Dosimetry of ^{60}Co gamma radiation source using polymeric materials

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ABSTRACT

The radiation dose deposited (energy per unit mass) in a material can be measured through various physical and chemical methods using a wide variety of detectors. This study aims to compare the dosimetric characteristics of commercial detectors in the films form with films developed in the high doses laboratory of the Metrology Radiation Management of IPEN. The detector's characteristic curve obtained by spectrophotometry graphically represents the change in optical density of the film for a selected wavelength as a function of total absorbed dose by the material under study. In order to be considered a promising detector, a material should presented some characteristics that become it appropriate to quality control of radiation processes, however, not all materials presents these properties simultaneously, and thus different detectors must be available to cover the full range of products and processes by radiation. Detectors presented large useful dose range and the influence of environmental conditions can be determined and avoided by proper handling of samples.

Keywords: dosimetry, films detector, spectrophotometric technique.

RESUMO

A dose de radiação depositada (energia por unidade de massa) em um material pode ser medida por variados métodos físicos e químicos usando uma grande variedade de detectores. Este estudo tem como objetivo comparar as características dosimétricas de detectores comerciais na forma de filmes com filmes desenvolvidos no Laboratório de Doses Altas da Gerência de Metrologia das Radiações do IPEN. A curva característica obtida por espectrofotometria representa graficamente a mudança na densidade óptica do filme em um comprimento de onda específico como uma função da dose absorvida total no material sob estudo. Para ser considerado um detector promissor, um material deve apresentar algumas características que o torna adequado para o controle de qualidade dos processos por radiação, no entanto, os materiais não apresentam todas estas propriedades simultaneamente, e, então, diferentes detectores precisam ser avaliados para abranger todo o intervalo de produtos e processos por radiação. Os detectores apresentam um intervalo de dose útil grande e a influência das condições ambientais pode ser determinada e evitada pelo correto manuseamento das amostras.

Palavras chave: dosimetria, detectores na forma de filmes, técnicas espectrofoto-métricas.

INTRODUCTION

A dosimetry system consists of dosimetric material, measurements instrumentation such as a spectrophotometer and a thickness gage, the calibration curve, reference standards and procedures for the system's use. Several dosimetry systems have been developed to assurance of radiation processing high quality. The radiation dose deposited (energy per unit mass) in a material can be measured through various physical and chemical methods using a wide variety of detectors. The detector's characteristic curve obtained by spectrophotometry graphically represents the change in optical density of the film for a selected wavelength as a function of total absorbed dose by the material under study.

There are several detectors available in the the market and others that were developed at IPEN, each one presenting a specific and characteristic curve dependent on their composition [1-6]. In order to be considered a promising detector, a material should have the following characteristics: linear response with the total absorbed dose; a large useful dose range; dose rate independent response; good reproducibility in the measured values; a response which is independent from temperature, light, humidity and other environmental conditions; easy handling and easy reading system; variety of sizes to allow doses measurements at various points of the irradiation chamber or irradiated materials; response stability over time before and after irradiation; low cost and easy availability, however, not all materials presents these properties simultaneously, and thus different detectors must be available to cover the full range of products and processes by radiation.

MATERIALS AND METHODS

Samples are supplied in different forms: polymethylmethacrylate sheets ((Red 4034 Perspex - Harwell) and (Red 5B - developed at IPEN)) rectangles sealed sachets in the dimensions 30 x 11 x 3 mm; cellulose triacetate (CTA – FTR-125 - Fujifilm) width 80 mm and length 100 m/reel, containing 15 % triphenylphosphate (TPP) by weight and its nominal thickness was 0.125 mm, and dyed thin nylon films with hexa(hydroxyethyl) aminotriphenylacetonitrile (HHEVC) (FWT 60 – Far West Technology) dimensions 10 cm x 10 cm x 42-52 microns.

A Gammacell 220 machine, cobalt-60 source, designed as a general purpose of research irradiator was used for samples irradiation. The cell comprises a small 3.7 litre sample chamber. Calibrated by IDAS/ IAEA program (International Dose Assurance Service) presented dose-rate of 1.93 kGy/h in 2010-Jan.

