A SYSTEM FOR POLYMER FILM IRRADIATION WITH HEAVY IONS ACCELERATED TO THE ENERGY OF 1 MeV/u

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At the Kharkov heavy ion linear accelerator MILAC experimental investigations on irradiation polymer films with heavy ion beams are carried out with the aim of obtaining track-etched membranes. Presently, the MILAC prestripping section accelerates tripled-charged Ar_{40}^{3+} ions to the energy of 1 MeV/u with the intensity of $10^9…10^{10}$ particles/s. To provide uniform track distribution with the specified density and orientation in the polymer film a system of ion irradiation was developed on the basis of electrostatic scanning device.

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1. INTRODUCTION

Polymer track-etched membranes take a special place among microfiltering membranes of various types due to the outstanding uniformity of pore distribution in sizes and orientation. Technology of the track-etched membrane production is well known; it is based on irradiation thin polymer films with high energy heavy ions and subsequent physical and chemical treatment of the irradiated films [1]. As a result, through pores are generated in the polymer film; their diameters depend both on parameters of bombarding particles and on conditions of treatment. To obtain calibrated pores cylindrical in shape the etching rate along the tracks should be essentially higher than the etching rated of undamaged polymer. To increase imperfection of the polymer in the zone of the tracks and etching rate along the tracks the polymer films are irradiated with heavier ions, and various sensitization procedures are used before chemical etching.

In NSC KIPT there operates the MILAC heavy ion linear accelerator [2,3] which accelerates ions within rather wide range of masses to the energy of 8.5 MeV/u. Presently, experimental investigations on irradiation the polymer films with heavy ion beams with the aim of obtaining track-etched membranes are being carried out at the MILAC accelerator [4]. In the MILAC prestripping section triple-charge Ar_{40}^{3+} ions were accelerated to the energy of 1 MeV/u with the intensity of $10^9…10^{10}$ particles/s; PETF films 6…10 μm thick were irradiated, and after subsequent physical and chemical treatment it was possible to obtain experimental samples of track-etched membranes with through pores from 2 to 0.05 μm in diameter [5]. To provide uniform track distribution in the polymer film with the specified density and orientation a system for ion irradiation of polymer film with horizontal beam scanning with the frequency of 20 kHz and sinusoidal voltage up to 20 kV was developed.

2. PRESTRIPPING SECTION OF THE MILAC LINEAR ACCELERATOR

The MILAC heavy ion linear accelerator consists of injector (1), prestripping (2) and main (3) accelerating sections. The structural scheme of the accelerator is given in the Fig.1.

Reconstruction of the MILAC prestripping and main sections was performed on the basis of interdigital (IH) structure that was developed in KIPT [2,3]. For the first time this promising accelerating structure was introduced in the large operating accelerator and demonstrated its high efficiency.

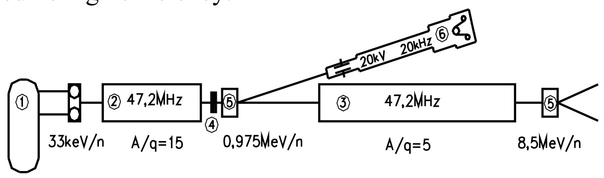

Fig.1. Structural scheme of the MILAC heavy ion linear accelerator

The prestripping section 4 m in length with the transverse dimensions 0.9×1.1 m with A/q =15 accelerates ion at the frequency of 47.2 MHz from 33 keV/u to 1 MeV/u with the intensity of the accelerated beam of 10^{12} particles/s; the main section accelerates ions with A/q =5 at the frequency of 47.2 MHz to 8.5 MeV/u with the intensity of the accelerated beam up to 10^{10} particles/s. The accelerating structure of IH-type of the MILAC prestripping section provides the acceleration rate of 3.5 MeV/m with the uniform distribution of the accelerating field in the gaps between drift tubes [6]. Thus, with the average electric field gradient in the accelerating gaps of 91 kV/cm at the length of about 4 m the ions with A/q =15 are accelerated to 1 MeV/u. In the rectangular cavity at the beginning and end of the structure original resonance end adjustment elements are formed which allowed to create the uniform distribution of the accelerating field along the overall structure.

