

DETERMINATION OF THE ACCELERATED HEAVY IONS REGISTRATION THRESHOLD IN MULTILAYERED POLYMERIC FILMS

I.V. Vorobyova, B.V. Zajtsev, A.P. Kobets

National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

E-mail: kobets@kipt.kharkov.ua

As detectors high-energy ions polymeric films from polyethyleneterephthalate (PETF) were used. Films were irradiated on the Kharkov heavy ions linear accelerator MILAC with the accelerated ions of nitrogen and argon with energy of 1 MeV/u. Multilayered samples consisted of polymeric films of a various thickness contacting with each other (3,6,10 μm) from which various combinations of thickness of contacting films were made. For revealing of tracks after irradiation samples were handled in an alkali solution. Methods of optical microscopy investigated surfaces of films and formation of tracks by the accelerated ions of argon and nitrogen was compared. Researches are carried out and thresholds of registration of the accelerated ions of an argon and nitrogen in multilayered PETF films are spotted depending on energy losses

PACS: 61.80.Jh; 61.82.Pv

1. INTRODUCTION

The Kharkov *Multicharge Ion Linear Accelerator* (MILAC) is a unique physical and technology complex [1]. The structural scheme of the accelerator is given in Fig.1.

The complex is consists from: the first prestripping section PSS-15 (Fig.1, p.2), the second prestripping section PSS-4 (Fig.1, p.5), the main section MS-5 (Fig.1, p.3) and the system of the ion irradiation (Fig.1, p.8).

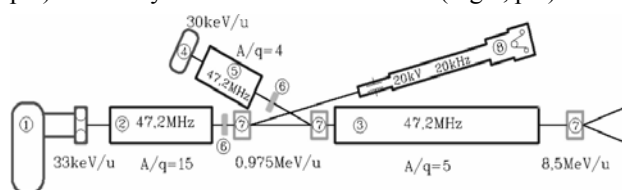


Fig.1. Structural scheme of the MILAC

The linear accelerator IH accelerating of structures of various modifications was leaded in MILAC [2]. That is given the possibility to expand considerably a scientific and applied range of researches. Experimental investigations with the heavy ion beams were carried out for obtaining track-etched membranes, production of unique radionuclides, developments of proton and ion therapy, studying of radiating characteristics of constructional materials of nuclear power, research processes of fusion-fission superheavy nucleus and other problems of nuclear physics. Experimental investigations of polymeric films irradiated by heavy ion beams were carry out in MILAC with the aim of obtaining of track-etched membranes [7-8]. The triple-charge Ar_{40}^{3+} ions were accelerated to the energy of 1 MeV/u with the intensity of 10^{10} particles/s in the MILAC prestripping section. PETF films of 6...10 μm thickness were irradiated of such ions and experimental samples of track-etched membranes with through pores from 2 to 0.05 μm in diameter were obtained after subsequent physical and chemical treatment (Fig.2).

A special system for the polymer film ion irradiation by horizontal beam scanning with the frequency of 20 kHz and sinusoidal voltage up to 20 kV was developed with the aim to provide uniform track distribution with the specific density and orientation.

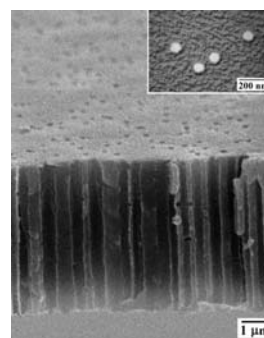


Fig.2. Pores at the cross section and the surface of track-etched membrane

In the presented work we describe the results of experiments where MILAC linear accelerator was used for the polymer film irradiation by ions lighter than Ar. On the last years different types of polymeric films are used for production of track-etched membrane with a system of through pores ranging from micrometers to sub-micrometers in diameter. The PETF (polyethyleneterephthalate) films belong to a polymer that are using for track membrane production most often because that polymer is characterized by high mechanical strength and by simple enough membrane production way. Xe ions having the energy of 1 MeV/u are most commonly used for irradiation of films. Methods for etching and sensitization of those tracks are investigated in a large number of works [3-6]. Nevertheless, application of Xe ions for track-etched membrane production demands large power consumption. On the last years it was shown that high-energy Ar ions can be used for manufacturing of track-etched membranes too [7-8]. Since acceleration of Ar ions is much less power-intensive process, cost of membranes should decrease essentially. Interaction of lighter than Ar ions with PETF films is not practically investigated.

