

The Radiation Effect of ^{60}Co Gamma Rays on Polycarbonate detector.

Ana Maria Sisti Galante*, Letícia Lucente Campos

Radiation Metrology Centre – Institute of Energetic and Nuclear Research, Av. Prof. Lineu Prestes 2242, 05508-900, Cidade Universitária, São Paulo, Brasil.

Abstract. The irradiation of polymeric materials with ionizing radiation (gamma rays, X rays, accelerated electrons, ion beams) leads to the formation of very reactive intermediates products (excited states, ions and free radicals), which result in rearrangements and/or formation of new bonds. The effects of these reactions are formation of oxidized products, grafts, scission of main chain (degradation) or cross-linking. Often the two processes (degradation - cross- linking) occur simultaneously, and the outcome of the process is determined by a competition between the reactions. Polycarbonate detectors are used as a particle track detector for neutrons and alpha particles detection. This work aims to study the ionizing radiation dose response of polycarbonate samples using spectrophotometric technique. A commercially available polycarbonate was analysed and its dosimetric characteristics were studied: radiation-induced absorption spectra, ambient light, temperature and humidity influence, pre- and post-irradiation stability, reproducibility and dose range useful response. Samples of polycarbonate ($3 \times 1 \text{ cm}^2$) were irradiated with ^{60}Co gamma radiation in free air at electronic equilibrium with absorbed doses between 1 and 95 kGy. When exposed to gamma radiation the polycarbonate detectors undergoes changes in their optical response, the colour variation is used for determining the absorbed dose. A Shimadzu UV-2101PC spectrophotometer was used for scanning the absorption spectra and measuring the optical density of film detectors irradiated with different radiation doses. Polycarbonate film detector are easy to prepare and to analyse, of good optical quality, inexpensive and of small size. The dosimetric accuracy can be affect by environmental conditions so, the detectots must be stored in appropriate conditions. The reproducibility of the detectors response can be improved by careful monitoring of optical densities before irradiation. The dose response curve presents linear behaviour in the studied interval. The obtained results indicate that the polycarbonate present good performance to be used as gamma radiation dosimeter.

KEYWORDS: *gamma radiation; dosimetry system; PC polycarbonate; spectrophotometric analyses.*

1. Introduction

New technologies to the materials industrial processing has been applied aiming economy, efficiency, speed, security and high-quality; the nuclear radiation can initiate chemical rections or destroy micro-organisms leading to large-scale use in medicine, in diagnostic methods, in archaeology, in dating techniques, in chemistry, certain analytical methods, the food preservation and other fields.

The passage of ionizing radiation through matter gives whole range of reactive species - positive ions, free electrons, free radicals and excited molecules. Presents special advantages: no catalyst or additives are required to initiate the reaction, large reactions as well as product quality can be controlled; saving energy and resources, clean process [1].

The use of ^{60}Co gamma ray facilities and electron beam accelerators for industrial processing has increased in recent years. For the control of this processes are available various dosimetric systems, Table 1 [2-4]. The quality control of these processes depends on the performance of the dosimeter, then, the research in dosimetry is stimulated aiming the development of new materials and the optimization of the dosimetry.

Effects induced by ionizing radiation (accelerated electrons, ion and protons, gamma and X rays) have been largely used to modify the chemical and physical properties of the polymers. Some of the changes have been atributed to the scissioning of the polymer chains, breaking of covalente bonds, promotion of cross-linkages, formation of carbon clusters, liberation of volatile species and, in some cases, even formation of new chemical bonds [5,6].

Table 1. Dosimetric Systems used in radiation processes [4].

Dosimeter	Measured property	Method of measurement	Dose Range (Gy)
Fricke (aqueous ferrous sulphate)	Oxidation of ferrous ion to ferric ion	Spectrophotometry	40 to 400
Alanine	Formation of trapped radicals	Electron paramagnetic resonance	10 to 10 ⁵
Radiochromic dye film	Formation colored dye	spectrophotometry	10 to 10 ⁶
Photographic film	Darkening	Densitometry	100 to 10 ⁶
Lithium fluoride	Formation of trapped electrons and positive holes	Thermoluminescence	10 ⁻⁵ to 10 ³

Dosimetric systems based on radiation-induced colour change in polymeric material are useful in the quality control of industrial radiation processing using the spectrophotometric technique. Advantages of using these relatively simple dosimetric material are their inexpensiveness, ruggedness, and ease of handling. Clear polymer and dyed polymer (PVC polyvinylchloride, PMMA polymethylmethacrylate, MD-55 polyester base, HD-810 polyester base, CTA cellulose triacetate, FWT amine triphenyl methane) are commercially available in large batches.

