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Fast neutron dose response of a commercial polycarbonate

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Abstract

A commercial polycarbonate produced in Brazil is being studied to be used as neutron detector material using Solid State Nuclear Track Detection (SSNTD) method replacing the well-known detector materials Makrofol and CR-39. This technique is based on the damage (tracks) registration of charged particles produced by the interaction of neutrons with carbon and oxygen atoms of some dielectric materials. The IPEN dosimeter prototype is composed by $30 \times 10 \times 1.5\,\text{mm}^3$ polycarbonate piece inserted between two Polymethyl Methacralate (PMMA) plates 2 mm thick. The prototypes were irradiated placed on an ISO slab phantom using an isotropic ^{241}AmBe source at LN/LNMRI (Neutrons Laboratory of the National Laboratory of Ionizing Radiation Metrology). To study the dose response groups of five prototypes were irradiated with Hp(10) from 0.5 to 20 mSv with normal incidence and to investigate the angular incidence effect with Hp(10) = 5 mSv with incidence angles of 15°, 45°, 60°, 75°, 85° and 90°. The detectors were revealed by chemical etching with the solution PEW-40 during 3 h. The track density of the detector surface was determined by the average of track counting of five fields ($20 \times 0.1\,\text{mm}^2$). The track response to equivalent dose Hp(10) showed a good agreement with linear fit in the studied interval. The track density strongly decreases for incidence angles higher than 45°.

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Keywords: Neutron dosimetry; Solid state detectors

1. Introduction

Few Brazilian workers that are exposed to neutron sources are monitored to fast neutrons due to the costs of detectors' materials that are imported. The development of a fast neutron dosimeter of low cost and easy obtaining becomes necessary to supply this demand. The Radiation Metrology Center (CRM) of Instituto de Pesquisas Energéticas e Nucleares—IPEN/CNEN-SP is studying a commercial polycarbonate produced in Brazil in substitution to well-known materials as Makrofol and CR-39, on Solid State Nuclear Track Detection (SSNTD) [1,2] that are imported.

SSNTD is a technique based on the damage (tracks) registration of charged particles produced by the interaction of neutrons with carbon and oxygen atoms of some dielectric materials, as polycarbonates. The tracks are revealed and amplified for visualization in an optic microscope through a technique known as chemical etching [3].

The polycarbonate studied is a Brazilian commercial resin for use in the civil construction and industry. This material is being characterized for neutron detection using the SSNTD technique [2].

Prototypes were produced and the dose response up to 20 mSv and the angular dependence were studied.

2. Experimental procedure

2.1. Prototype description

The polycarbonate is a Brazilian commercially available resin, named SS-1, produced with the same chemical monomer of Makrofol, $C_{16}H_{14}O_3$. It is offered in plates ($165 \times 244 \times 0.15\,\text{cm}^3$) with both sides protected by a plastic film. Small pieces ($3 \times 1\,\text{cm}^2$) are cut and selected. One corner of the rectangle is signed, always the same side of the plate, to obtain reproducible positioning.

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The detectors were always stored at room temperature and ambient light.

The dosimeter prototype is composed of an SS-1 detector inserted between two Polymethyl Methacralate (PMMA) plates 2 mm thick. The PMMA plates contribute also to shield the detector against natural radon (alpha particles) which affects the neutron response.

2.2. *Prototypes irradiation*

The prototypes were previously tested in alpha, beta, gamma and neutron fields [1] for evaluation of track production, sensitivity, background tracks and mechanical defects influence in the radiation induced track detection.

The dosimeters were positioned on an ISO slab phantom and irradiated using an isotropic ^{241}AmBe source at Neutrons Laboratory of the National Laboratory of Ionizing Radiation Metrology—LN/LNMRI. The neutron source is calibrated against a primary standard of $MnSO_4$ and maintains traceability to BIPM. The personal doses equivalent [Hp(10)] are calibrated using the same ISO slab phantom.

Groups of five prototypes were irradiated with Hp(10) from 0.5 to 20 mSv with normal incidence and with Hp(10) = 5 mSv with incidence angles of 15°, 45°, 60°, 75°, 85° and 90°.

2.3. *Chemical etching*

This procedure was established previously [2]. Detectors irradiated with same doses were submitted to a chemical solution PEW-40 (15% KOH, 45% H_2O, 40% C_2H_5OH) [5] under etching temperatures between 50 and 100 °C and heating times between 1 and 6 h. The best result was obtained evaluating the relationship among the amount of revealed tracks, their clearness and the time spent for this.

