THE DESIGN AND MANUFACTURE OF A 300 KV HEAVY ION IMPLANTER FOR SURFACE MODIFICATION OF MATERIALS

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Abstract

300keV ion implanter has been designed for studies of surface modification of several materials by ion beam. The purpose of design is domestic development of the basic technology for the high energy ion implanter. The main point of design is production, acceleration and transportation of high nitrogen ion beam current up to 5mA and ion energy up to 300keV. 300keV ion implanter consists of Duo-PIGatron ion source, einzel lens, mass separation magnet, acceleration tube, magnetic quadrupole doublet, electrostatic scanner and target. Beam optics design carried out where space charge effect in the acceleration tube and second order aberrations in the mass separation magnet were considered. The mass numbers range from 1 to 140 and the resolving power M/ΔM is 131. Implanter control system includes fiber optics links for the monitoring and control of the ion source parameters in the high voltage zone and computer system for the characterization of the ion beam and whole control of an implantation process.

INTRODUCTION

Ion implantation method is world-widely used for high quality semiconductor production, and development for new materials to have special properties [1,2]. Ion implantation technology, which is one of ultramodern technologies, can be used in enhancing chemical and physical properties of materials, such as anti-corrosion, wear resistance and electrical conductivity. Comparing with conventional surface modification technologies, it does not generate toxic wastes, which can threaten the environment. It provides precise control of surface thickness and strong adherence of surface material. Therefore, this technology will be used in surface modification along with steady improvement of ion implantation technology.

PEFP(Proton Engineering Frontier Project, sponsored by Ministry of Science & Technology) has been developed some test facilities using domestic accelerators for the basic experiments and pilot studies of proton & ion beam application technology developments.

300keV ion implanter has been designed for studies of surface modification by ion beam. The purpose of design is domestic development of the basic technology for the high energy ion implanter. This research was sponsored by ARTI (Advanced Radiation Technology Institute).

The main request of design is production, acceleration and transportation of high nitrogen ion beam current up to 5mA and ion energy up to 300keV and beam size on target up to 15cm x 15cm.

DESIGN & MANUFACTURE OF ION IMPLANTER

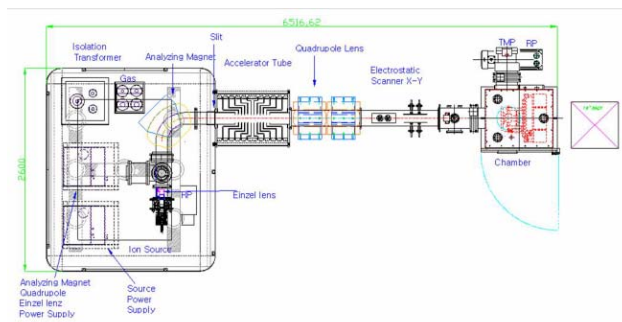

Figure 1: Schematic of 300kV heavy ion implanter.

The schematic of 300kV heavy ion implanter is shown in fig. 1. A horizontal, rather than vertical, design simplified extension of the beam line and provided floor level access to all components for easy maintenance.

It consists of Duo-PIGatron ion source, einzel lens, mass separation magnet, 4-way slit, acceleration tube, magnetic quadrupole doublet, electrostatic scanner and target. High voltage power is provided from a 300kV, 12mA supply positioned by the high voltage terminal. Alongside it is an oil type isolation transformer providing 15 kVA to the terminal electronics. The terminal contains power supplies for the ion source, einzel lens, mass separation magnet, cooling water pump, chiller and vacuum system.

The controlling and monitoring of components in the high voltage terminal is accomplished via a serial fibre optic loop to the ground level of the implanter system. The ion source and mass separation magnet are cooled by a closed loop water heat exchanger within the terminal.

Ion Source

We designed and manufactured Duo-PIGatron ion source for plasma generation and ion beam extraction. The drawing and photograph of ion source are shown in fig. 2. The specification of ion source is nitrogen ion beam current up to 20mA and ion energy up to 30keV. The detail specifications of ion source are as followings:

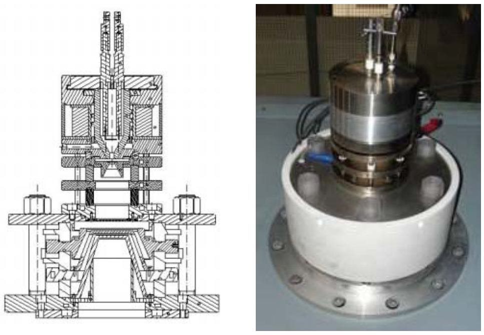

Figure 2: Drawing and photograph of ion source.

- Duo-PIGatron Ion Source (30kV, 20mA):
  - Thermal cathode : W Filaments
  - Source Magnet : 500 G (2A)
  - Intermediate Electrode : Cone Angle of 60 degree
  - Distance between Intermediate Electrode and Anode 1 : 4mm
  - Anode 1 : Concave shape, 8mm dia.
  - Anode 2 : Donut shape, 48mm dia.
  - Cathode : 1 hole , 8mm dia.
  - Extraction electrode : Con shape, 1 hole, 8mm dia

This extraction system of ion source was three electrode-one aperture system including plasma, electron suppression, extraction electrode. The space charge limit current of nitrogen ion was limited 18.8mA at 20kV. The result of ion beam optics at extraction system of ion source using igun code is shown in fig. 3. Trajectory of ion beam runs parallel to beam axis and does not diverge at suppression voltage upto -2kV.

