A CHANNEL FOR ION IRRADIATION OF MATERIALS AT THE ACCELERATOR "SOKOL"

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At the accelerator "Sokol" a channel for ion irradiation of materials is constructed. The channel comprising a beamline system, a slit device, an electrostatic scanning system with power and control modules, and an irradiation chamber is placed behind the analyzing magnet. The main technical parameters of the channel are the following: ions used – H, He, N, Ar; ion energy – 0.2…2 MeV; ion beam current – 2 µA; target zone being irradiated – from 2 ×2 mm up to 40×40 mm; target holder temperature – 80…450 K. Irradiation channel tests are performed together with experiments on polyimide films irradiation with hydrogen ions with an energy of 400 keV.

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Investigations of changes in the properties of constructional materials under irradiation effect are necessary for prediction of the material behaviour under extremes operating conditions (cosmic space, nuclear power) in order to obtain materials with given properties (mechanical, electrical etc.) For this purpose at the accelerator "Sokol" an additional channel for ion irradiation of materials was constructed [1]. Proceeding from the problems that have been put, for irradiation of materials one need to obtain the beams of accelerated ions H^+, C^+, N^+, O^+ and the beams of inert gas ions. It is desirable to have a possibility of changing the accelerated ion energy from several hundreds of keV to 1.8 MeV, the beam current from 0.01 to 1 µA. The beams of accelerated ions with such parameters can be produced at the accelerator "Sokol". The mass-analyzer of the accelerator is a distributing magnet and, simultaneously, permits to transport accelerated ion beams via fifth channels by ±26°, ±45° (relatively to the initial beam direction) and 0° (direct exit). The first four channel are used for carrying out of analytical investigations by the different nuclear-physics methods.

Besides, in the case of heavy ion beam bending by 26° or 45° there are limitations for maximum energies of accelerated ions. Taking into account the above-said it should be more reasonable to make an irradiation channel with the use of a direct exit in the mass-analyzer.

Under irradiation of specimens with ions of hydrogen, carbon, nitrogen and oxygen it is necessary to perform resolution of ion beams by the mass, as the accelerated beam contains both the atomic and molecular ions. Therefore, the irradiation channel was disposed at some angle relatively to the initial beam direction. The angle of beam bending was chosen considering the geometrical room dimensions and design features of the installation. A bending angle of 5°40′ was maximally possible that corresponds to the ion beam bending radius equal to 2.5 m. Such a bending radius gives a possibility to transport into the irradiation channel the heavy ions up to Xe with energy of 2 MeV.

The irradiation channel is shown schematically in Fig.1. It is constituted from the following basic units: slit device (1); scanner system (2); irradiation chamber (3); vacuum pumpdown systems; ion beamline sections; supports with adjusting systems.

The slit device performs two functions - it serves as an exit slit of the mass-analyzer and, simultaneously, as an element of the accelerated ion energy stabilization system.

An important unit of the irradiation system is the beam scanning system. The electrostatic scanning system, providing an equal beam ion deflection independently on the mass, was chosen.

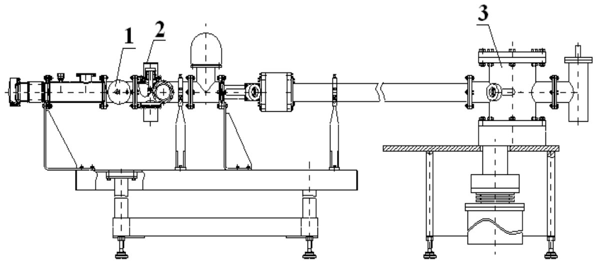

Fig.1. Layout the irradiation channel

The basic parameters of the scanning system of the material irradiation channel are the following:

- ion beam energy range	0.2...2 MeV;
- ion beam current	0.01...5 µA;
- dimension of the target scanning section (x, y)	±2...±20 mm;
- ion beam diameter	~2 mm;
- frequency of beam scattering on the «X» axis	260 Hz;
- frequency of beam scattering on the «Y» axis	4 kHz;
- space between the scanning device and the target	1800 mm;
- inhomogeneous distribution of irradiation dose by the «expsure»	~10% (±5%);
- space between the deflecting plates	10 mm;
- plate length	100 mm;
- plate width	30 mm;
- maximum difference of potentials between the plates	4 kV.