3. ION IRRADIATION SYSTEM

Polymer film irradiation is carried out with argon ions accelerated at the prestripping section of the MILAC linear accelerator to 1 MeV/u. Main requirements on the track-etched membrane parameters are reduced to necessity to provide the same pore diameter with the spread in diameters no more than 1%, and the same density of the openings over the all membrane surface with the error of no more than 10%. High uniformity of pore distribution over the membrane surface is essentially necessary for applications in radio-electronic industry as different kinds of masks for manufacturing microchip and semiconductor instruments, and for creation the edge arrays for cold cathodes.

The system for polymer film irradiation is dedicated for forming the tracks of the specified orientation and high uniformity of distribution of the openings in the track-etched membrane. There exist different methods for obtaining the uniform particle distribution on the target. The simplest and commonest of them is the beam sweeping in the horizontal plane with an electrostatic or magnetic scanner. In this case, in vertical direction the beam sweeping is achieved due to the film transportation with a tape drive.

Each of the listed methods for sweeping (either electrostatic or magnetic) has advantages and drawbacks. The electrostatic scanner is simple in manufacture; however, its application in the ion irradiation system may lead to some technical difficulties rise. For example, corona discharge in the place of the scanner plates location in the ion channel, and also high requirements on the insulator inputs of the scanning plates. The drawbacks of the magnetic scanner lie in nonlinearity of the current in the magnet windings causing the field nonuniformity, and also the high cost and complexity of the linear current generator. The system for ion irradiation of the MILAC accelerator is based on the electrostatic scanner (in the given case the electrostatic scanner was chosen due to availability of the appropriate element base).

The system for ion irradiation includes: stripping chamber, beam forming system, deflecting magnet, measuring unit, scanner, irradiation chamber with a tape drive, system of vacuum pumping-out. The schematic view of the system for ion irradiation is given in the Fig.2.

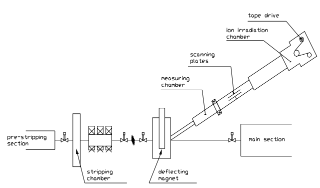

Fig.2. The scheme of the ion irradiation system

In the stripping chamber the ion charge increases. The beam of the charged ions passing the special stripping foils loses several electrons from the upper shell increasing their charges in that way. Application of recharging (stripping) in the heavy ion linear accelerator gives a possibility to broaden the range of ions being accelerated and to increase the acceleration rate in the following sections. For irradiation the polymer film higher charge of ions is necessary in order to simplify bending the beam with the deflecting magnet and beam sweeping and scanning.

For recharging triple-charged argon ions accelerated to 1 MeV/u, a solid target 16…20 mm in diameter in the form of a thin carbon film with the density of 10^{17}…10^{18} atoms per cm^2 is used. After passing the stripping carbon target the components of the accelerated beam (Ar^{11+}, Ar^{12+}, and Ar^{13+}) are generated which are approximately equal in intensity (25…30% of initial value).

The deflecting magnet directs the accelerated beam of twelve-charged argon ions from the accelerator axis into the system of scanning and ion irradiation; the beam profile is imparted the necessary geometry (1 cm in horizontal direction and 6 cm in vertical direction) with electromagnetic quadrupole lenses assembled in doublets and triplets.

The scanning device serves for sweeping Ar^{12+} beams in horizontal plane; it consists of a sweep generator and deflecting plates. Any of the three forms of voltages (sinusoidal, sawtooth, or triangular) may be applied to the plates of this scanner; but only their linear part would be used. Linearity of this part should be no worse than 5%. The main advantage of this scanner is its capability of scanning accelerated ion beam in the wide frequency range due to the fact that ion beam acceleration occurs in the pulsed mode with duration the flat part of RF envelope up to t = 500 μs.

At the initial stage sinusoidal voltage was chosen for scanning the ion beams at the frequency of $f_o = k/t = 20$ kHz with the number of scanning periods within the pulse duration, k = 10.

Energy of the accelerated ions is 1 MeV/u, charge $Z = +12$, mass number $A = 40$, width of the film being irradiated $b = 30$ cm, distance between the scanner and the target L = 7 m, dimensions of the plates of the electrostatic scanner are: length – 50 cm, width – 10 cm. With these parameters the amplitude of the electric field intensity $E_a = (\alpha_1 \beta^2 A E_o)/(ZeL_1) \approx 2.8$ kV/cm. Then with distances between scanner plates 7 cm the amplitude of the voltage difference between the plates will be $U_a = +19$ kV.

