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EFFECT OF GAMMA RAYS ON FAST NEUTRON REGISTRATION IN **CR-39**

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Introduction

Solid-state nuclear track detectors are now widely used in several applications; one of these applications is neutron detection [1, 2]. Thermal neutron dosimetry is based on using a fissile material as a converter to produce fission fragments and alpha particles, which are registered in track detector placed behind the converter. With regard to the registration of fast neutrons their sensitivity depends on recoiling nuclei within the volume of the detector itself and, in addition, on recoiling protons when hydrogen-bearing converter is placed in front of the detector.

CR-39 is a plastic detector [3] with hydrogen concentration of 6.6%, therefore it can record the protons recoiled by the neutrons of energy above 110 keV [4]. So, CR-39 has been widely investigated as a potential fast neutron dosimeter, because its response to protons over a wide band of energy insures the possibility of fast neutron registration. Furthermore, subsequent electrochemical etching leads to enlarging of the protons recoil tracks several times, which allows one to scan easily a large area of low spatial density of the tracks as it would normally be encountered in neutron dosimetry.

Several reports demonstrated that the detector response depends on the external radiation of material and the hydrogen content [5,6]. Other authors discussed the background, and fading characteristics [7]. It has been found that the background depends mainly on the manufacturing of the plastic detectors and the fading begins to appear within 25 days after the irradiation date [8]. As all neutron sources and nuclear reactors are associated with attendant γ-rays, the influence of γ-ray irradiation on the neutron detector response should be studied exactly. Hence, the aim of the present work is the studying of the effect of gamma rays on CR-39 registration of fast neutrons.

Experimental

Three sets of CR-39 detectors of thickness 0.7 mm were prepared. The first set was etched in shacked 6.5N NaOH aqueous solution at 60 ^{0}C for different durations and then the background track density was measured. The second set of detectors was irradiated by different neutron doses (2.75, 5, 7, 9 rem), using Am-Be source placed at about 40 cm apart from the detector. Then the samples were etched at the same etching conditions during different durations. The change of track density with etching time and neutron doses was studied. The third set of CR-39 samples was irradiated by neutron dose 4 rem with subsequent gamma-ray irradiation with different doses from 1 up to 10 Mrad.

The last set of detectors was etched in shacked 6.25 N NaOH aqeous solution at 60°C for 20 min. In order to determine the track development properties the diameter of the tracks induced by recoiled protons and the bulk-etching rate V_B were measured. In the framework of the mass decrement method, the track density and track diameter were measured using LIECA image analyser which consists of PC with LIECA QWIN program, the DMRE optical microscope, equipped with motorized x-y stage and auto focus options controlled by special program operated under Windows 98.

Results and discussion

Background

Figure 1 shows the background of CR-39 measured at different etching time. The mean value of background was found to be 157 tracks/cm^2 with statistical error 5% for different etching durations up to 16 hours. This result confirms the fact that the background is caused by the defects created in manufacturing process of material itself.

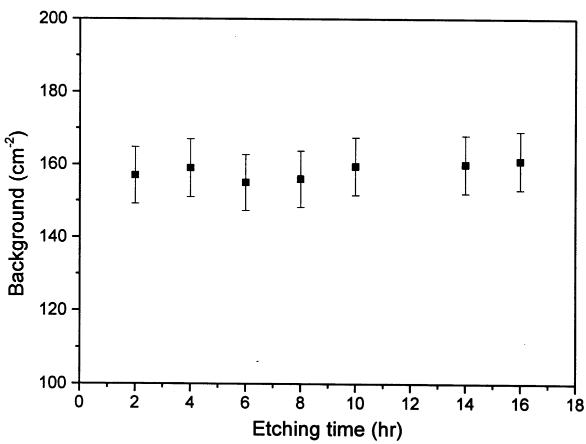

Fig.1. Background as a function of etching time for unirradiated CR-39 sample etched in 6.25 N NaOH at 60 ^{0}C

CR-39 response to neutron dose

Figure 2 shows that the track density grows with the increase of the neutron dose. This result agrees well with previous report [4] and is of great importance in fast neutron dosimetry. But the increase of track density with increasing etching time can be attributed to some tracks formed at larger depth from the surface, and a longer time of etching is need in order the tracks to be revealed. However we expect that after certain etching duration the track density will decrease then, because the recoiled protons have a limited range in material. So, the optimal etching duration exceeds 14 hours (Fig.3).