The best chemical etching of the detectors consists of 3 h etching under PEW-40 solution at 75 °C. The detectors were dried in air at room temperature.

2.4. *Track counting*

The detectors' surfaces were visualized through a video camera Samsung SDC-312ND connected to an optical microscope Optovac OptoNTIM with magnification of 160:1. The counting procedure was that referred in the literature [4].

The counting area is defined by fields of 20 × 0.1 mm^2 of the detector surface. The track density is the arithmetic mean of five different fields counting and the uncertainty is the mean standard deviation (1σ).

3. Results and discussions

The SS-1 detector dose response is shown in Fig. 1. It can be seen that there is a good agreement between the experimental points and a linear fit in the studied interval. The correlation coefficient is 0.993.

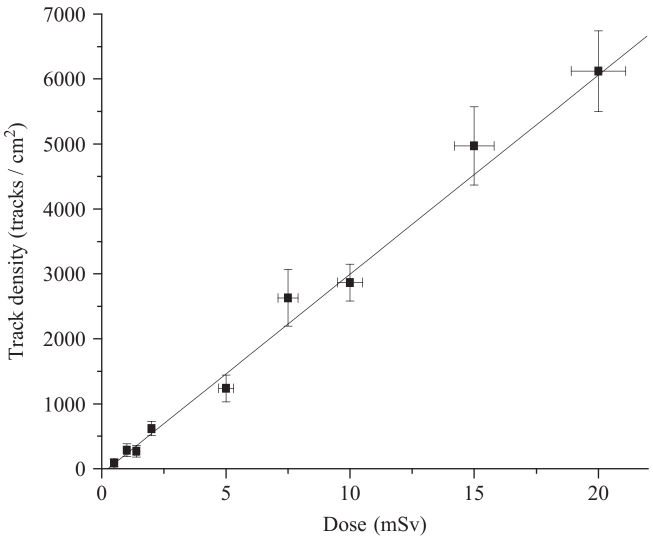

Fig. 1. SS-1 detector neutron dose response to Am–Be neutron source.

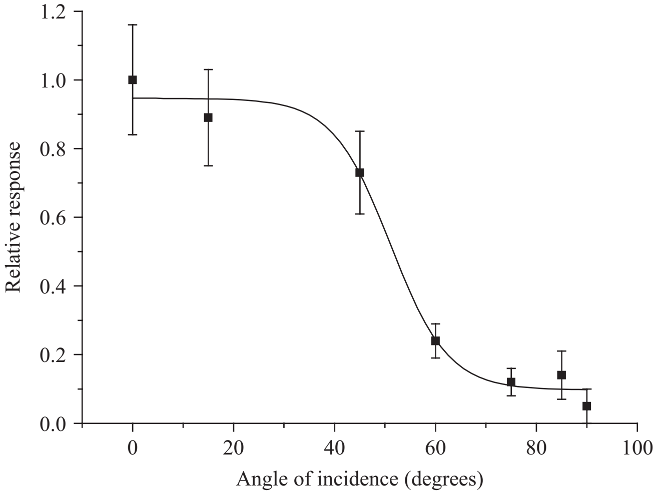

Fig. 2. Angular dependence response of the SS-1 detector.

The lower detectable dose limit was calculated considering the mean of five unirradiated detectors plus three mean standard deviation, and is 0.2 mSv.

In spite of presenting a linear behavior the SS-1 detector response strongly decreases as the incidence angle increases (Fig. 2).

Considering the ISO/DIS 21909 [6], the critical angle for this film is 45°with counting decrease of 78%.

4. Conclusion

The polycarbonate studied is found for purchase and has low cost. The plates can be easily cut in small pieces. The prototype is simple and of practical use. The SS-1 detector shows a linear dose response in the dose range between 0.5 and 20 mSv, test interval recommended by ISO/DIS 21909

[6]. The weak directional dependence up to 45° is also in agreement with ISO/DIS 21909, but it is clear that a correction factor must be applied. The lowest detectable dose is 0.2 mSv.

The obtained results indicate that the dosimeter prototype presents properties and characteristics required to be used as fast neutron dosimeter.

Acknowledgments

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