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The power supply unit of the scanning device consists of three modules: power supply module; module of high-voltage amplifiers; control module.

The power supply module supplies a stabilized voltage ±12 V, +9 V, +5 V and unstabilized +5 kV to all other modules of the unit.

The module of high-voltage amplifiers consists of four amplifiers made with 6P13C lamps and has the amplification of signal by voltage of about 500. The output signals from the amplifiers are applied to the plates of the scanning device. The control signals to the module arrive from the control module.

The control module generates four voltages of a triangular shape controlling the high-voltage amplifiers. The voltages are phase matched in pairs, their amplitudes depend on the ion beam energy and on the size of the target zone being scanned; and the pulse repetition rate continues to be constant (260 Hz and 4 Hz for scanning on «X» and «Y» axes, respectively). The functional circuit of the one channel of the control module («X» or «Y»), is given in Fig.2.

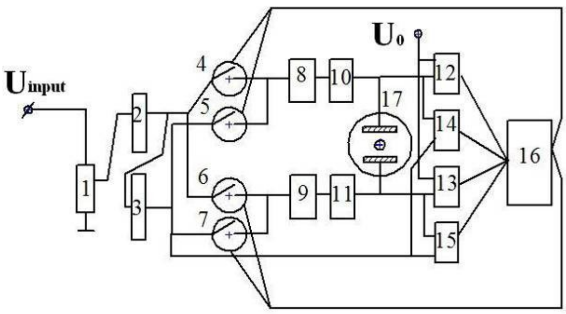

Fig.2. Functional circuit of the one channel of the «X» or «Y» unit. 1 – setting the size of the zone being scanned; 2 – follower, 3 – invertor; 4...7 – current switches; 8...9 – integrator; 10...11 – high-voltage amplifiers; 12...15 – threshold unit; 16 – logic unit, 16 - deflecting unit; 18 – supplying voltage module

The input signal (U_{input}), proportional to the ion beam energy, arrives from the rotor voltmeter exit. Depending on the required dimensions of the scanning zone its amplitude can be decreased by means of the potentiometer 1 and, using the follower 2 and the invertor 3, from this signal two signals are formed having opposite signs and an equal amplitude. Via the switch 4 the formed signal arrives to the entrance of the integrator 8, at the exit of which formed is a linearly increasing voltage the rate of which is proportional to the input signal value. The linearly increasing voltage obtained is amplified by the high-voltage amplifier 10 and is applied to one of the plates of the deflecting device 17 deflecting the ion beam from the axis. Also, it is applied to the threshold units 12 and 14. When the voltage reaches the level deflecting the beam at the given distance on the target, the threshold unit 14 begins to operate and the logic unit 16 forms the control signal that cuts off the switch 4 and opens the switch 5. The reverse integration begins. Thus, the duration of the direct integration does not depend on the input signal value. During the reverse integration the voltage at the high-voltage amplifier entrance linearly decreases and, after reaching 100 V value, the threshold unit 12 begins to operate. Then the logic unit 16 cuts off the switch 5 and opens switch 6, thus starting the direct integration by the integrator 9 and, consequently, the ion beam deflection in the direction opposite to the axis. After finishing the reverse integration by the integrator 9, the logic unit 16 repeats the cycle.

The curve of voltage changing at the «X» plates is presented in Fig.3. The shape of the voltage curve at «Y» plates is similar.

