ELECTROPHYSICAL COMPLEX ON BASIS OF THE ELECTROSTATIC ACCELERATOR ESA-2 FOR FUNDAMENTAL AND APPLIED INVESTIGATIONS

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Abstract

Electrostatic accelerator ESA-2 is a multy-purpose tool for fundamental and applied research in nuclear and particle physics. Usage of ESA-2 in quality an implanter, and as a source of ions for conducting of investigations of solid-state materials by non-destructive control methods, such as, for example, the Rutherford backscattering (RBS) is discussed. The Rutherford backscattering spectrometer has been designed and assembled. The present paper deals with the interaction of 380 keV H^+ ions with Si surface at glancing angles corresponding to the quasi-channeling regime. The outcomes of the experimental researches of sliding interaction of beams of the accelerated protons with energy from 180 up to 350 keV with a surface of a dielectric capillary are presented.

INTERACTION OF FAST HYDROGEN IONS WITH SILICON SURFACE AT GLANCING ANGLES OF INCIDENCE

Angular distributions of 380 keV protons reflected from (111) surface of Si monocrystal were measured in the range of projectiles glancing angle from 0.3° up to 0.8°. It is shown that increase of glancing angle causes non-linear change of such distribution parameters as angular width of the front rise, angular width of the distribution, the maximum yield value. Registered energy spectrum of reflected particles for glancing angle of 0.5° consists of several peaks with practically constant angular intervals between them and maxima weakly reducing towards lower energy region. It is experimentally shown that the most energetic peak relates to the reflection from the very surface and the rest ones are caused by successive scattering of ions by inner silicon crystallographic planes [1]. Fig.1 is a scheme of the experimental setup used in the present study. Monoenergetic proton beam, generated by the Van de Graaf accelerator, is collimated by 1 mm circular diaphragms S_1 and S_2. Twinned diaphragm S_3 is used for ion beam monitoring. The exit part of S_3 has a diameter of 0.5 mm. One more 0.5 mm collimator S_4 is placed in front of the sample to avoid the influence of the particles scattered at the edge of S_3. The sample is placed on two-axis goniometer having an accuracy not worse than 10^{-2} degree. Silicon surface-barrier detector with an aperture 0.3 mm is placed at a distance of 115 cm from the sample. The detector can move perpendicularly the ion beam axis direction in the range from 0 to 6.9 degrees with the velocity of $2.42 \cdot 10^{-3}$ degree per second. Measured angle divergence of the ion beam was not worse than $\pm 2.0 \cdot 10^{-2}$ degree. The energy of the proton beam was set by calibrated magnetic analyzer with the accuracy of ± 0.1 %. The overall measured energy resolution of the system including the energy spread of the ion beam did not exceed 19 keV.

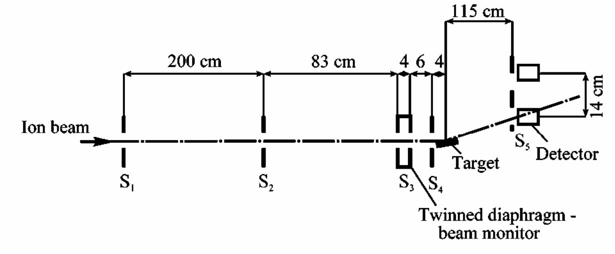

Figure 1: Schematic of the experimental setup.

The samples for angular distribution measurements were cut from (111) silicon wafers with epitaxially grown Si film 3.94 μm in thickness and the resistivity of 1 Ω·cm. Strips 20 mm wide and 70 mm long were cut parallel to (110) plane. After cleaning in boiling toluol samples were pasted to the sample holder. Samples were mounted in the goniometer in such a way that the angle between their long side and the beam axis was near 11°, that allowed to avoid the influence of (110) plane on the process of ions scattering at (111) silicon surface. Rutherford backscattering with 1.1 % resolution electrostatic analyzer was used to control crystal structure and surface quality of the samples. The pressure in the vacuum chamber during measurements was $6 \cdot 10^{-5}$ Pa.

