Characterization of polycarbonate dosimeter for gamma-radiation dosimetry

Galante, A. M. S.; Campos, L. L.

Institute of Energetic and Nuclear Research, IPEN – CNEN/SP, Brazil.

Abstract

A simple and inexpensive polymeric material whose special properties can be determinate, quantified and related to absorbed dose was studied in this work. Commercial polycarbonate (PC) is a new type of film detector that suffers yellowing upon radiation exposure and the color change was used as dosimetric property to measure the absorbed doses. The dosimeter consists of a piece of polycarbonate film of dimensions 3 x 1 cm^2 and 3 mm thick and the spectrophotometry was the investigation technique used. PC films were irradiated with gamma doses between 1 and 150 kGy from a ^{60}Co Gammacell source. The absorbance was measure on a spectrophotometer Shimadzu UV-2101PC. The main dosimetric characteristics studied were: pre- and post-irradiation stability, dose – response, environmental conditions influence and response dependence with dose rate. PC films are easy to prepare and to analyze. The influence of environmental conditions was observed and must be corrected. Polycarbonate dosimeters presents good stability and reproducibility and linear behavior in the dose range studied indicating that the dosimetric characteristics are suitable to determine high gamma doses.

Introduction

Some polymeric materials present changes in their properties due to the interaction of ionizing radiation that can be related with the absorbed dose [2]. Radiation induced chemical reactions results in rearrangements and/or formation of new bonds and the main effects are scission of main chain (degradation) or cross-linking, which are simultaneous and competing processes. To be applied in radiation dosimetry polymer films must present preferentially linear response in the dose range to be measured. It is necessary to determine its dosimetric properties such as lower and upper limits of useful dose range; dose rate dependent response; stability before and after irradiation and environmental conditions effects [1,4,5]. Polycarbonates are usually applied in neutron and alpha particles detection using nuclear tracks detection technique nowadays they have been studied as a dosimeter to measure gamma-rays doses [6]. The radiation induced main chain scission of PC and produces phenoxy radical responsible for the yellowing [4,5]. PC films are easy to prepare and to analyze and inexpensive. The influence of environmental conditions was observed and must be corrected in the studied material. Polycarbonate dosimeters presents linear behavior in the dose range studied and indicates that the dosimetric characteristics of are suitable to determine high gamma doses. In this work samples of commercial polycarbonate were investigated to be applied as dosimetric material evaluating the radiation dose response to ^{60}Co gamma radiation.

Material and methods

Samples of commercially available polycarbonate with and without protection against UV radiation manufactured by "Policarbonatos do Brasil" (3 x 1 x 0.3 cm^3) were irradiated free in air, under electronic equilibrium conditions and at room temperature with doses between 1 and 150 kGy and dose rate of 2.60 kGy/h using a ^{60}Co gamma radiation source.

The radiation induced color change was the basis of measuring absorbed doses. Optical absorption measurements of non irradiated and irradiated samples were taken in a Shimadzu spectrophotometer UV-2101PC at wavelength ranging between 190 and 900 nm.

The lower dose detection limit was obtained by the absorbance values of the maximum wavelength of at least 60 non irradiated detectors and the upper limit was determinate by external limitations.

All presented results are the average of 3 measures and the error bars the standard deviation of the mean. The observed standard deviation of the mean for all applied doses was better than 96 %.

Results

The typical non irradiated PC spectrum was obtained and presents differences between PC with and without protection against UV radiation damage as showed in Fig. 1.

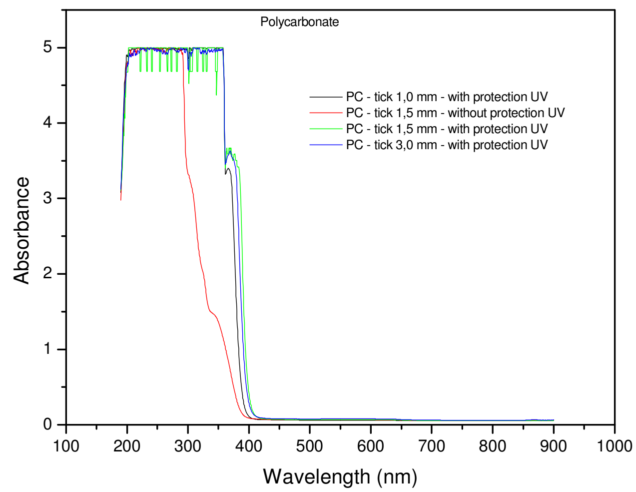

Fig. 1. Non irradiated polycarbonate samples absorption spectra.

The optical response stability before irradiation is better than 95% when PC samples are exposed to normal ambient conditions (20°C and 60% humidity), however, after irradiation the samples must be maintained at low temperature to avoid losses of response, approximately 30% after 48 hours at room temperature and 8 % if maintained at 5°C and light protected.

