ANALYTICAL COMPLEXES FOR ION BEAM ANALYSIS AND MODIFICATION OF MATERIALS IN ST. PETERSBURG AND BRATISLAVA

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1 INTRODUCTION

Megavolt ion beams have proven to be of interest for ion beam analysis as well as for materials modification [1]. In the last years High Voltage Ion Accelerators Department of Efremov Institute (NIIEFA, St. Petersburg) and Department of Nuclear Physics and Technology of Slovak Technical University (STU, Bratislava) developed analytical complexes suitable for both techniques. The base of the complex in St. Petersburg is 5 MeV Van de Graaff accelerator but Bratislava 0.9 MeV electrostatic open air accelerator. The accelerators are able to produce a variety of continuous homogeneous and highly collimated mass-analysed ion beams of from several to dozens µA in the energy range 50 keV up to 900 keV (Bratislava) and 400 keV up to 5 MeV (St. Petersburg) using singly charged ions. These complexes including various end stations for ion beam analysis (RBS, channelling, PIXE, NRA, ERD) and ion implantation are suitable for research and modification of different materials. The energy range from 50 keV up to 5 MeV is covered by two accelerators. It allows to carry out the set of experiments on modification and analysis of diverse materials.

2 DESCRIPTION

Fig. 1 shows a schematic diagram of the original electrostatic open air accelerator (STU) [2]. A special nonhomogeneous potential distribution was found which allows application of high voltage within the range 50 - 900 kV. The accelerating voltage (HV) is provided by a commercial two-stage cascade power supply of the type GPA 300/50 (300 kV/50 mA/50 Hz), TUR, Dresden, Germany. Considering the accelerator construction and accelerator hall dimensions, 900 kV was found to be the maximum voltage applicable. This was realised by the addition of the six-stage cascade GZ 900/10 produced by the same manufacturer. Both cascades can be used alternatively. The nominal ripple factor of 1 % at full load was reduced by a factor of 10 in practice by adjustment of the resistor column current to max 0.5mA.

The ion injector located in the HV terminal consists of an exchangeable RF or Penning ion source (LaB_6 cathode) [3], [4] followed by electrostatic focusing system, Wien filter [5] and adjusting mechanism.

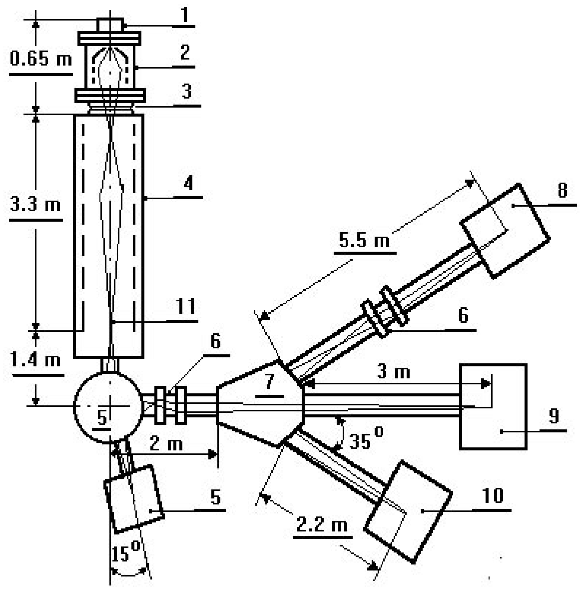

Fig. 1. Schematic diagram of the analytical complex at STU Bratislava.

1 - Ion source, 2 - electrostatic focusing system, 3 - adjusting bellows, 4 - accelerator tube, 5 - bending magnet, 6 - quadrupole doublets, 7 - switching magnet, 8 - UHV target chamber, 9,10 - HV target chamber, 11 - beam envelope, 12 - ion implantation chamber.

The Wien filter acts on every electrically charged particle passing through and insures that only ions with a velocity (or mass) such that the electric and magnetic forces are evenly balanced will follow a straight line and enter the acceleration tube. In this manner , the filter also reduces contamination of the acceleration tube and indirectly the X-ray radiation level of the accelerator. The injection energy varies from 5 to 25 keV (H^+). The injected beam is accelerated and further focused by the vertical accelerating tube. The gas inlet system enables a quick change of the ion species.

The operating vacuum of the accelerator, 2x10^{-4} Pa, is kept by a 2200 l/s turbomolecular pump connected to the LN_2 trapped fore- vacuum system (2x20 m^3/h rotary oil pumps). This central fore-vacuum system is also used for roughing other pumping units attached to the beam lines and target chamber.

At the accelerator exit it is bent in the double focusing sector magnet to (15° , 90°) to the horizontal plane. After focusing in the quadrupole doublet the beam is transported to one of the three target chamber by a double focusing switching magnet (0°, -35°, +35°). The +35° beam line is designed for experiments under UHV condition (RBS, channelling, ERD and PIXE). The 0° line is terminated by standard chamber for PIXE analysis. The -35° line server the purpose of channelling and blocking measurements and the development and testing of particle detectors.

