Stability of Response of Red PMMA Dosimeters at Different Temperatures

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Dosimetric response and post-irradiation stability of commercially available 2 mm thick polymethyl methacrylate sheets have been investigated spectrophotometrically. The response curves at 615, 650 and 700 nm show linear response from 4 to 15 kGy. At 640 nm the response is linear from 4 to 20 kGy and with proper calibration, the dosimeter can be used up to 50 kGy. The stability of response of red PMMA dosimeter during post-irradiation storage at different storage temperature (-10, 26, 35, 40, 50°C) has also been investigated at 640 nm. The dosimeters irradiated to 10 or 20 kGy and stored at room temperature show stable response for about three weeks, which is followed by slight and gradual decrease in response. The response during post-irradiation storage at lower temperature (-10 to 35°C) is stable over a period of 15 days while at higher temperature (45 and 55°C), fading of colour takes place which is faster at higher temperatures. These results show that the dosimetric characteristics of commercially available 2 mm thick red PMMA sheets are suitable for its possible application in radiation processing, such as sterilization of medical supplies and food irradiation, however storage of dosimeters at temperatures above 35°C should be avoided.

Introduction

Dyed or undyed polymethyl methacrylate (PMMA) sheets have widely been used for routine measurement of absorbed dose in radiation chemistry. These PMMA dosimeters are preferred as routine dosimeters since they are inexpensive, can be handled and transported easily and can be conveniently analyzed spectrophotometrically. At present in Pakistan, imported PMMA dosimeters are being used, such as by Pakistan Radiation Service (PARAS, Lahore) and there is need to evaluate locally manufactured low-cost PMMA sheets as radiation dosimeter. We have recently evaluated some commercially available PMMA sheets as well as some radiochromic film dosimeters [1-6]. In the present work, we are reporting some dosimetric characteristics of locally manufactured red PMMA sheets as high dose radiation dosimeter.

Results and Discussion

On irradiation by gamma-rays, red PMMA sheets develop darker colour in the wavelength range of 590 to 700 nm with maximum around 605 nm. There was a significant difference in the absorbance of irradiated (10 kGy) and unirradiated PMMA in the above mentioned wavelength range which can be used for dosimetric characterization [6]. In practice, 640 nm is generally used as read-out wavelength for red PMMA dosimeters [8].

Response curves

The response curves (radiation induced absorbance per unit thickness, ΔA (mm^{-1}), versus absorbed dose) can give information about useful dose range of the dosimeter. The response curves for red PMMA sheet samples were drawn at a number of wavelengths (e.g. 615, 640, 650 and 700 nm) as shown in Figure 1. The response curve at 640 nm follows a linear relationship up to an absorbed dose limit of 20 kGy, whereas the responses at the other wavelengths of analysis show a linear behaviour over a smaller absorbed dose range (4 to 15 kGy). The response becomes nonlinear at higher absorbed doses, however, with proper calibration, the response curves at 650 and 700 nm can be useful up to 50 kGy.

Post-irradiation stability of red PMMA dosimeter

The stability of the radiation induced absorbance with storage time between irradiation and spectrophotometric analysis at 640 nm is shown in Figure 2. These post-irradiation storage effects were studied for a period of about 80 days following irradiation. The red PMMA dosimeters were irradiated to absorbed doses of 10 or 20 kGy, stored in the dark at 25°C and the absorbance was measured at different storage times after irradiation. The results show that at both the absorbed doses there is no significant

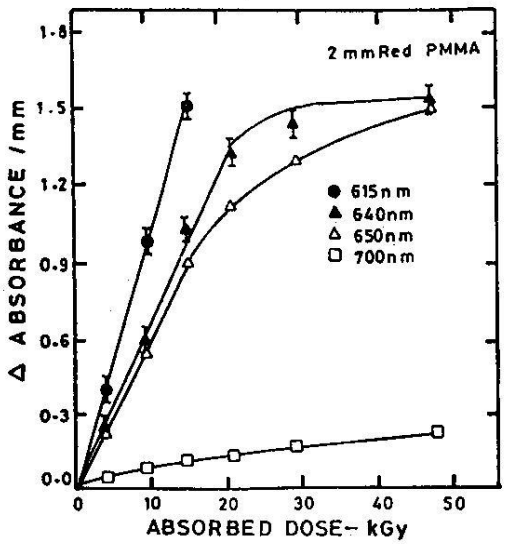

Fig.1: Response curves for 2 mm thick red PMMA sheets at 615, 640, 650 and 700 nm.

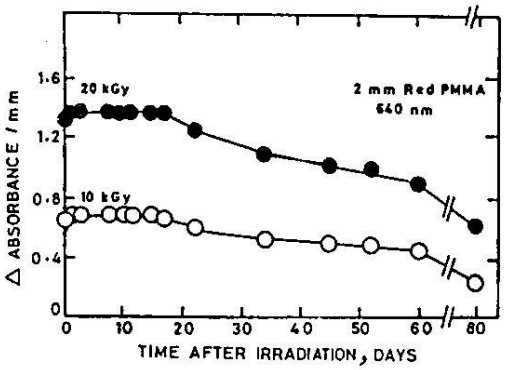

Fig. 2: Stability of response of 2 mm red PMMA dosimeter during post-irradiation storage at room temperature in dark. Absorbed doses 10 and 20 kGy.

change in the radiation induced absorbance over a period of about 20 days after irradiation. However, long term storage showed that a mild decrease occurred in the response of the red PMMA dosimeter.