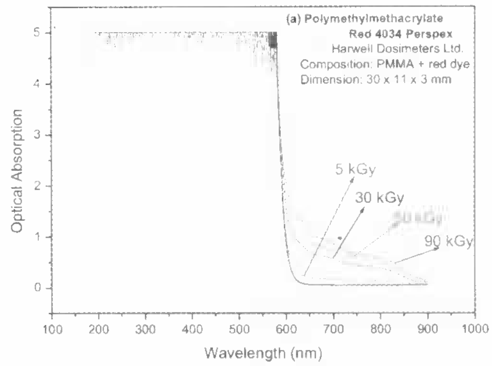
The optical absorption measurements were made on a Shimadzu UV-2101PC spectrophotometer. The absorbed dose is evaluated from the measurement value of the optical density at the wavelength of 640 nm (Red 4034), 415 nm (Red 5B), 280 nm (CTA) and 510/605 nm (FWT 60). For each irradiated dosimeter the absorbance and thickness values were recorded and the k-value (mm-1) was calculated.

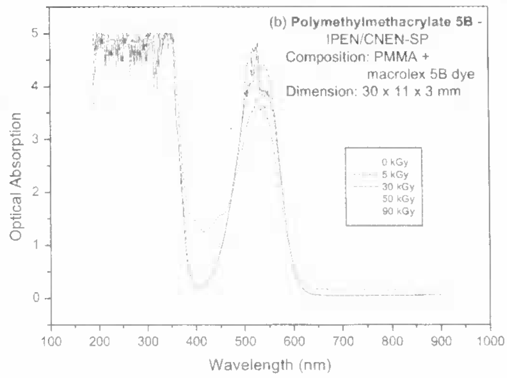
For irradiation in the ɣ-cells, to each dose the CTA and FWT films were grouped and sandwiched between two polymethylmethacrylate (PMMA) plates of 3 mm thickness to maintain electronic equilibrium conditions, and the other films were irradiated inside of the itself sachets (surrounding 1 mm PMMA).

RESULTS

Absorption optical spectra

Absorption optical spectra typical of four different kinds radiochromic films were obtained and are shown in Fig. 1 (a) and (b) to Red 4034 Perspex and Red 5B non-irradiated and irradiated samples, respectively, and, Fig. 1 (c) and (d) to CTA and FWT, respectively, to non-irradiated samples, cause, the analyses of irradiated samples were made only in the dosimetric wavelength.





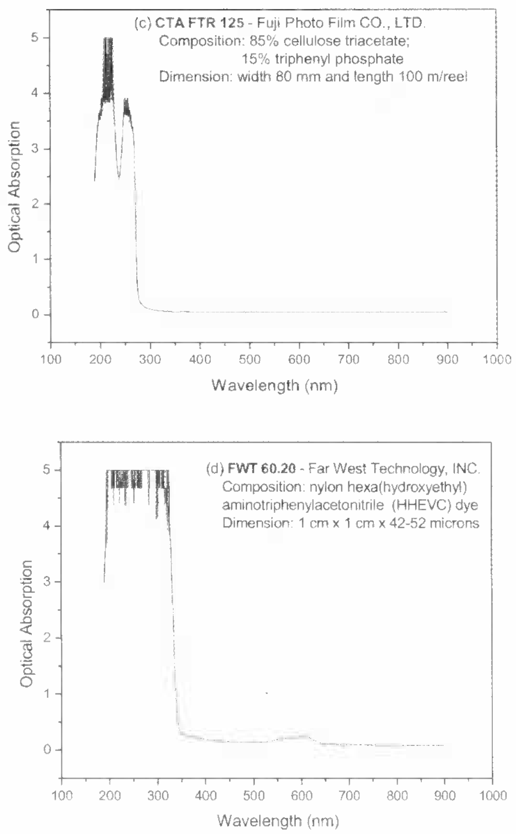


Figure 1: Optical absorption spectra of non-irradiated radiochromic films.

Temperature influence

The temperature effect on optical response of samples was investigated. Slight variations were observed in non-irradiated and irradiated (20 kGy) exposed PMMA Red 5B, PMMA Red 4034 and CTA samples in the wavelength 640, 415 and 280 nm, respectively, at range between 4 oC and 100 oC as shown in the Fig. 2. The irradiated samples present the same behavior. The FWT dosimeters (=605 nm) present some temperature dependence, the best storage conditions are between 15 and 30 oC, above this temperature occur color development and in low temperature occur water condensation and the films sticks.

