

# Preliminary investigations of several new dyed PMMA dosimeters

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## Abstract

Radiochromic dosimeters such as Red 4034 Perspex and Gammachrome YR show good performance in the absorbed dose control quality in industrial radiation processes. Aiming to develop a sensitive, useful, practical and cheap dosimeter, dyed Polymethylmethacrylate (PMMA) sheets using yellow, red, blue and green colouring compounds, commercially available in Brazil, were developed and the dosimetric properties related to ionizing radiation were studied. Small pieces of  $1 \times 3 \text{ cm}^2$  of dyed PMMA were cut, cleaned, sealed in special pouches and irradiated with  $^{60}\text{Co}$  gamma doses between 0.5 and 100 kGy. The ionizing radiation effects on the optical properties were evaluated by means of spectrophotometric analysis. The studied parameters were: absorption spectra of irradiated and non-irradiated samples, batch reproducibility, dose response, thermal and optical fading and dose rate dependence between 0.49 and 4.9 kGy/h. The obtained results show the viability of using these developed dosimeters for dose evaluation in industrial gamma radiation processes.

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*Keywords:* Dosimetry; PMMA dosimeters; Gamma radiation; High dose

## 1. Introduction

Several works have been carried out after the first researches realized by Day and Stein (1951) on the effects of the ionizing radiation in polymethylmethacrylate (PMMA) sheets.

These materials are commonly used as routine dosimeters for measurement of absorbed doses in industrial radiation process (Barret et al., 1990; Whitaker et al., 1997).

PMMA is a very useful material, cheap and easy to obtain. It can be produced in different forms and colours, and has been studied as dosimeter material, considering the changes of the optical properties as a function of radiation dose.

The aim of this work is to develop and characterize PMMA dosimeters produced in Brazil using dyes

produced by Bayer, commercially known as Macrolex®: yellow 3G (class pyrazolone dyes); yellow 4G and red H (class azo dyes) and blue RR, green G, green 5B, red G and red 5B (class athraquinone dyes) to be applied in routine quality control of industrial radiation processes.

## 2. Experimental

A private firm using the dyes yellow, green, blue and red, from Bayer, produced specially sheets of PMMA ( $120 \times 60 \text{ cm}^2$  and thickness between 2 and 2.5 mm) to be used in this work. The PMMA sheets were cut into strips (10 mm width and 30 mm length) and sealed in special aluminium/paper/polyethylene pouches.

The dosimeters were irradiated at electronic equilibrium conditions and room temperature and humidity with  $^{60}\text{Co}$  gamma radiation, using the Gammacell 220 source installed at the Radiation Technology Center

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CTR/IPEN-CNEN/SP. The absorbed dose rate corresponding to 4.9 kGy/h in April/2003, was determined by Fricke dosimeter.

The commercial Red 4034 Perspex and Gamma-chrome YR dosimeters were used for comparison with the new PMMA dosimeters. The absorbance changes were measured with a Shimadzu UV-2001PC spectrophotometer at the wavelength of maximum absorbance or maximum transmittance, depending on the dosimeter absorption spectrum.

Each related point is the average of three measurements and the error bars the standard deviation of the mean ( $1\sigma$ ).

### 3. Results

The absorption spectrum obtained from non-irradiated PMMA dosimeters are shown in Figs. 1 (a)–(d). Figs. 2 (a)–(h) show dose–response curves to  $^{60}\text{Co}$  gamma irradiation with doses between 0.5 and 100 kGy, of the PMMA dosimeters produced with dyes yellow 3G, yellow 4G, blue RR, green G, green 5B, red H, red G and red 5B measured at 300, 353, 450, 528, 405, 620, 397, and 415 nm, respectively. The wavelengths of yellow 3G, yellow 4G, blue RR, green G and red 5B PMMA dosimeters were taken from transmittance spectrum and green 5B, red H and red G PMMA dosimeters were taken from absorbance spectrum. The

selected wavelengths presented higher sensitivity as a function of the dose and better stability as a function of environmental conditions.

To evaluate the dose rate dependence of the optical response, the samples were irradiated with 20 kGy of  $^{60}\text{Co}$  gamma radiation, with dose rates between 0.49 and 4.9 kGy/h. The relative response of the dosimeters was determined in terms of value of the absorbance by unit of thickness normalized for lower value of the dose-rate. The results obtained by the PMMA dosimeters yellow 3G, yellow 4G, green G and green 5B, and for the dosimeters red H, red G, red 5B and blue RR in Figs. 3 and 4, respectively, show a decrease in response of approximately 10% as the dose rate is increased.

