Neutron dosimetry device using PADC nuclear track detectors

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ABSTRACT

The principle of producing and observing neutron induced tracks in organic detectors exhibits most attractive properties and is the basis of one of the main methods used in neutron personal dosimetry. A device consisting of Poly Allyl Diglycol Carbonate (PADC) foils with a polyethylene and Polyvinylchloride (PVC) radiator was calibrated in order to perform the dosimetry of neutron sources covering a wide range of doses. Working conditions were established for a good visualization and counting of tracks. Chemical attack was made in two steps with different solutions and etching times. A good fit was obtained for the dose as a function of the number of tracks per unit surface area.

INTRODUCTION

The method is based on the interaction of neutrons with the nuclei of the detector plastic material. In fact, neutrons do not cause direct ionization by themselves, but secondary particles resulting from nuclear reactions between them and target nuclei are responsible for creating etchable damage zones. The most probable track producing particles are recoils from scattering reactions with hydrogen, carbon and oxygen nuclei, and charged particles from nuclear reactions of the type (n, α).

A better performance in the dosimetry using solid nuclear track detectors can be obtained by adding an extra foil or radiator because secondary charged particles can also be originated there. In the present work, a device consisting of PADC foils with a polyethylene and PVC radiator is calibrated and the working conditions are optimized, in order to perform the dosimetry of a ^{241}Am-Be source.

MATERIALS AND METHODS

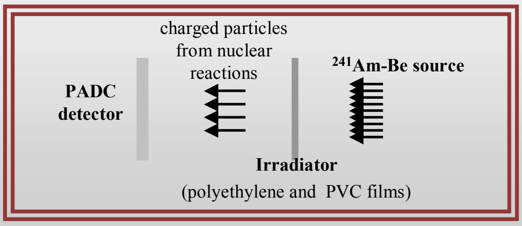
Dosemeters calibration was carried out in the laboratories of the ARN, according to ISO 8529. A ^{241}Am-Be source calibrated using a multispheres spectrometric system was employed to irradiate the samples.

The parameters obtained for this source were:

Rate: 1,12 10^7 neutrons s^{-1}

Hp(10) : 269,22 mSv/h

Four sets of 1 mm thickness PADC foils with polyethylene and PVC films (50 µm and 100 µm thickness respectively) as radiators, were irradiated with the ^{241}Am-Be source. Irradiation doses ranged from 0 to 3.1 mSv.



Scheme showing the dosemeter arrangement

The chemical etching process of each set was made in two steps. *PEW* solution (30g KOH + 80g C_2H_5OH + 90g H_2O) at 70 °C for 45 minutes was used at first. The samples were than washed in abundant cold water and dried in room air. The second etching stage was realized with 6.25N NaOH water solutions at 70 °C for 6 hours. Unirradiated foils were etched simultaneously with irradiated foils, for background determination.

The tracks were observed on the front face of the detector with an optical microscope (Axioplan Carl Zeiss) and manually counted over fields of 40x10 magnification.

RESULTS AND DISCUSSION

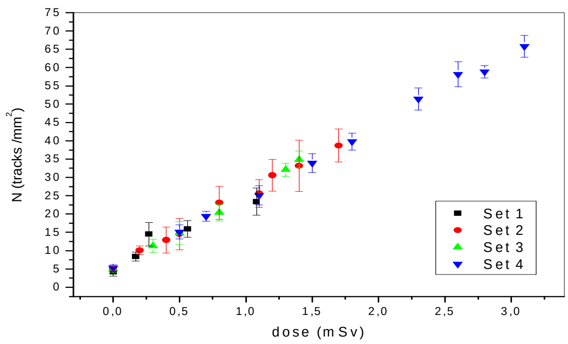
Mean values of tracks per unit surface area (*N*) as a function of nominal dose are shown in the figure, the error bars corresponding to standard deviations. A linear fit of the data can be represented by

$$N = S \cdot D + B$$

where *S* is the sensitivity (in number of tracks/dose), *D* is the nominal dose and *B* is the background.

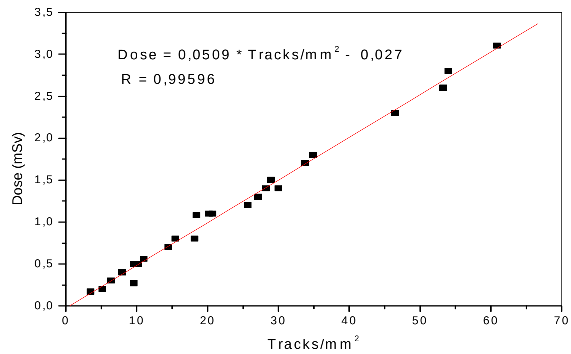
The experimental neutron response in terms of Hp(10) has been calculated from the net measured track densities (measured track density minus average background) taking into account the corresponding reference values of the source.

Experimental response (tracks cm^{-2} mSv^{-1}) = 2084 ± 341



In the figure it is shown a linear fit of the obtained data (the background was already substracted), here representing Dose as a function of Mean values of tracks per unit surface area (N). The obtained equation is

Dose (mSv) = 0,0509 * N (Tracks/mm²) - 0,027



Minimum Detectable Dose Equivalent (MDDE).

This magnitude corresponds to three standard deviations on the background divided by the sensitivity. This is a very useful criterion for quantifying the performance of a dosimetry system at low doses, since it defines the level at which doses may be regarded as statistically significant. So the MDDE is used to define the threshold at which track densities become sufficiently different from background to be reported as doses. This value was calculated as:

$$MDDE = \frac{3\,\sigma_b}{S}$$

The calculated MDDE was 0.12 mSv.

CONCLUSIONS

- **A personal dosimetry device has been developed which permits the evaluation of neutrons radiation from a ^{241}Am Be source.**
- **The use of PADC as nuclear track detector makes it possible to obtain a permanent register of neutron dose which is of legal importance.**
- **A good fit was obtained for the dose as a function of the number of tracks per surface. Moreover, the MDDE was 0.12 mSv. It must be noticed that the detection efficiency is good, the detection limit value is comparable to that obtained in the literature and is adequate for radiological protection applications. Though the statistics of not automatized measurements may be worse than that of automatized lectures, the efficiency may be better, and the final limit number is within the range of those reported in the literature.**