Polycarbonate (PC) is a well-known engineering thermoplastic with an excellent balance of optical, physical, mechanical, and processing characteristics [7]. Polycarbonate detectors are used as a particle track detector for neutrons and alpha particles detection [8-10]. This work aims to study the ionizing radiation dose response of polycarbonate samples using spectrophotometric technique. Polycarbonate film detector are easy to prepare and to analyse, of good optical quality, inexpensive and of small size.

2. Experimental

2.1 Preparation of the film

Polycarbonate are commercially available and supplied in sheets of 2 x 1 m, films were cut in small strips of 30 x 10 mm dimensions, cleaned and sealed in polyethylene-aluminium package for this work.

2.2 Optical density measurements

Optical densities were measured on a Shimadzu UV-2101PC spectrophotometer before and after irradiation of each film.

2.3 Irradiation source

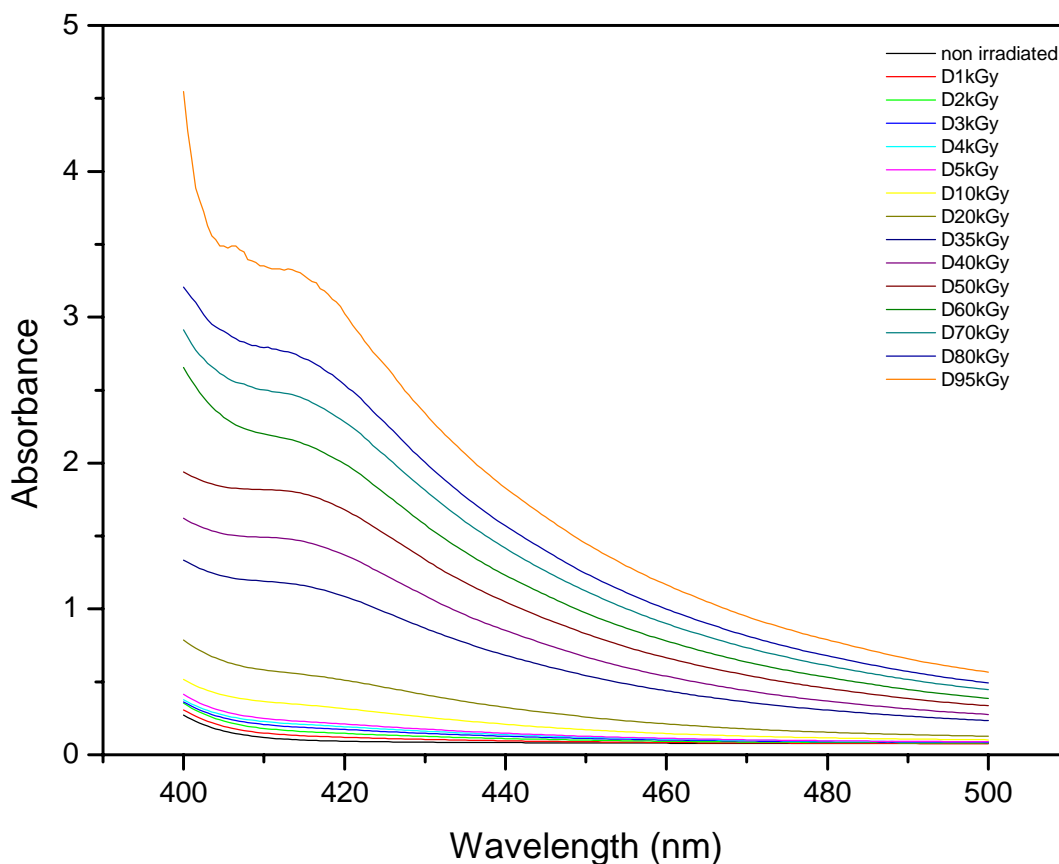
All irradiations were carried out with the ⁶⁰Co gamma Gammacell source at the IPEN – CNEN Institute with doses between 1 and 95 kGy in air and under electronic equilibrium conditions. The dose rate was measured with Fricke dosimeter by IDAS programme of IAEA and was 2.55 kGy/h in march/2008.

3. Results

3.1 Absorption spectrum

The absorption spectrum of non irradiated and gamma irradiated PC films are plotted in the wavelength range 400 – 500 nm and showed in Fig. 1. A peak centered in 412 nm appears after irradiation and the absorption intensity of this peak increase linearly in function of absorbed dose.

