ТЕХНІКА ТА МЕТОДИ ЕКСПЕРИМЕНТУ
ENGINEERING AND METHODS OF EXPERIMENT

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PADC RESPONSE TO 0.3 - 3 MeV PROTONS

Two types of Poly-Allyl-Diglycol Carbonate, the Neutrak and PN3 were investigated using track diameter distribution induced by the monoenergetic protons with energies in the range of 0.3 to 3 MeV. The energies and intensities were controlled by a silicon surface barrier detector and a nickel scattered foil placed in a 4 MV Van der Graaf accelerator. After different etching times, the etch track-sizes were scanned and measured with the optical microscope. PN3 and Neutrak track diameter responses to protons were measured, plotted, and discussed as a function of energy.

Keywords: track diameter, Poly-Allyl-Diglycol Carbonate, monoenergetic protons, etched track.

1. Introduction

Poly-Allyl-Diglycol Carbonate (PADC), also known as CR-39, has been used as a track detector for almost 40 years [1, 2]. Due to its advantages such as simplicity, cheapness, insensitivity to photons, non-fading tracks, high sensitivity to charged particles, this material has been successfully employed in various areas of research, industry, nuclear plants, and neutron dosimetry [3, 4]. The tracks produced in the detector bulk depend on the identity and energy of the incident particle and etching conditions.

It is clear that the proton recoil is an important mode of interaction for the detection of fast neutrons [5 - 8]. It is generally agreed that the properties of PADC vary from one batch to another and from one foil to another in the same batch [9, 10]. In other words, it is known that the properties of track-etched detectors significantly depend on the producer. For all these reasons, we have undertaken in this study to determine the response of this material to protons.

For this purpose, two types of PADC detectors, the PN3 and Neutrak, were irradiated with low intensity and low energy proton beams in order to determine the correlation between the mean proton track diameter and the incident energy impinging on PADC surface taking into account the resolution.

2. Experimental procedure

2.1. Detectors

Two types of commercially available PADC detectors from different manufacturers were used:

PN3, manufactured by APVL (http://www.apvl.com), which consists of a bare PADC detector (Fig. 1, *a*);

Neutrak 144-J (see Fig. 1, *b*), which is sold by Landauer EUROPE (http://www.landauer.co.uk/neutron.html) as ready-to-use cases containing the PADC detector [11].

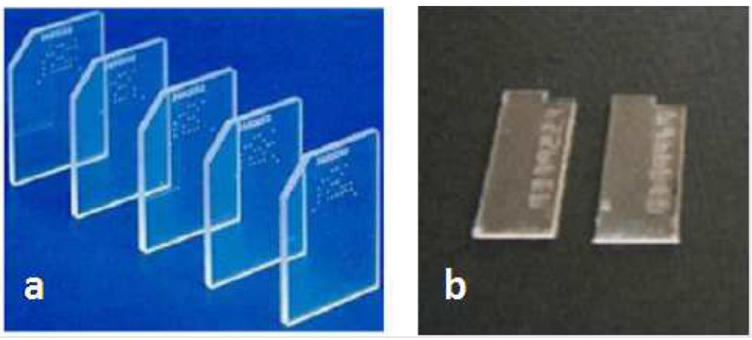

Fig. 1. PN3 (20 × 25 × 1.5) mm^3 (*a*) and Neutrak 144-J (19 × 9 × 0.8) mm^3 (*b*).

2.2 Detector irradiation

All the PADC detectors were placed in a vacuum chamber (P = 10^{-5} mbar) and irradiated with the 4 MV Van de Graaf accelerator in Strasbourg with proton energies going from 0.3 to 3 MeV. Two thin Ni foils (0.13 and 0.50 μm), placed on an aluminium holder at 30 cm distance from the exit window of the proton beam of the accelerator were respectively used to backscatter protons in order to limit the track density on the Neutrak and PN3 detectors. Proton energy was monitored with a 0.80 cm^2 silicon barrier detector. An acquisition time of each irradiation was set to 30 s (corresponding to an intensity of ~$60 \cdot 10^{11}$ protons in the beam) with 10 nA beam current.

2.3. Etching conditions

After irradiations, PN3 and Neutrak detectors were etched in a 6.25 N NaOH solution under continuous stirring at 70 ± 0.5 °C for 7 and 9 h. After etching, the detectors were dipped in dilute HCl solution and rinsed in flowing water for a few minutes. The detectors were then scanned by an automatic image analysis system connected to a CCD camera. The camera was mounted on an optical microscope (10× magnification) and a PC-controlled motorized XYZ stage. Track image acquisition was made with visilog 5.4 software (Noesis, http://www.noessisvision.com) and analysed with Image J1.44 software (https://imagej.nih.gov/ij/) taking into account criteria such as the circularity of the tracks, optimized grey-level threshold and the size of tracks.

3. Results and discussion

The results of Figs. 2 and 3 show the track-size distributions as a function of the etching time and the proton energy. The two curves, for both types of PADC, hit their maxima at the same value of energy i.e. 500 keV above which the track diameters uniformly decrease. Indeed, it is well known that the uniform decrease in the diameter with increasing proton energy is caused by the decrease in the rate of energy loss [12, 13]. The most important result of the study can be summarized in four points.

