effect, the dosimeters were stacked between two 5 mm thick polystyrene blocks and then tightly wrapped in a thin black polyethylene bag. The dosimeters were stored in the dark at room temperature (*ca.* 25 °C) before and after irradiation. The ionizing radiation source was calibrated using ferrous sulphate (Fricke) dosimetric solution [10] or Gafchromic film [4]. The radiation dose rate measured at the irradiation position was 3.54 $\pm$ 0.11 kGy/hours.

For studying post-irradiation stability at different storage temperatures, the irradiated dosimetric strips were stored in a constant temperature freezer or oven (temperature variations$\pm$ 2 °C) for the desired interval of time. Prior to spectrophotometric analysis the dosimetric strips were allowed to attain room temperature.

Conclusions

The FWT-63-02 dosimetric film is potentially useful for quality assurance and dosimetric applications in radiation processing industry. The dose range covered by the film is from 0.01 to 25 kGy. The dosimeters can be used for a number of applications, such as in sterilization (medical products, pharmaceuticals) and food irradiations (inhibition of sprouting in potatoes and onions, insect disinfection, extension of food shelf-life, etc.). These are important fields where there is potential for commercialization of radiation technology in Pakistan. The response of the dosimeter is stable for more than one month during post-irradiation storage at a wide range of temperature (-10 to 60 °C), making it suitable for routine commercial use. The dosimeter shows desirable characteristics for use in routine dosimetry and quality control of radiation processing industries; it is rugged, easy to handle, has wide absorbed dose range, long post-irradiation stability, simple read-out system (spectrophotometry), insensitive to different temperature, light and humidity conditions and economical price.

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*(FWT-63-02) film is available from Far West Technology, Inc. Goleta, CA 93227 USA

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