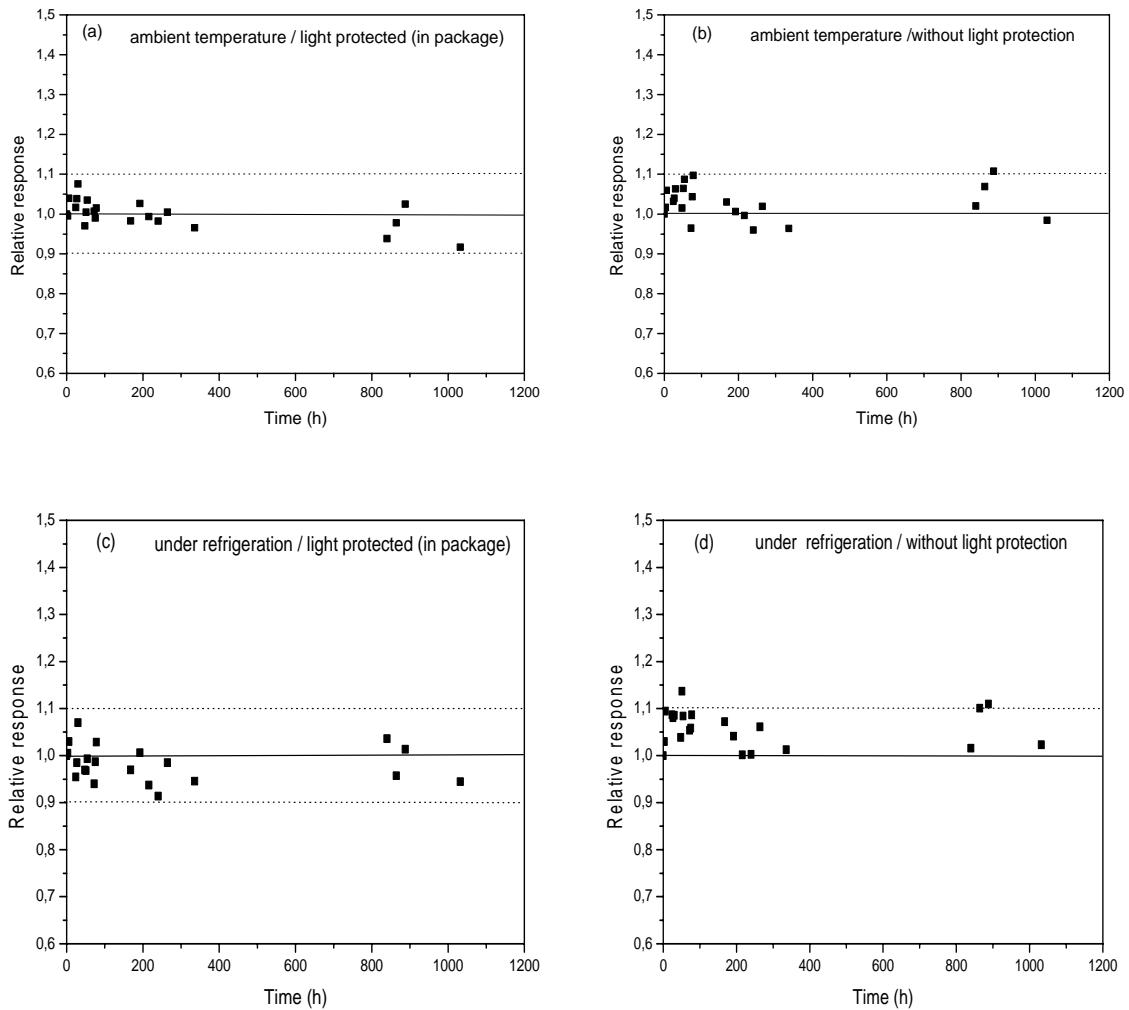
Figure 1. Absorption spectrum for non irradiated and gamma irradiated PC films.



3.2 Effects of temperature and ambient light on PC films response

PC films non-irradiated were exposed to ambient / low temperature and in light / dark environment. In the Fig 2 (a) – (d) are showed the optical response as a function of the time. The response fluctuation was found to be less than 10% demonstrating that there is no significant variation in the response in the stored conditions studied.