The lower detection limit was obtained taking three times the value of the standard deviation of measurements of at least 60 non-irradiated PC samples, expressed in units of absorbed dose. The dose value of 1 kGy was obtained [7].

After irradiation PC spectra presents an absorption band centred in 412 nm, Fig. 2, that was used to evaluate the optical response.

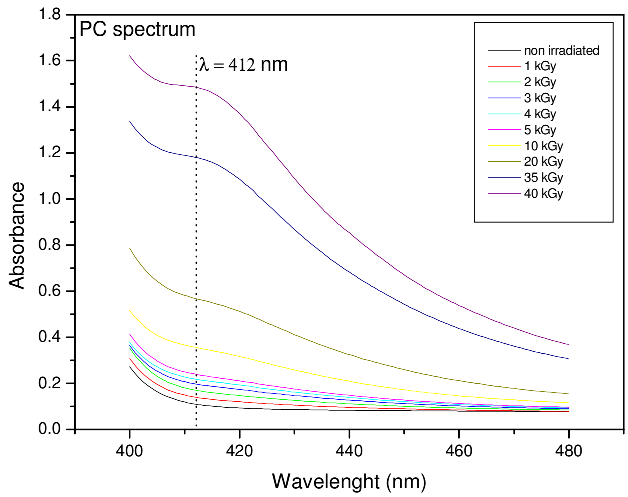

Fig. 2. Non irradiated and irradiated PC absorption spectra.

The change color of PC samples originally transparent to yellow dark when are irradiated with different gamma radiation doses can be seen in the Fig. 3

Fig. 3. Color change of PC samples irradiated with gamma doses between 1 and 150 kGy.

Experimental results show that the response reproducibility is better than 96%.
The dose rate dependence was significant for low doses and reading corrections must be made because this dependence can introduce large errors in the dose measures [3].
The absorption intensity of the 412 nm peak increase linearly as a function of absorbed dose as showed in the Fig. 4 to gamma radiation in the dose range between 1 and 150 kGy.

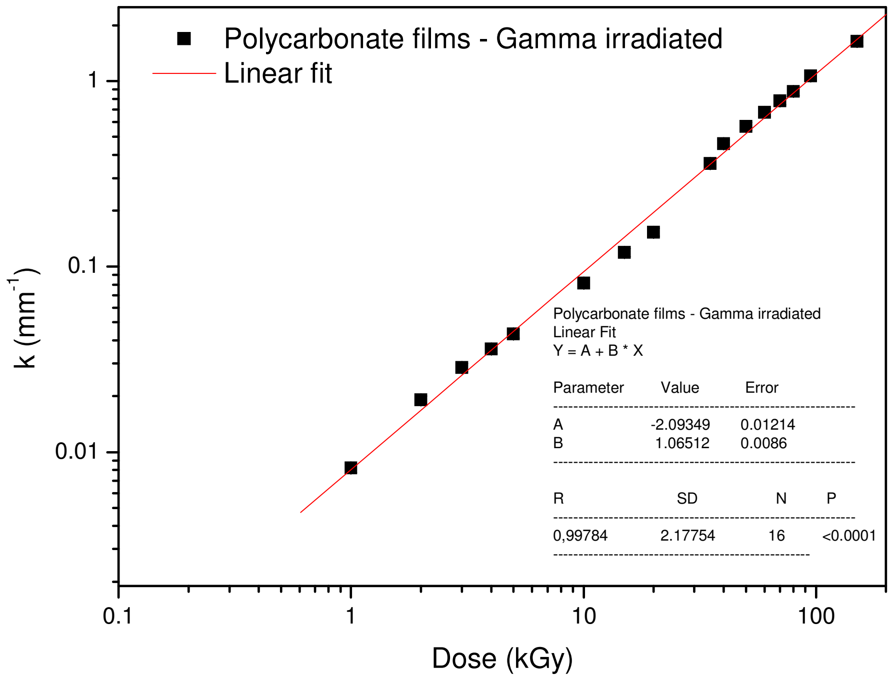

Fig. 4. Dose response curve of polycarbonate films irradiated with ^{60}Co gamma radiation, λ = 412 nm.

Conclusions

The results obtained indicate that PC can be used as an alternative dosimetric material.
The advantages of the use of PC detectors in high-dose dosimetry are the reduced size, very low cost, easy handling and the fact that the absorbance analysis is very simple.
The storage conditions doesn't affect the non-irradiated detector response, however, after irradiation the detector must be kept under refrigeration to preserve its optical response and reading must be done up to 24 hours after irradiation.
The dose response curves obtained show that this dosimeter can be used in an useful dose range between 1 and 150 kGy.

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.

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