Thus, a generator of high sinusoidal voltage with amplitude of +20 kV and frequency up to 20 kHz is necessary to create the scanning device. The self-contained generator circuit was chosen on GI-39B pulse generator triode with transformer feedback and series feeding on the anode of the tube in the mode of anode modulation. Bias voltage is applied to the triode grid automatically. The oscillating circuit built on the six capacitors of K15Y-1-470 type and three windings on the ferrite ring: W_1 outline winding has 40 turns, feedback winding W_2 has 3 turns, and W_3 load winding has 400 turns. A locking choke is used. The generator operates in the pulse mode.

The ion channel (Fig.3) represents a vacuum chamber of alternating cross-section 8 m in length provided with the system of high vacuum pumping including three oil-vapor diffusion pump assemblies with the total pumping rate of 3000 l/s. The length of the ion channel defines the necessary beam spread in the horizontal plane over the target being irradiated.

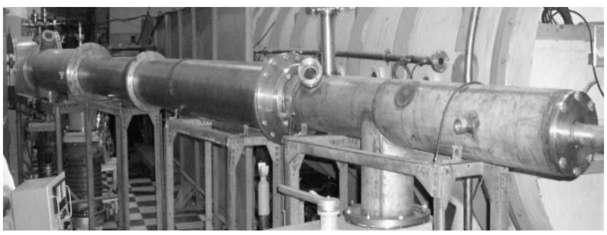

Fig.3. The photo of the ion irradiation system

In the irradiation chamber the tape drive of the tape recorder type supplies the polymer film to the zone of irradiation with the rate of 1…5 m/s.

The minimum diameter and cylindrical shape of the pores in the track-etched membrane is achieved the easier the higher is the atomic number of accelerated ions which irradiate the polymer film. Thus, in order to increase the mass and intensity of ions accelerated to 1 MeV/u a new prestripping section of the MILAC accelerator rated for $A/q \leq 16$ and frequency 23.6 MHz is presently developed; it is based on the interdigital accelerating structure combining alternating phase focusing and RF quadrupoles [7]. The calculations show that the two methods for RF focusing combined will allow acceleration of heavy ion beams without preliminary acceleration in the RFQ structure. This will create conditions for track-etched membrane production, and allow using heavy ion beams accelerated in the main section to 8.5 MeV/u for reactor engineering and also solving various problems in nuclear physics.

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СИСТЕМА ОБЛУЧЕНИЯ ПОЛИМЕРНОЙ ПЛЕНКИ ТЯЖЕЛЫМИ ИОНАМИ, УСКОРЕННЫМИ ДО ЭНЕРГИИ 1 МэВ/нукл.

В.А. Бомко, М.Т. Брык, А.Ф. Дьяченко, А.В. Заботин, Б.В. Зайцев, В.В. Жук, В.Г. Журавлев, А.Ф. Кобец, А.И. Кравченко, М.С. Лесных, В.Н. Решетников

На Харьковском линейном ускорителе тяжелых ионов ЛУМЗИ проводятся экспериментальные исследования по облучению пучками тяжелых ионов полимерной пленки для получения трековых мембран. В настоящее время предобдирочная секция ускорителя ЛУМЗИ ускоряет трехзарядные ионы аргона Ar_{40}^{+3} до энергии 1 МэВ/нуклон с интенсивностью $10^9…10^{10}$ част./с. Для обеспечения равномерного распределения треков в полимерной пленке с заданной плотностью и направленностью треков разработана система ионного облучения. Работа выполнена по гранту №2476.

СИСТЕМА ОПРОМІНЕННЯ ПОЛІМЕРНОЇ ПЛІВКИ ВАЖКИМИ ІОНАМИ, ПРИСКОРЕНИМИ ДО ЕНЕРГІЇ 1 МеВ/нукл.

В.О. Бомко, М.Т. Брик, О.Ф. Дьяченко, О.В. Заботін, Б.В. Зайцев, В.В. Жук, В.Г. Журавльов, А.П. Кобець, А.І. Кравченко, М.С. Лєсних, В.М. Решетніков

На Харківському лінійному прискорювачі важких іонів ЛУМЗІ проводяться експериментальні дослідження по опроміненню пучками важких іонів полімерної плівки для одержання трекових мембран. На цей час передобдиркова секція прискорювача ЛУМЗІ прискорює тризарядні іони аргону Ar_{40}^{+3} до енергії 1 МеВ/нуклон з інтенсивністю $10^9…10^{10}$ част./с. Для забезпечення рівномірного розподілу треків у полімерній плівці із заданою щільністю и спрямованістю треків розроблена система іонного опромінення. Робота виконана по гранту №2476.