Fig. 2 is schematic diagram of the analytical complex for materials research (NIIEFA), showing the major components within the beam lines. The ion beam, which may be now H^+, D^+, He^+, C^+, N^+, O^+ or Ar^+, is extracted from an r.f. source or a cold - cathode duoplasmatron type [4] in the top terminal of the 5 MeV High Voltage Ion Accelerators Department of Efremov Institute Van de Graaff (EG5T). The accelerator operates reliable in the energy range 400 - 4800 keV with beam current up to 50 μA. Beam energy stability is better than 0.2 % at maximum voltage. The vacuum system on this accelerator has been extensively modified and now includes two 2500 l/s turbomolecular pumps and additional ion pumps along the beam lines to give a base pressure of better 5 x 10^{-7} Torr.

The analysing magnet serves as beam switch to deflect the ions into one of the two lines (15° and 90°). The 15° beam line is used for high energy ion irradiations. The 90° line is used for surface analysis.

For use of the MeV heavy-ion beam the 90° bending is usually not realistic. In these cases the low angle exit of the bending chamber can be the solution. However, the resulting short distance to the floor disables the use of standard electrostatic or magnetic sweeping systems. Therefore the system based on the movement of the sample rather than the beam has been designed. To achieve the homogeneous implantation of the desired sample area, the two-coordinate sample manipulator together with the special target chamber (Fig. 1, pos. 12; Fig.2, pos.15) has been constructed. The working vacuum of the whole unit is 5x10^{-5} Pa. The movements of the target holder are realised by the stepping motors placed inside the vacuum chamber. The present construction enables the coverage of the area of 35 x 110 mm^2 with a single step of 0.008 mm in each direction. For the hot implantation the heater up to 1000° C for the sample of 20 mm diameter can be installed [6]. The maximum speed of the sample movement is 1.6 mm/s. For the charge collection is the target holder electrically isolated. To ensure sufficient cooling during the long-lasting implantation the motors are attached to the LN_2 vessel by flexible Cu connection.

The stepping motors are powered and manually controlled by the control unit SMC-01 [7]. Motors may be selected and operated either from the front panel switches or from host computer across the serial port. In the manual mode the control unit carries out the permanent alpha-numeric display of the coordinates or error conditions, the selection of the single-step or multiple-step operation with preset the number of steps in the defined direction with constant step rate 200 steps/seconds. The motor over-temperature interlock prevents operation when winding temperature exceeds 70 Celsius.

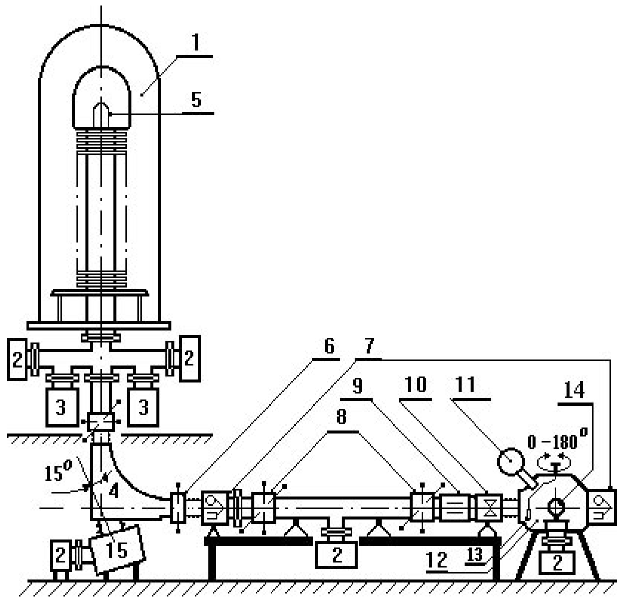

Fig. 2. . Schematic diagram of the analytical complex at NIIEFA St. Petersburg.
1 - 5 MeV Van de Graaff, 2 - ion pump, 3 - turbomolecular pump, 4 - bending magnet, 5 - ion source, 6 - control slits, 7 - beam viewer and Faraday cup, 8 - collimating slits, 9 - electron stripper, 10 - beam monitor, 11- Si(Li) - detector, 12 - target chamber, 13 - surface barrier detector, 14 - four-axis goniometer.

The host computer in the remote mode of control unit is able to control the acceleration, the direction, the motor selection, the number of repetition of movement in range from 1 to 999, and to put the selected motor into the operating and stopping.

To analyse the implantation profiles , an UHV system for RBS , ERD and PIXE is available (Fig. 1, pos. 8; Fig. 2, pos. 11, 12, 13, 14). The system includes the microprocessor controlled four-axis sample manipulator with full channelling capability [7], rotatable detector holder (used adjust the scattering angle depending on the experiment) and PC-based computerised system for data acquisition and spectra interpretation. One sample with the diameter up to 80 mm or 21 samples of 10x10 mm^2 may be placed on the target holder. The manipulator construction allows also another type of target holder to be used if necessary. For instance, to heat the sample the target holder with direct resistive heating are used. The sample with size up to 20 mm may be placed on those type of holder. The temperature of a sample may be reached up to 900°C [6]. For a high throughput of samples pumping-down times after breaking the vacuum play an important role. Therefore a fast sample changer was developed. The small volume of the chamber and a lock system allow a fast change of the sample with a short prepamping time.

3 CONCLUSION

Within the framework of scientific - technical collaboration between STU (Bratislava) and NIIEFA (St. Petersburg) on presented analytical complexes the investigations of material modification, imitation of radiation damages, analysis of materials using RBS, channelling, PIXE, NRA - technique were carried out. The employment of the both accelerators allowed to execute the researches in wide range of energy and ion masses. The combination of the analytical methods expands the field of investigation.

4 REFERENCES

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