Angular distributions of hydrogen ions with the energy of 380 keV reflected from the polished silicon surface for glancing angles 0.3° and 0.5° are shown in fig.2. The difference between the distributions is clearly visible. Maxima position for reflected particles distributions. At glancing angle of 0.3° the maximum yield in the angular distribution is situated at scattering angle of 0.48°, whereas for glancing angle of 0.5° – at 0.90°, i.e. these values are substantially less than those for mirror reflection. The same maximum behaviour was observed at larger glancing angles. E. g., for glancing angle of 0.8° the maximum was situated at 1.4°.

Energy spectrum of 380 keV protons reflected by (111) Si crystal plane at glancing angle of 0.5° is given in fig. 3. The angle value of 0.5° was chosen with the aim both to minimize the spectrum background, as in this case projection of the beam cross section lies entirely on the

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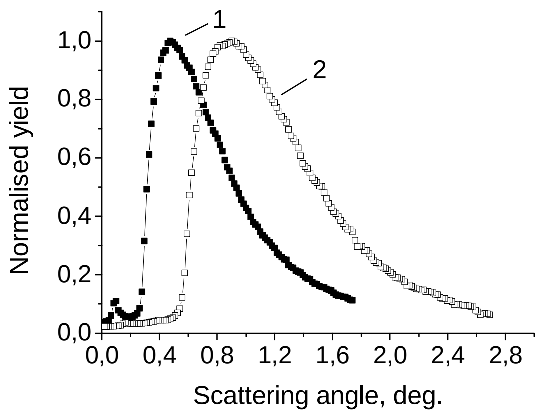

Figure 2: Angular distributions of 380 keV protons scattered by the (111) silicon surface for glancing angle values of 0.3°(1) and 0.5°(2).

sample surface, and to provide quasichanneling conditions for projectiles. It can be seen that the energy spectrum consists of several peaks situated at practically equal distances between them and peak heights weakly reducing towards the lower energies. This is evidence that ion-target interaction is regular by origin and the shape of energy distributions of the scattered particles is defined by the crystalline structure of the target.

The measurements of angular distributions and energy spectra of the protons reflected by (111) Si surface at glancing entrance angles showed that:

1) When the glancing angle of projectiles with respect to the plane exceeds the critical one further increase of the angle value causes non-linear change of such angular distribution characteristics, as angular width of the front rise, the angular width of the distribution, the maximum yield value.

2) At glancing angle values larger than the critical angle for planar channeling the energy spectra possess fine structure reflecting the peculiarities of charged particles interaction with monocrystals.

3) Mechanical damage of the reflecting surface leads to smoothing of the peaks in energy spectra corresponding to scattering inside the crystal and suppresses the surface scattering peak.

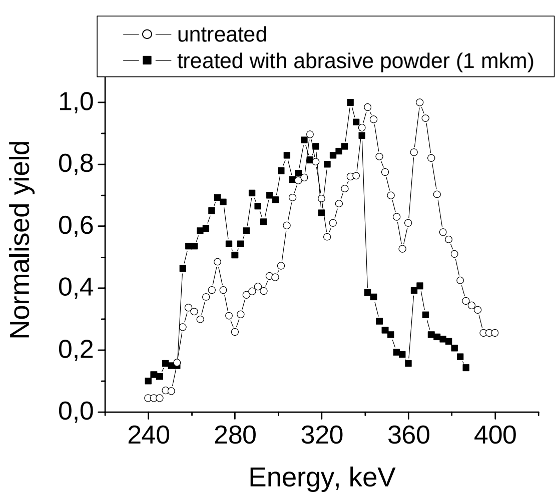

Figure 3: Energy spectra of 380 keV protons scattered by (111) silicon surface registered at 1° scattering angle. Glancing angle value was 0.5°.

RBS SPECTROMETR WITH IMPROVED ENERGY RESOLUTION

The Rutherford backscattering spectrometer has been designed and assembled [2]. It has a high resolution provided for usage an electrostatic energy analyzer. The energy range of detected ions is 40 to 300 keV. The energy resolution is better than 1.1 percent. Basing on experimental results it is shown that RBS spectrometer with electrostatic analyzer as a sensor can be successfully applied both for shallow depth impurities profiling (fig. 4) and also for measurements such ion beam parameters of neutron generator NG-12 as energy and energy width (table).