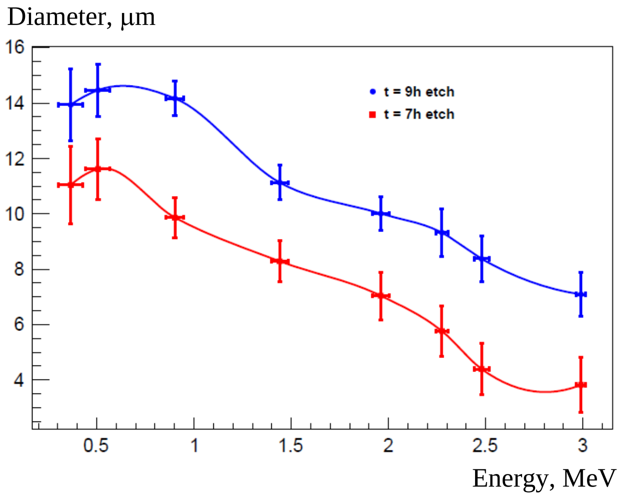

Fig. 2. Mean proton track diameter as a function of the incident mean proton energy using 0.50 μm Ni scatterer in PN3.

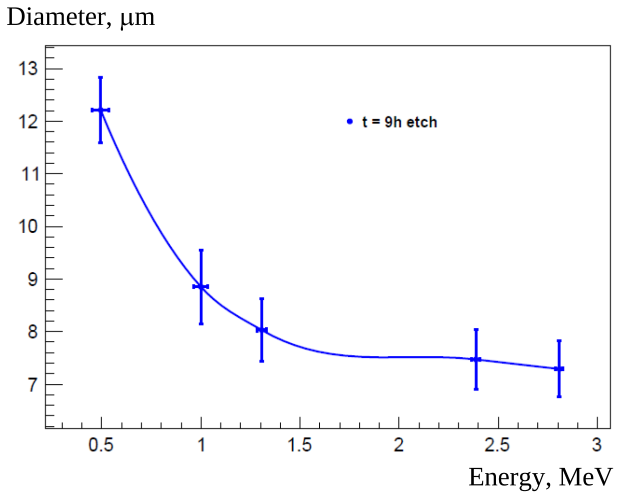

Fig. 3. Mean proton track diameter as a function of incident mean proton energy using 0.13 μm Ni scatterer in Neutrak.

Firstly, our optical system has been limited for the observations and measurements of etched track diameters of protons in Neutrak for etching time of fewer than 9 h.

Secondly, for the same etching time (9 h), PN3 detectors show tracks of diameter always larger than that of the Neutrak detector. The large uncertainties observed in Figs. 2 and 3 are mainly due to protons straggling in the nickel foil which impacts the track geometric shape.

Thirdly, it can easily be seen that the PN3 demonstrates tracks of diameters larger than Neutrak detector. The difference between the PN3 and Neutrak calibration curves may be due to the fabrication technologies as the two types of material came from two different suppliers.

Fourthly, we have compared our outcomes with those of previous publications where the experiments were carried out under almost similar conditions as we can see in Table. We found that there is sometimes a large discrepancy between the diameters of the tracks from one publication to another. More investigations must be carried out in order to understand these differences.

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Track diameter values vs etching conditions for 1 MeV

References	Solution normality (N or M)	Temperature, °C	Etching time, h	Diameter, μm
[17]	7.25	70	6	~6
[20]	6.25	60	6	~9.7
[21]	6	70	6	~1.9
[16]	6	60	7	~3.2
[18]	7	70	7	~6.5
This work	6.25	70	7	~9.5
[14]	6	70	8	~9.1
[15]	6.25	70	8	~8.5
[19]	6.25	70	8	~ 2
[20]	6.25	60	8	~13
[16]	6	60	9	~5.26
[18]	7	70	9	~8.5
[21]	6	70	9	~2.8
This work	6.25	70	9	~14
This work	6.25	70	9	~8.8

4. Conclusion

The main aim of the present paper was to compare the response of PN3 and Neutrak detectors irradiated with a quasi monoenergetic beam of protons ranging from 0.3 up to 3 MeV. We found that Neutrak detector is unreadable with our optical system for etching times less than 9 h. For given energy of proton, preliminary investigations showed the difference in terms of variations of track diameter with etching conditions. Upcoming investigations will be carried out to determine the sensitivity of these detectors to protons according to the PADC marks and experimental conditions by using new methods.

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ВІДГУК PADC ДЕТЕКТОРІВ ДЛЯ ПРОТОНІВ З ЕНЕРГІЯМИ 0,3 - 3 МеВ

Два типи полі-аліл-дигліколевого карбонату, Neutrak і PN3, було досліджено з використанням розподілу діаметра треків, створених моноенергетичними протонами з енергіями від 0,3 до 3 МеВ. Енергія та інтенсивність їх контролювалися за допомогою кремнієвого поверхнево-бар’єрного детектора та нікелевої фольги, розміщених у 4 MB прискорювачі Ван дер Граафа. Після травлення різної тривалості розміри протравлених треків було відскановано та виміряно за допомогою оптичного мікроскопа. Діаметри треків в PN3 та Neutrak було виміряно та проаналізовано як функції від енергії протонів.

Ключові слова: діаметр треку, полі-аліл-дигліколь-карбонат, моноенергетичні протони, протравлений трек.

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