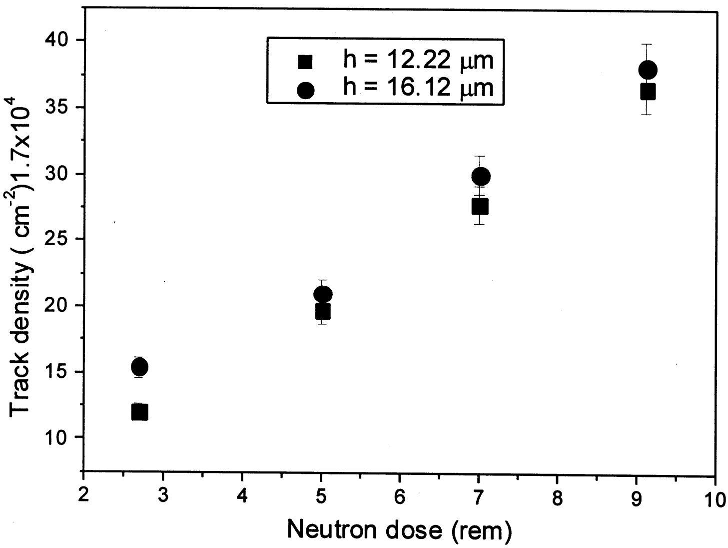

Fig. 2. The variation of track density as a function of neutron dose for two CR-39 samples etched for 5.5 and 8 hours

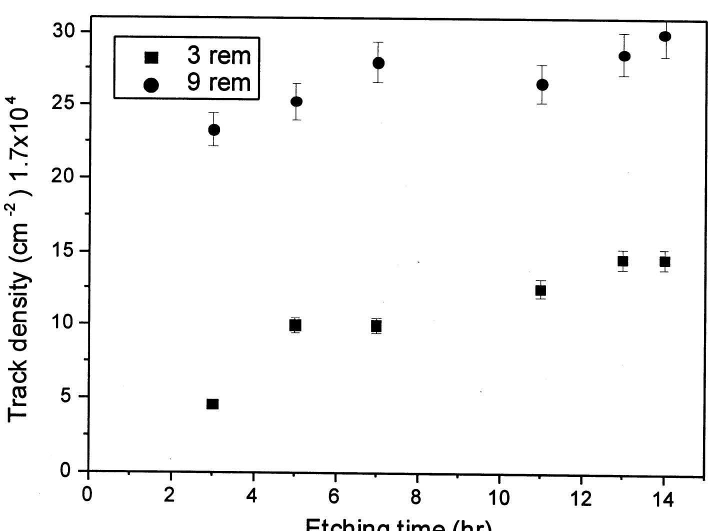

Fig. 3. The track density as a function of etching time for two samples irradiated by 3 and 9 rem neutron dose

Gamma-ray effect

Figures 4 and 5 represent the effect of gamma-ray irradiation on the solid-state nuclear track detector. We note the increase in both bulk-etching rate V_B and track diameter of the recoiled protons. V_B is a linear function of the gamma-ray dose and this result agrees well with the results of other works [9, 10].

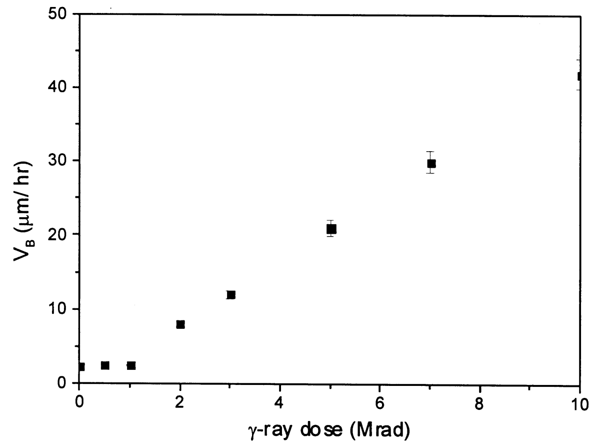

Fig. 4. The bulk-etching rate of CR-39 as a function of absorbed γ-ray dose. The etching process was held at 6.5 N, 60 °C for 20 min