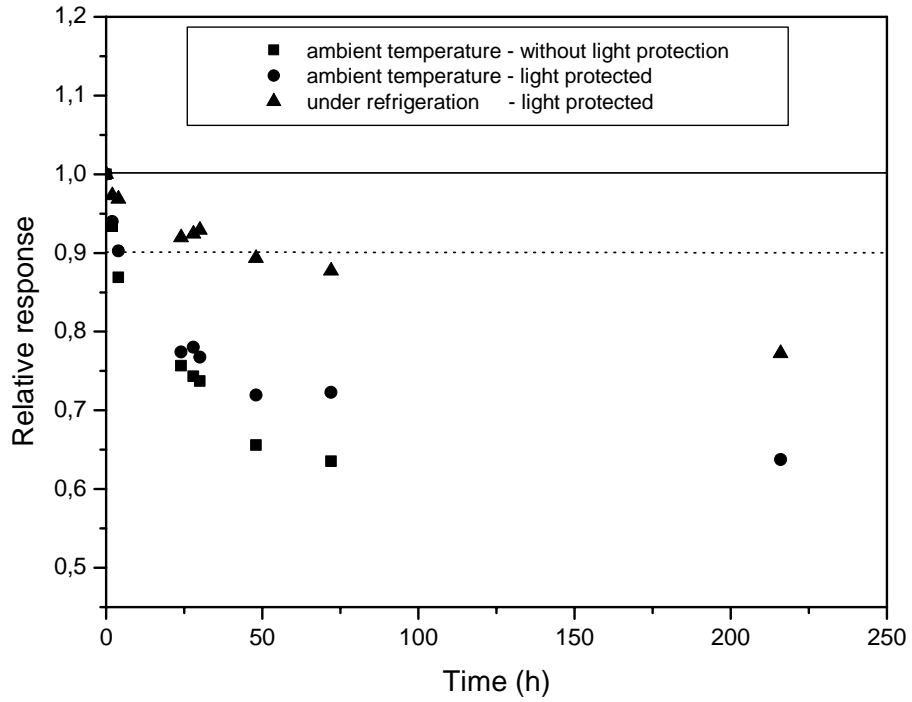
Figure 2. Effect of temperature and ambient light on PC films response. (a) ambient temperature / light protected (in package); (b) ambient temperature / without light protection; (c) under refrigeration / light protection and (d) under refrigeration / without light protection.



3.3 Post-irradiation stability

PC films irradiated with 10 kGy and dose rate 2.55kGy/s were exposed to ambient / low temperature and in light / dark. The color stability was tested in this conditions as a function of time. It can be observed in Fig 3, the absorbance values decrease as a function of the time, sample maintained at ambient temperature presents higher decrease than samples maintained under refrigeration, during 24 h, these presents a decrease in the optical response lower than 10%.

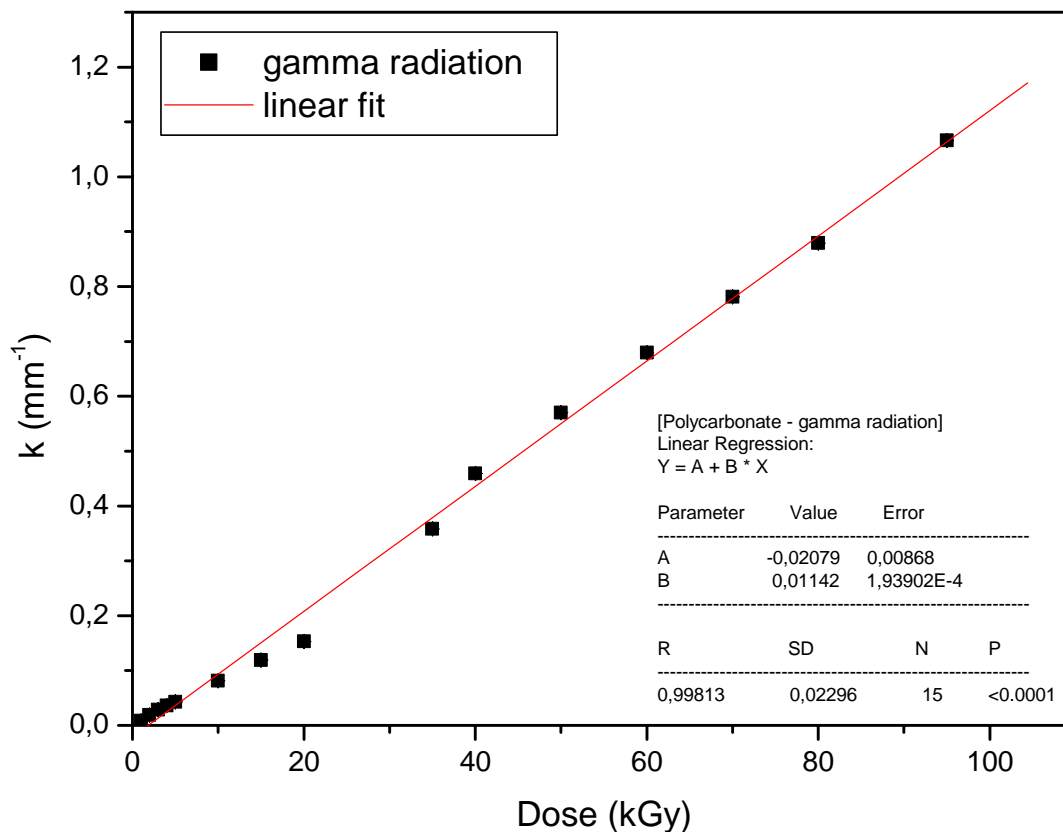
Figure 3. PC absorbance response under ambient / low temperature and in light / dark conditions as a function of time at 412 nm. Gamma Irradiation 10 kGy.