The red plastic sheets investigated in the present study show similar post-irradiation stability as reported by Whittaker and several other workers [8-10]. Whittaker found that the post-irradiation changes in the response of red PMMA did not amount more than 4% during storage period of 25 days after irradiation [8]. Likewise Olejnik [9] and Radak [10] also have found that the response of red PMMA remained stable at ambient conditions for at least 10 to 20 days during storage in the dark in the presence of oxygen or simply air. They have also observed a slight decrease in the response during first 1 to 2 days, thereafter the response continued to increase at an almost imperceptible rate. The fading process during post-irradiation storage was found to be more severe at higher absorbed dose levels [10]. Foregoing discussion indicates that locally manufactured red PMMA sheets have good post-irradiation stability at least for three weeks, a behaviour similar to that observed by other for red PMMA specially manufactured for dosimetry [8,9].

Effect of temperature on the response of red PMMA dosimeter during post-irradiation storage

The degree of stability of 2 mm thick red PMMA dosimeters response during post-irradiation storage at a number of storage temperatures (-10, 26, 35, 45 and 55°C) was also measured at 640 nm. The results for 20 kGy are presented in Figure 3 and show that the response of dosimeter is almost stable at lower temperatures (-10, 26 and 35°C) and no major changes in absorbance are observed over a storage period of 15 days after irradiation. However, at higher temperature (45, 55°C), the absorbance is not stable and its values depend on the storage temperatures and on the storage time following irradiation. At these temperatures, initially there was a slight increase in absorbance over a period of 72 hours followed by fading of colour as shown in Figure 3. The extent and the rate of fading at 55°C was faster than at 45°C.

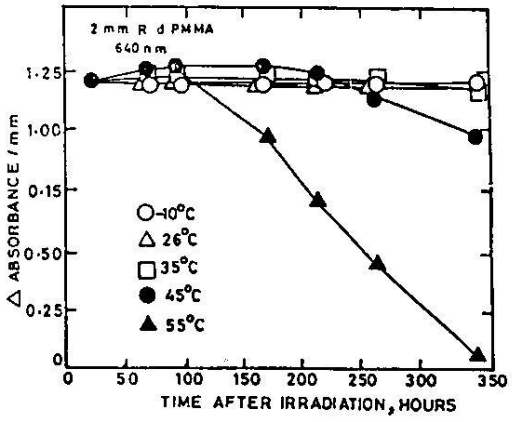

Fig. 3: Effect of post-irradiation storage temperature on the response of 2 mm red PMMA dosimeter. The symbols represent different post-irradiation storage temperatures used. Absorbed dose 20 kGy.

The results presented above show that the response of red PMMA dosimeters are affected by post-irradiation storage temperature. Temperatures between -10 to 35°C induced no significant changes in the response of irradiated red PMMA dosimeter and the dosimeters showed fairly stable response for a storage period of at least 15 days. At higher temperatures (45 and 55°C), the process of fading, which occurs at an almost imperceptible rate at ambient conditions is accelerated resulting in a drastic change in colouration. The speed and extent of fading has been associated with oxygen diffusion [11] and the present work shows that the fading increases with temperature. Storage temperature effects on the response of dosimeters found in the present study are also similar to those reported by Whittaker [11] and Olejnik [9]. These authors found out that the performance of red PMMA dosimeter during post-irradiation storage at ambient temperature was quite satisfactory. Our results at lower temperatures are also supported by a recent study which reported that the response of red PMMA did not depend on temperature within the range of 10 to 40°C during post-irradiation storage [12]. However, at elevated temperatures the results were not reproducible and either a large increase or decrease in the response was reported [9,11]. The locally manufactured red PMMA dosimeters tested in the present work also showed a severe fading at elevated temperatures. The above results have shown that locally manufactured 2 mm thick red PMMA sheets can be used as dosimeter for a wide dose range of 4 to 50 kGy which includes the radiation dose range used in industrial radiation processing, such as, radiation sterilization and food irradiation. In view of the enhancement of post-irradiation fading observed at elevated temperatures, it is suggested that irradiated dosimeters should be stored at lower temperatures.

Experimental

Red PMMA sheets (2 mm thick) manufactured by Pak Poly Industries (PPI), Karachi were purchased from local market. A cobalt-60 gamma rays source at the Nuclear Institute for Food and Agriculture (NIFA), Peshawar was used for irradiation. This radiation source was calibrated using Fricke dosimetry [7] and has typical dose rate of 3.76 kGy/h. The PMMA samples were irradiated at the room temperature (ca. 25°C). The thickness of the unirradiated PMMA strips and their absorbance before and after irradiation were measured. A Varian DMS-200 uv-visible spectrophotometer was used for optical absorbance measurements. Other experimental details have been given elsewhere [1,3,4].

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