The effects of temperatures, humidity and light on the dosimeters response were studied. The different humidity conditions between 0 and 100% were obtained by means of saturated salt solutions that are very useful in producing known relative humidity. The non-sealed dosimeters were maintained, for a preliminary test, during 24 h in specific conditions of relative humidity and then irradiated at same conditions. The irradiated dosimeters were stored at temperatures between 20°C and 35°C and under two different conditions, ambient and UV light, during 30 days. The dosimeters did not present significant variation on the absorbance response when exposed to the normal conditions of light and temperature, therefore, can be manipulated without special care. Although the dosimeters have not presented

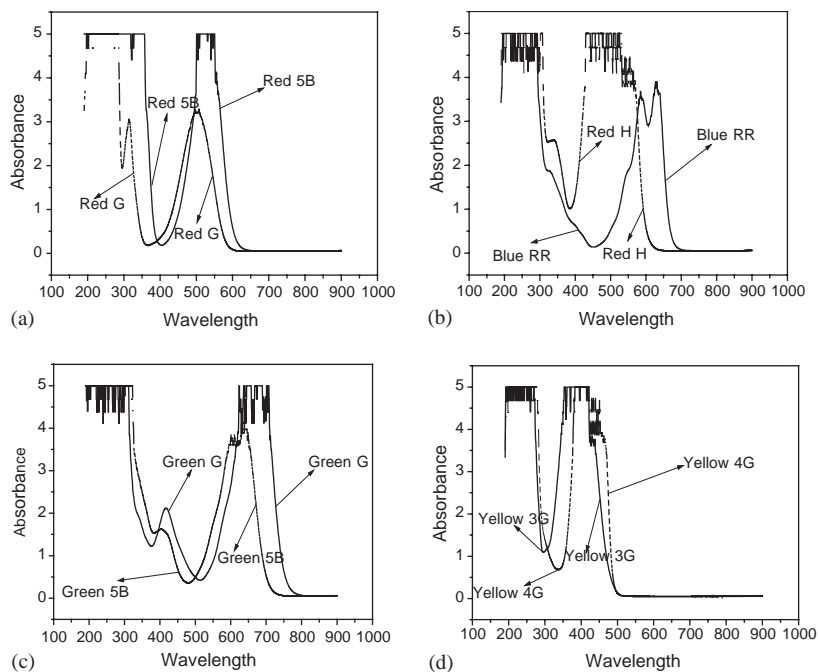


Fig 1. Absorption spectrum of the non-irradiated dyed PMMA dosimeters: (a) red 5B and red G; (b) red H and blue RR; (c) green 5B and green G; (d) yellow 3G and yellow 4G.