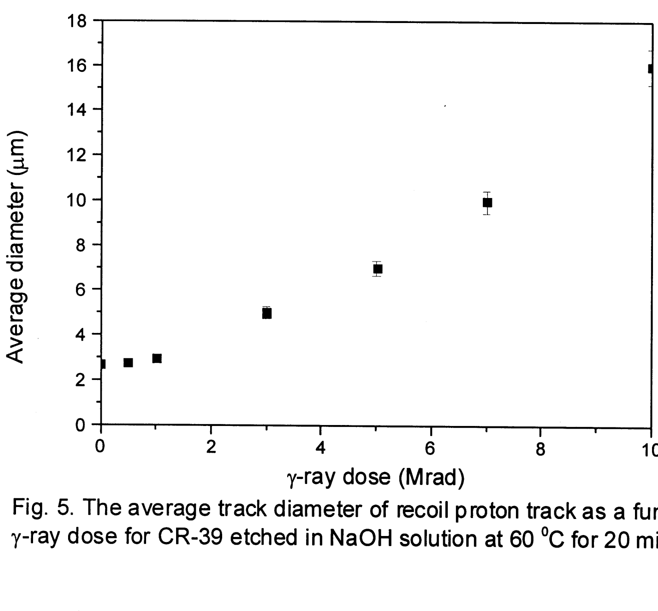

Fig. 5. The average track diameter of recoil proton track as a function of γ-ray dose for CR-39 etched in NaOH solution at 60 °C for 20 min

A probable explanation for the increase in bulk-etching rate can be attributed to the decrease in the average molecular weight by scissions of the molecular chains caused by gamma rays [11]. On the other hand, existing latent tracks produced by recoiled protons are enhanced by further scissions of the molecular chains along the particle trajectory by gamma radiation. So, the sensitivity increases for the high gamma doses as is shown in Fig. 6. An increase of the sensitivity (tracks/neutron) starts at 4 Mrad ($2.5x10^{-4}$ tracks/neutron) and has a maximum value at 10 Mrad ($1.5x10^{-2}$ tracks/neutron).

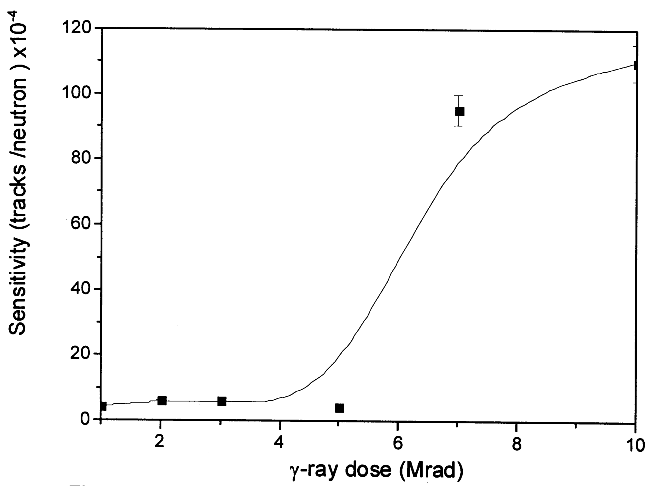

Fig. 6.Sensitivity of CR-39 to fast neutrons as a function of γ-ray dose for neutron irradiated sample 4 rem

The other very important effect of gamma rays on CR-39 is possibility to distinguish easier the recoiled proton tracks from background after irradiation by gamma rays. As an example, a photomicrograph for CR-39 sample irradiated by fast neurons and etched in NaOH aqueous solution 6.25N at 60 ^{0}C for 12 hours is represented in Fig.7. The CR-39 sample irradiated by fast neutrons with subsequent gamma irradiation (10 Mrad), then etched in NaOH aqueous solution for 30 min is represented in Fig.8. The removed layer was the same in these two cases but, as we see, the sample irradiated by gamma rays has an unclear surface covered with white bubbles and background, whereas the other sample has a clear surface with lower background. Such an effect makes the real tracks to be recognizable easily.

This phenomenon may be explained on the basis of gamma interaction with CR-39 films. This interaction strongly depends on the internal structure of the absorbed material and usually produces displacement of orbital electrons from their original sites. As a result a diffusion of the defect center originally produced by the background radiation and in the material itself may move from the surface of the detector to the inside. It then follows that a repairing of some broken molecular chains, formed near the detector surface, may result and a reduction of background track is obviously noticed. Moreover, real tracks were easily separated from remaining background because the latter were, at least, distorted in shapes and we can verify the real tracks formed by recoil protons and those for background. One can say that a gamma dose in the absorbed γ-ray dose range (4-10 Mrad) will preserve CR–39 sensitivity response to recoil protons.

The investigated properties of solid-state nuclear track detector of the CR-39 type allow expecting its wide application as a fast neutron dosimeter.