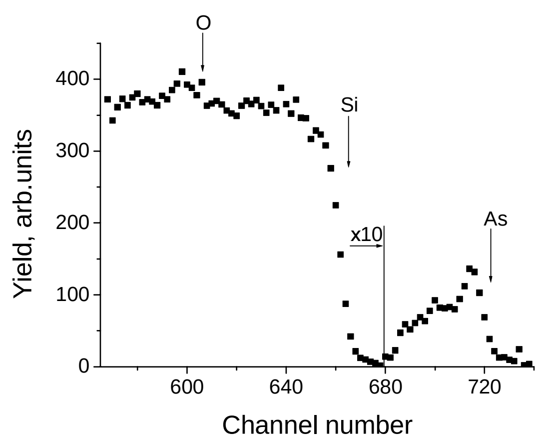

Figure 4: RBS of protons with energy 214 keV from GaAs.

Table: Parameters of ion beam NG-12

$E_{accel.}$, keV	$E_{meas.}$, keV	ΔE, keV
100	75,5	2,42
120	92,5	4,27
130	115,0	5,06
150	133,0	2,53
200	200,0	3,65
240	222,0	3,38

ION IMPLANTATION

Ion implantation usage for electrical isolation of microelectronic devices based on IV group (Si) and III-V (GaAs) semiconductors is described [3]. In case of Si, substoichiometric nitrogen implantation is proposed as method for the creation of buried dielectric layers for device/substrate isolation. For III-V semiconductors, device/device isolation can be achieved by the formation of ion beam induced defect regions where radiation defects produce deep-level traps for carriers. Polyenergetic and high energy ion implantation is studied as the method for the formation of uniform defect distributions.

The isolation behaviour in n-type GaAs due to proton implantation is considered. Good quality electrical isolation has been achieved by polyenergetic implantation of H^+ ions with energies up to 400 keV. A conductivity dependence on the frequency 1 kHz has been measured for the GaAs layers modified by proton irradiation both before and after annealing in the temperature range 100-400° C [4]. Fig. 5 shows the evolution of the implanted layer resistivity (ρ) as a function of annealing temperature.

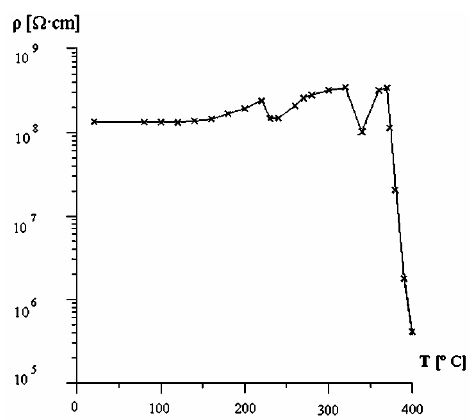

Figure 5: Evolution of layer resistivity as a function of post – implant annealing temperature registered.

TRANSMISSION OF ACCELERATED PROTONS THROUGH CAPILLARIES

In this paper we present the results of an experimental program which demonstrates that dielectric capillaries can significantly enhance the transport of current through evacuated cavities. The power spectrum of a sliding beam coincides with a spectrum of the initial beam that point to absence of ionization losses of energy. Fig. 6 shows angular distribution of H^+ ions (E = 240 keV) transmitted through capillary with length 60 mm and diameter 0.5 mm.

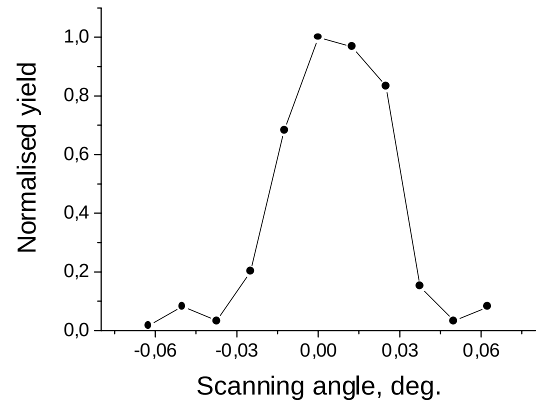

Figure 6: Angular distribution of H^+ ions (E = 240 keV) transmitted through capillary.

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