In this study we investigate the etched-track formation in PETF films irradiated by N ions. We compare the conditions of the track etching in PETF films irradiated by N and Ar ions. The Ar ions are chosen for comparison because they are one of the lightest ions used for a track membranes production.

2. EXPERIMENTAL DETAILS

PETF films were irradiated with accelerated of N and Ar ions with energy of 1 MeV/u at the MILAC heavy ion linear accelerator. Irradiation dose corresponded to the track density of $5 \cdot 10^6 \text{ cm}^{-2}$ for N ions and density of 10^6 cm^{-2} for Ar ions. Samples were consisting from contacting films of different thickness with each other. We used the films with thickness of 3, 6 and 10 μm and we made various combination of thickness of contacting films. The samples were etched in 5N solution of $NaOH$ at 55°C for 1 hour and were examined in the optical microscope (MIM-10).

3. RESULTS AND DISCUSSION

For description of the received results, it is enough to consider two types of samples: the first consists from films with thickness 3, 3 and 6 μm , the second-3, 3, 3 and 6 μm . All other combinations of film thickness (3, 6, and 10 μm ; 6 and 10 μm ; 3, 3 and 10 μm ; 3, 3, 3 μm) yielded similar results.

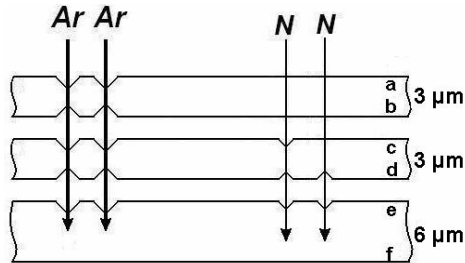


Fig.3.a. Schematic image of the multilayered sample irradiated with Ar and N ions. The sample was consisted of two films with thickness of 3 microns and one film with thickness of 6 microns

Schemes of the irradiated samples and etched tracks on their surfaces are shown in Fig.3,a,b. The Ar ions are shown by bold lines, N ions - by thin lines. The triangular grooves are shown of etched tracks.

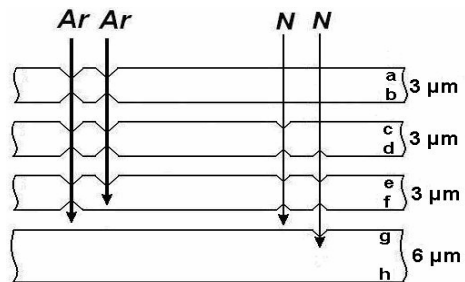


Fig.3.b. Schematic image of the multilayered sample irradiated with Ar and N ions. The sample was consisted of three films with thickness of 3 microns and one film with thickness of 6 microns

It is established that tracks of Ar ions only were etched on (a) and (b) surfaces of all samples. Photos of these tracks are shown in Fig.4.

The small amount of etching pits of N ions tracks has appeared on surfaces (c) except of etching pits of Ar ion track. On surfaces (d) and (e) of both samples all tracks of Ar and N ions were etched. Their density corresponds to the irradiation dose. Photos of the Ar and N ion etched tracks are shown on Fig.5.

Tracks of Ar and N ion were not etched on the surface (f) (Fig.3,a). On a surface (f) (Fig.3,b) all tracks of N ions and about a half of Ar ion tracks were etched. On

a surface (g) (Fig.3,b) about 80% of N ion tracks were etched and there were no tracks of Ar ions. On a surface (h) (Fig.3,b) tracks of any ions were not etched.