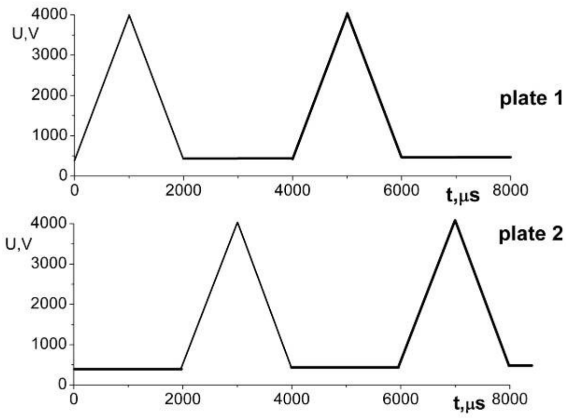

Fig.3. Curve of voltage changing at the «X» plates

The chamber is made on the platform of a vacuum universal post VUP-4 and permits to use under irradiation its standard equipment (heater, cooler, systems for specimen fastening etc.) The chamber is equipped with a new high-efficient pumpdown system on the base of a turbomolecular pump making it possible to maintain the residual gas pressure in the chamber during irradiation at a level of 5×10^{-4}Pa; the temperature monitoring for the specimen holder is provided in the range from 80K to 450 K. The channel system was adjusted and tested. The experiments have been carried out on irradiation of the polyimide film using the energy of 400 keV. Fig.4 presents the polyimide film irradiated with hydrogen ions.

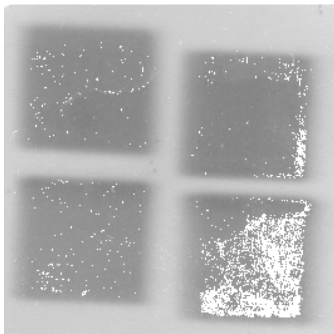

Fig.4. Polyimide film irradiated with hydrogen ions. The upper left dark square is for the irradiation dose of 3×10^{15}ion/cm^2; the upper right square – for 4×10^{15}ion/cm^2; the lower left square – for 1×10^{15}ion/cm^2; the upper right square – for 2×10^{15}ion/cm^2

So, the channel for irradiation of materials with gas ions was designed and constructed at the accelerator "Sokol".

It is intended to imply the equipment developed for modification of properties of structural materials, as

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well as, for studies on the processes of irradiation damage of polymeric materials.

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КАНАЛ ИОННОГО ОБЛУЧЕНИЯ МАТЕРИАЛОВ НА УСКОРИТЕЛЕ «СОКОЛ»

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На ускорителе «Сокол» создан канал ионного облучения материалов. Канал установлен после анализирующего магнита и состоит из ионопровода, щелевого прибора, электростатической сканирующей системы с блоком питания и управления, камеры облучения. Основные технические параметры разработанного устройства следующие: используемые ионы H, He, N, Ar; энергия ионов 0,2…2 МэВ; ток пучка до 2 мкА; площадь облучения образца ─ от 2×2 мм до 40×40 мм; температура держателя образца ─ от 80 до 450 K. Проведены испытания канала облучения и выполнены эксперименты по облучению полиимидных пленок ионами водорода с энергий 400 кэВ.

КАНАЛ ІОННОГО ОПРОМІНЕННЯ МАТЕРІАЛІВ НА ПРИСКОРЮВАЧІ «СОКІЛ»

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На прискорювачі «Сокіл» створений канал іонного опромінювання матеріалів. Канал встановлений після аналізуючого магніту і складається з іонопроводу, щілинного пристрою, електростатичної скануючої системи з блоком живлення і управління, камери опромінювання. Основні технічні параметри розробленого пристрою наступні: іони, що використовуються, ─ H, He, N, Ar; енергія іонів ─ 0,2...2 МеВ; струм пучка ─ до 2 мкА; площа опромінювання зразка ─ від 2×2 мм до 40×40 мм; температура утримувача зразка ─ від 80 до 450 K. Проведені випробування каналу опромінювання та експерименти по опромінюванню поліімідних плівок іонами водню з енергією 400 кеВ.