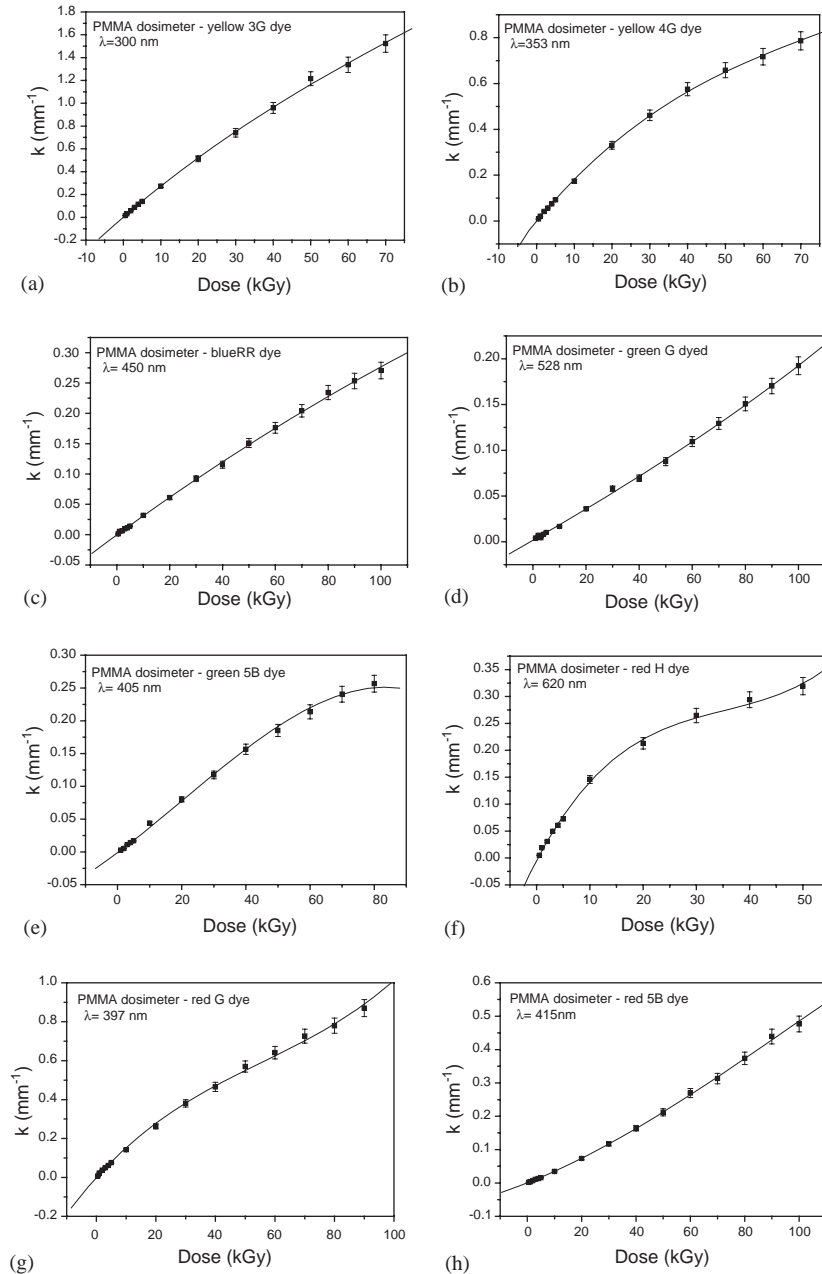


Fig. 2. Dose–response curves for PMMA dosimeters irradiated with  $^{60}\text{Co}$  gamma rays: (a) yellow 3G,  $\lambda=300$  nm. (b) yellow 4G,  $\lambda=353$  nm. (c) blue RR,  $\lambda=450$  nm. (d) green G,  $\lambda=528$  nm. (e) green 5B,  $\lambda=405$  nm. (f) red H,  $\lambda=620$  nm. (g) red G,  $\lambda=397$  nm. (h) red 5B,  $\lambda=415$  nm.

significant variation on the absorbance response for the different humidity conditions it is desirable that the dosimeters be maintained sealed in pouches.

The batch reproducibility was evaluated and was found to be better than 95% from batch to batch, represented by a sheet produced in the dimensions  $60 \times 120 \text{ cm}^2$ .

#### 4. Conclusions

The obtained results show the viability of using these developed dosimeters for dose evaluation in industrial gamma radiation processes. The dosimeters are easy to prepare, manipulate and analyze.

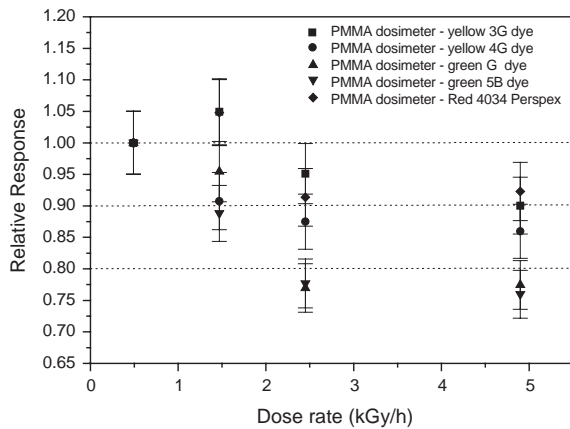


Fig. 3. Dose-rate response of absorbance of dyed PMMA dosimeters yellow 3G, yellow 4G, green G and green 5B: dose 20 kGy.

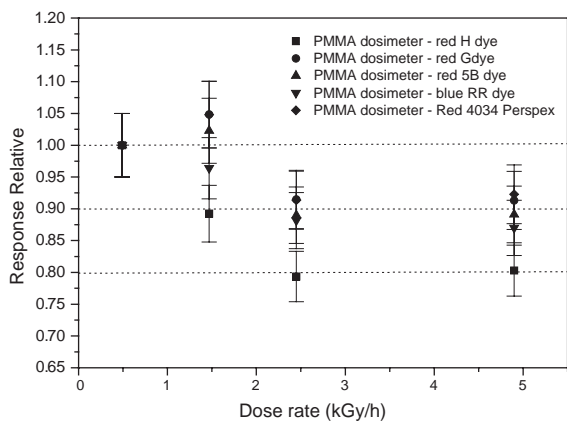


Fig. 4. Dose-rate response of absorbance of dyed PMMA dosimeters red H, red G, red 5B and blue RR: dose 20 kGy.

The useful dose range of the eight dyed PMMA dosimeters developed is large and interesting for dose evaluation in industrial gamma radiation process and can be compared to the commercially available Red 4034 Perspex and Gammachrome YR.

Absorbance changes that can be caused by adverse conditions of light, temperature and humidity, can be minimized if the dosimeters be maintained sealed in pouches.

The yellow 3G, yellow 4G and blue RR dosimeters indicate to be the most promising ones, considering their response function and dose range, although all others dosimeters can also be used for different dose ranges.

### Acknowledgements

The authors are thankful to FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the financial support.

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