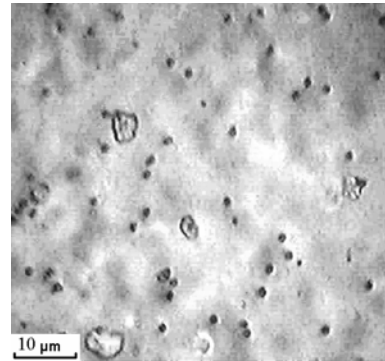


Fig.4. Etched tracks of Ar ions on the surface (a) of a sample (Fig.3,a)

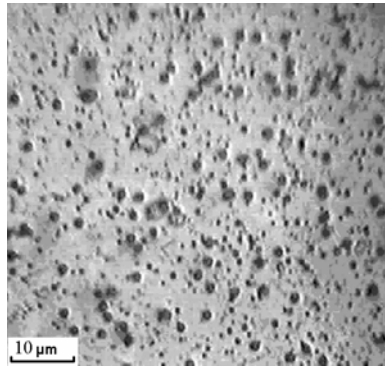


Fig.5. Tracks of Ar and N ions on the surface (d) of a sample (Fig.3,b)

Analyzing all samples with various combinations of film thickness, we have established that Ar ions with energy of 1 MeV/u have path about 9 microns in PETF films and form etched tracks along the whole path. N ions of the same energy have path about 10 microns. The main received result is as follows: the N ions are not formed the etched tracks in the beginning of path. These ions begin to form tracks only when ions will travel the distance of about 3 μm in the film bulk and lose some part of its energy. It is possible to explain this result as follows. It is known that each detector is characterized by the value of a threshold of registration i.e. the minimal energy losses which a given ion must produce in a given detector for the etched track formation. On Fig.6 dependences of ionization losses for various ions in various detectors from energy and velocity of ions are shown [9]. The registration thresholds of tracks in these detectors are shown by dotted horizontal lines. From [10] we established that the energy of N ions is decreased to 0.7 MeV/u after 3 micron of path in polymer.

Then the value of the registration threshold of tracks in PETF films is such as shown in Fig.6 by the continuous horizontal line. It is seen that Ar ions with energy of 1 MeV/u, having in the beginning of path energy losses are higher than the registration threshold, create etched tracks along all trajectory of their movement. The N ions of the same energy in the beginning of path make energy losses below the registration threshold. These ions begin to create etched tracks only after their energy losses become higher than the losses corresponding to a threshold of registration, i.e. after 3 micron of path.

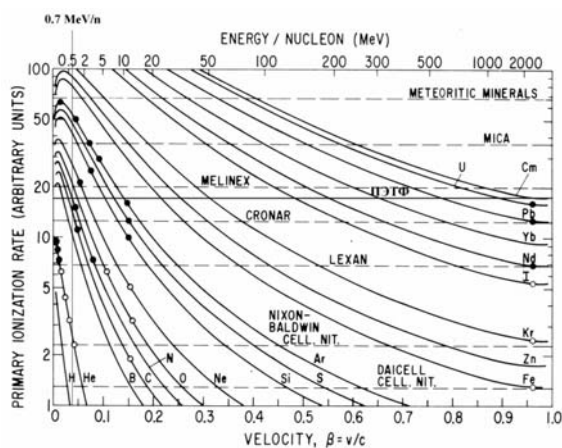


Fig.6. Dependences of the ionization losses from energy and velocity of various ions in various detectors [9]

Thus, a simple method of definition of a registration threshold of high energy ion tracks in polymeric films is found. Earlier the threshold of registration was determined as a result of the long experiments based on an irradiation of detectors by ions of various mass and energy [9]. We found that the usage of a multilayered sample allows to determinate of a registration threshold after only one irradiation. The result will be more exact if one uses layers as thin as possible. Also it is established that N ions create etched tracks only when their energy is ≤ 0.7 MeV/u. Ions of such energy have path about $7 \mu\text{m}$ in PETF films. It defines the maximal thickness of the filter which can be obtained after irradiation of PETF films with N ions.

CONCLUSIONS

It is shown that Ar ions with energy of 1 MeV/u form etched tracks along all trajectories of movement in PETF films. The N ions of the same energy do not form etched tracks on an initial part of a path (about 30% of full path). This phenomenon related with the fact that the energy losses of N ions are less than a registration

threshold of tracks in PETF films on this piece of a path.

The method of determination of a registration threshold of high energy heavy ions in polymeric films is suggested. This method is based on an irradiation and etching of the multilayered samples.