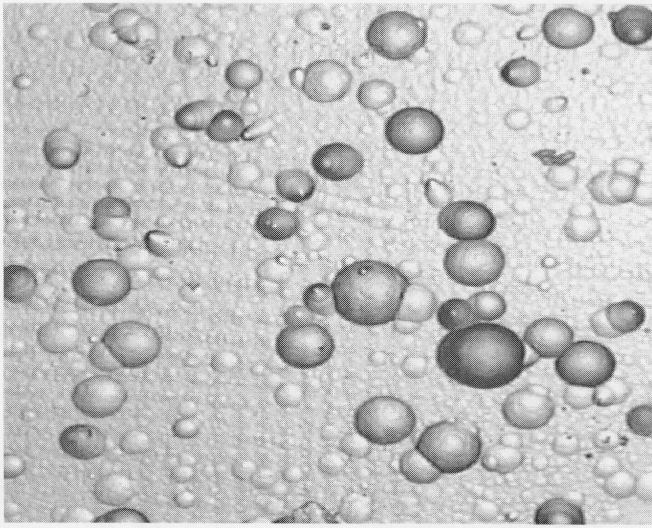

Fig.7. Photomicrograph of recoil protons tracks in CR-39 plastic detector irradiated with ^{241}Am-Be source, etched in NaOH 6.5 N for 12 hours, magnification 500x

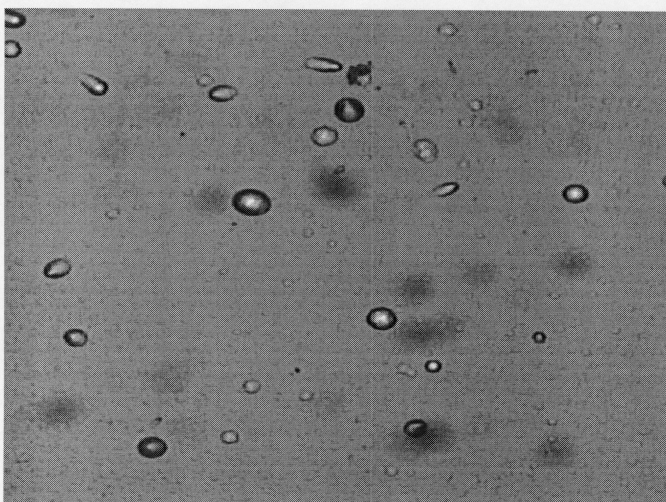

Fig. 8. Photomicrograph of recoil protons tracks in CR-39 irradiated by ^{241}Am-Be source, post exposed to 10 Mrad γ-ray, etched for 0. 5 hour, magnification 500x

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Воздействие гамма-излучения
на регистрацию быстрых нейтронов с помощью CR-39

Набор пластических детекторов типа CR-39, покрытых полиэтиленовыми радиаторами, облучался от Am-Be-источника нейтронов с интенсивностью $0{,}86 \cdot 10^7\ c^{-1}$, что на расстоянии 1 м от источника соответствует эквивалентной дозе 11 мбэр/ч. Другой набор образцов был облучен нейтронной дозой 4 бэр, а затем экспонирован на различных дозах γ-излучения от источника ^{60}Co. Было найдено, что плотность треков возрастает с увеличением нейтронной дозы и времени травления. Также показано, что массовая скорость травления V_B, диаметр треков и чувствительность пластического детектора CR-39 по отношению к нейтронному облучению увеличивается с увеличением дозы γ-излучения в диапазоне 1–10 Мрад. Эти результаты показывают, что CR-39 может рассматриваться как перспективный дозиметр быстрых нейтронов и γ-лучей.

Работа выполнена в Лаборатории нейтронной физики им. И. М. Франка ОИЯИ.

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Effect of Gamma Rays on Fast Neutron Registration in CR-39

A set of CR-39 plastic detectors with front PE radiator was exposed to Am-Be neutron source, which has an emission rate of $0.86 \cdot 10^7\ \mathrm{sec}^{-1}$, and the neutron dose equivalent rate 1 m apart from the source is equal to 11 mrem/hr. Another set of samples was irradiated by a neutron dose of 4 rem, then exposed to different gamma-ray doses using ^{60}Co source. It was found that the track density grows with the increase of neutron dose and etching time. It was also found that the bulk etching rate V_B, the track diameter and the sensitivity of the CR-39 plastic detector with respect to the neutron irradiation increased with increasing γ-ray dose in the range 1–10 Mrad. These results show that CR-39 can be considered as a promising fast neutron dosimeter and γ-ray dosimeter.

The investigation has been performed at the Frank Laboratory of Neutron Physics, JINR.

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