3.4 Gamma radiation response

The dose response curves were drawn at 412 nm. Samples were irradiated with gamma dose between 1 and 95 kGy. It can be observed, Fig 4, that the dose response curve follow a linear relationship between specific absorbance and absorbed dose in the range studied. The lower detected dose calculated is 4.5 kGy and the upper limite can be extended.

Figure 4. Dose response curve of polycarbonate (PC) films at gamma doses of 1 to 95 kGy



4. Conclusion

These results show that the Polycarbonate can be used as a radiation dosimeter by spectrophotometric technique. There is no significant changes before irradiation with the storage conditions. The irradiated detectors must be storage under low temperature and its measures should be made in 24 h at most.

The useful dose range is large and interesting for dose evaluation in radiation process, doses greater than 95 kGy can be applied, there was no saturation of the response, at this dose. The upper limit of measurable dose may be extended, a complementation study is being done.

Acknowledgements

The authors wish to thank FAPESP (Fundação de Amparo a Pesquisa no Estado de São Paulo) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the financial support.

REFERENCES

- [1] BHATTACHARYA, A. Radiation and industrial polymers. Prog. Polym. Sci., v. 25, p. 371-401, 2000.
- [2] GALANTE, A. M. S.; VILLAVICENCIO, A. L. C. H.; CAMPOS, L. L. Preliminary investigations of several new dyed PMMA dosimeters. Radiat. Phys. Chem., v. 71, p. 391-394, 2004.

- [3] GALANTE, A. M. S.; CAMPOS, L. L. Electron dose radiation response of dyed PMMA detectors developed at IPEN. *Radiat. Prot. Dosim.* v. 120, n 1-4, p. 113-116, 2006.
- [4] McLAUGHILIN, W. L.; DESROSIERS, M. C. Dosimetry systems for radiation processing. *Rad. Phys. Chem.*, v. 46, n. 4-6, p. 1163-1174, 1995.
- [5] KUMAR R., VIRK H.S., VERMA K.C., DE U., SAHA A., PRASAD R. Physico-chemical modifications induced in Makrofol N-polycarbonate by swift heavy ions. *Nuclear Instruments and methods in Physics Research B* 251, p. 163-166, 2006.
- [6] SINHA, D.; SAHOO, K. L.; SINHA, U. B.; SWU, T.; CHEMSEDDINE, A.; FINK, D. Gamma-induced modifications of polycarbonate polymer. *Radiation Effects & Defects in Solids*, v. 9, p. 587-595, 2004.
- [7] CHUNG, J. Y. J. Stabilization of Gamma-Irradiated Polycarbonate. *Medical Plastics and Biomaterials. TECHNICAL PAPER SERIES*, v. 49, 1997.
- [8] PRICE, B. P.
Science and technology with tracks in solids
Radiation Measurements, v.40, p.146-159, 2005.
- [9] SOUTO, E. B. Projeto, montagem e caracterização de um dosímetro para radiação de nêutrons. 2007. Dissertação (Mestrado) - Instituto de Pesquisas Energéticas e Nucleares - IPEN/CNEN-SP, São Paulo.
- [10] NOUH, S. A., MORSY, A. A., EL-HUSSEINY, H. M. Radiation-induced changes in some SSNTDs. *Radiation Effects & Defects in Solids*, v.159, p.115-124, 2004.