REFERENCES

1. B.O. Bomko, A.P. Kobets, Ju.P. Mazalov, B.I. Rudyak. Linear Accelerator of the Heavy Ions KIPT// *Ukr. Phys. Journal*. 1998, v.43, №9, p.1144.
2. V.A. Bomko, N.I. Demchuk, A.F. Dyachenko, et al. Interdigital Accelerating H-structure in the Multi-charged Ion Linac (MILAC) // *Review of Scientific Instruments and Methods*. 1997, v.69, №10, p.3537-3540.
3. G.N. Flerov, P.J. Apel, A.J. Didyk. Preprint JINR, Dubna, 1988, P7-88-696.
4. P. Apel, A. Shulz, R. Spohr, et al. // *Nucl. Instr. and Meth. in Phys. Res.* 1998, v.B146, p.468.
5. Z. Zhu, Y. Maekawa, H. Koshikawa, et al. // *Nucl. Instr. and Meth. in Phys. Res.* 2004, v.B217, p.449.
6. P.Yu. Apel, S.N. Dmitriev, D. Root, V.A. Vutsadakis // *Particles and Nuclei, Letters*, 2000, №4, p.69.
7. M.T. Bryk, A.P. Kobets, A. Kryshchal, et al. // *Nucl. Instr. and Meth. in Phys. Res.* 2006, v.B251, p.419.
8. V.A. Bomko, A.F. Burban, A.P. Kobets, et al. // *Nucl. Instr. and Meth. in Phys. Res.* 2008, v.B266, p.256.
9. R.L. Fleisher. *Corporate Research and Development. Technical Information Series*. Schenectady, New York, 1978.
10. J.F. Ziegler, J.P. Biersack, U. Littmark. *The Stopping and Range of Ions in Matter*. Pergamon Press, New York, 1985.

Статья поступила в редакцию 03.11.2009 г.

ОПРЕДЕЛЕНИЕ ПОРОГА РЕГИСТРАЦИИ УСКОРЕННЫХ ТЯЖЁЛЫХ ИОНОВ МНОГОСЛОЙНЫМИ ПОЛИМЕРНЫМИ ПЛЕНКАМИ

И.В. Воробьева, Б.В. Зайцев, А.Ф. Кобец

В качестве детекторов высокоэнергетических ионов использовались полимерные плёнки из полиэтилентерефталата (ПЭТФ). Плёнки облучались на Харьковском линейном ускорителе тяжёлых ионов ЛУМЗИ ускоренными ионами азота и аргона с энергией 1 МэВ/нукл. Многослойные образцы состояли из контактирующих друг с другом полимерных плёнок различной толщины (3,6,10 мкм) из которых составлялись различные комбинации толщин контактирующих плёнок. Для выявления треков после облучения образцы обрабатывались в растворе щелочи. Методами оптической микроскопии исследовались поверхности плёнок и проводилось сравнение формирования треков ускоренными ионами аргона и азота. Проведены исследования и, в зависимости от энергетических потерь, определены пороги регистрации ускоренных ионов аргона и азота в многослойных ПЭТФ плёнках.

ВИЗНАЧЕННЯ ПОРОГА РЕЄСТРАЦІЇ ПРИСКОРЕНИХ ВАЖКИХ ІОНІВ БАГАТОШАРОВИМИ ПОЛІМЕРНИМИ ПЛІВКАМИ

І.В. Воробйова, Б.В. Зайцев, А.П. Кобець

Як детектори високоенергетичних іонів використовувалися полімерні плівки з поліетилентерефталату (ПЕТФ). Плівки опромінювалися на Харківському лінійному прискорювачі важких іонів ЛУМЗІ прискореними іонами азоту і аргону з енергією 1 МэВ/нукл. Багатошарові зразки складалися з контактуючих одна з одною полімерних плівок різної товщини (3,6,10 мкм). Для виявлення треків після опромінення зразки оброблялися в розчині лугу. Методами оптичної мікроскопії досліджувалися поверхні плівок і проводилося порівняння формування треків прискореними іонами аргону та азоту. Проведено дослідження методами оптичної мікроскопії і залежно від енергетичних втрат визначені пороги реєстрації прискорених іонів аргону і азоту в багатошарових ПЕТФ плівках.