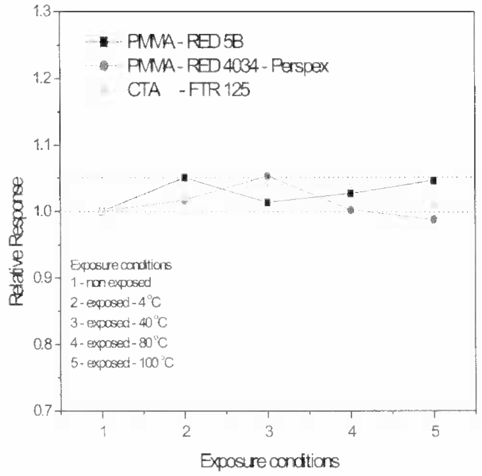
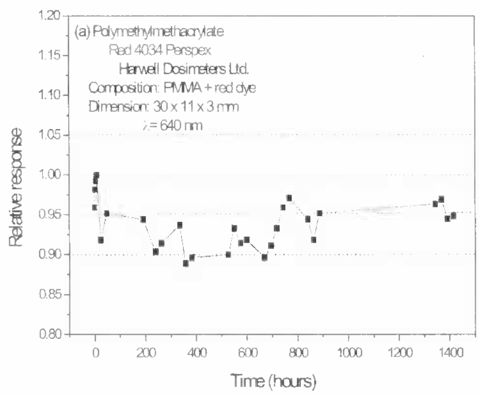


Figure 2: Temperature effect on PMMA Red 5B, PMMA Red 4034 and CTA samples at range between 4 oC and 100 oC.

Light influence

The absorbance was measured after time intervals, in which detectors were exposed to room light as shown in Fig. 3 to PMMA Red 5B, PMMA Red 4034, CTA and FWT, respectively. It was observed that Red 4034 and Red 5B detectors response is stable in the studied range and they can be manipulated without special cares. The CTA detector can be exposed to room light until 3 hours without significant variations of its response. The FWT detector is extremely sensitive to light and more intensive at wavelength 605 nm. The time to the dosimeters develop full color vary depending of exposure time on the ambient conditions (humidity, light and temperature) and the absorbed radiation.



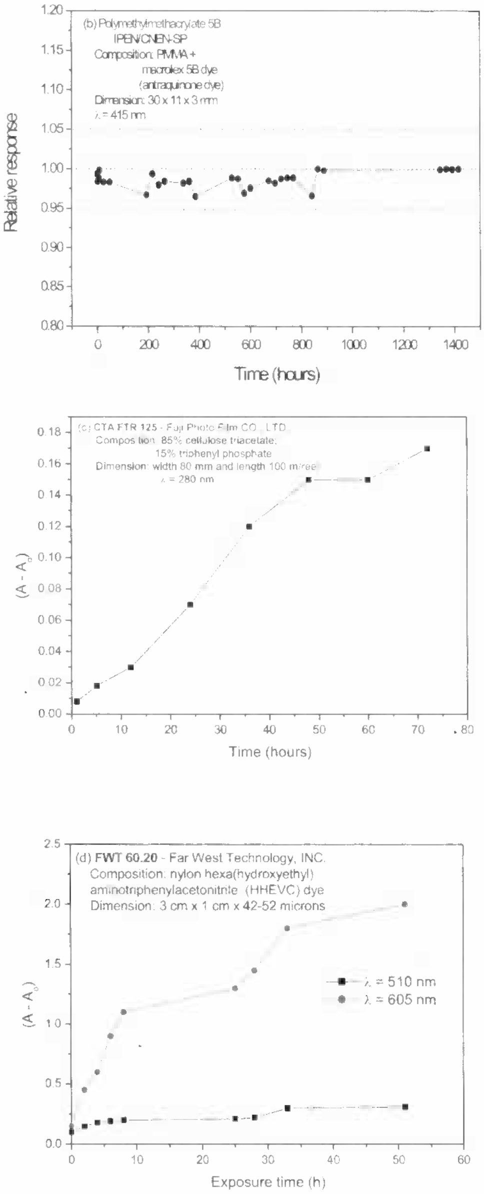


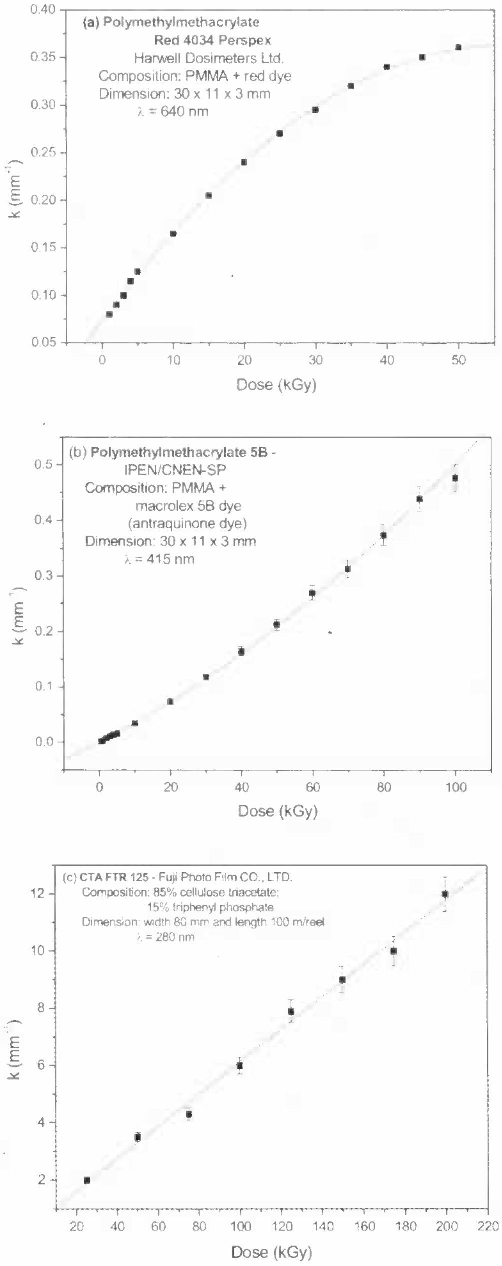
Figure 3: Ambient light influence on Red 4034, Red 5B, CTA and FWT film.

Reproducibility

In order to determine the radiochromic films samples reproducibility the dose response were obtained on different occasions in two different doses, 20 and 40 kGy. The optical response presents intra-batch reproducibility better than 96 % (1σ) for all films.

Dose response curves

The dosimetry systems must be calibrated prior to use, a calibrated 60Co source by the IDAS/IAEA programme was used. The detectors were irradiated in different dose range, the calibration curves obtained are shown in Fig. 4. Can be observed that each detector operates in a specific dose range. The literature data are shown in Tab.1.



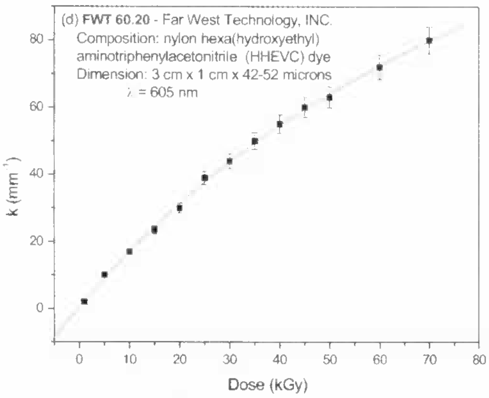


Figure 4: Dose response calibration curves of PMMA Red 5B, PMMA Red 4034, CTA FTR-125 and FWT 60.20 films.

Table 1: Useful dose range literature

Detector	Useful dose range (kGy)
PMMA Red 4034 Perspex	5-50
CTA FTR-125	10-300
FWT 60.20	0.01-1 kGy (605 nm) / 0.8-150 kGy (510 nm)

CONCLUSIONS

The accurate measurement of radiation dose is very important, for this reason a wide variety of radiation detectors and dosimeters have been developed.

These results show that all detectors are able to offer an accurate and precise gamma dose measures.

The measurement technique chosen is appropriate and provides fast and easy acquisition data.

Some radiation detectors are highly sensitive to room conditions and must be necessary to protect them. Light influence in FWT 60.20 films can be highly reduced sealing them between two aluminum layers paper and if manipulated in a low lighting room. The Red 4034 and Red 5B detectors are available sealed in sachets, and must be avoid the CTA detectors manipulation in light ambient condition for a long term.

The useful dose range of each analyzed detector is in agreement with the data found in literature for PMMA RED 4034, CTA FTR-125 and FW 60.20 and the Red 5B dose range was only experimentally determined.

ACKNOWLEDGEMENTS

The authors wish to thank FAPESP (Fundação de Amparo a Pesquisa no Estado de São Paulo), CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the financial support and CTR (Centro de Tecnologia das Radiações / IPEN) for samples irradiations.

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