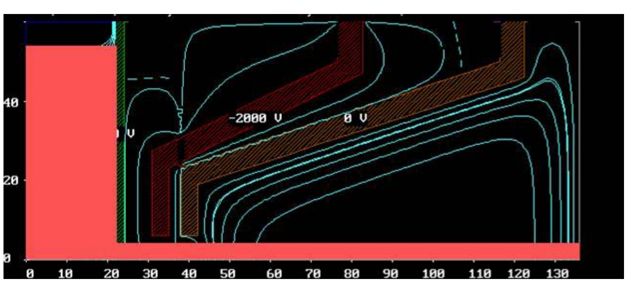

Figure 3: Trajectory of ion beam using igun code.

Einzel Lens

We designed and manufactured Einzel lens for 20keV ion beam focussing at inlet aperture of mass separation magnet. The drawing and photograph of Einzel lens are shown in fig. 4.

It consists of tube type 3 electrode system including ground electrode in ion source. The dimension of tube electrode was 6cm in diameter and 5.7cm in length. The gap distance among electrodes was 6mm. In this system, the focal length of Einzel lens was 35.4cm at applying a voltage of 10kV to center electrode.

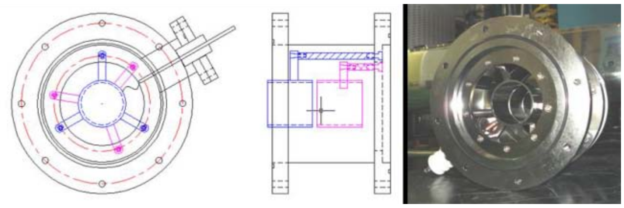

Figure 4: Drawing and photograph of Einzel lens.

Mass Separation Magnet

We designed and manufactured water cooling type mass separation magnet (MSM) for ion species separation as the ion mass up to 140amu. The drawing and photograph of mass separation magnet are shown in fig. 5.

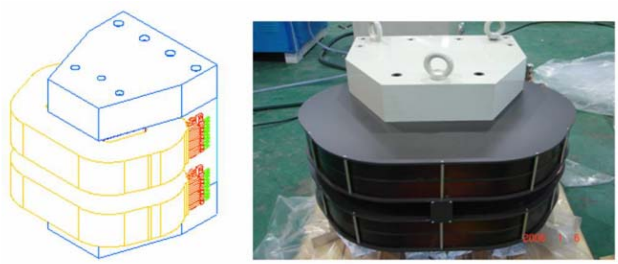

Figure 5: Drawing and photograph of MSM.

It is possible to separate from hydrogen to xenon species by controlling the current of electromagnet. The radius of magnet was 0.3 m and the beam deflection angle was 90 degree. For vertical focusing of ion beam, we designed that inlet and outlet edge angle of magnetic dipole was 15 degree. The number of turns of each electromagnet coil was 2,000 turns. For separation upto Xe ion, the value of magnetic field must increase up to 0.78T. The result of magnetic field simulation under 25,000 Ampere-turns was shown in fig. 6. As a result, this dipole magnet was able to operate up to 0.92T.

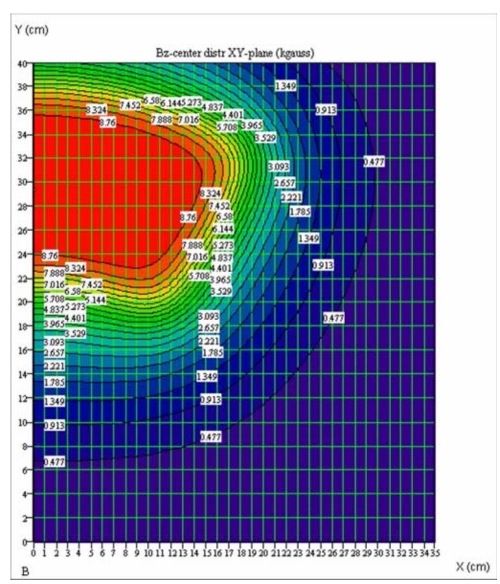

Figure 6: Magnetic field simulation of MSM.

Acceleration Tube

We designed and manufactured electrostatic acceleration tube for ion beam acceleration up to 300kV. The drawing and photograph of acceleration tube are shown in fig. 7. It consists of 12 cylindrical electrodes. We designed that the difference of electric field applied between electrodes is possible to operate up to 30kV. For gradually decreasing from 300kV level to ground level at each electrode, we used the divide resistor between electrodes. To prevent surge shock during operating the ion implanter, we designed that outer gap distance between electrodes in atmosphere was 40 □ and inner gap distance in vacuum was 15 □. For more comfortable beam transport and optimum beam optics, inner diameter of electrode was 100 □.

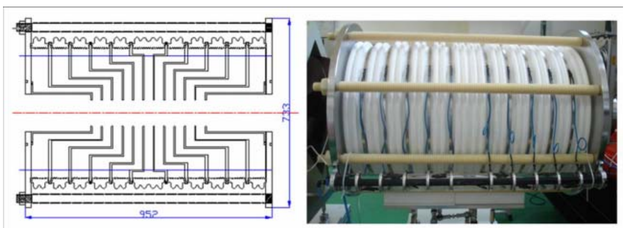

Figure 7: Drawing and photograph of Acceleration tube.

Magnetic Qudrupole Doublet

We designed and manufactured air cooling type magnetic qudrupole doublet (MQD) for 300keV ion beam focussing at input aperture of Electrostatic Scanner. The drawing and photograph of acceleration tube are shown in fig. 8. The dimension of qudrupole magnet pole was 69mm in pole diameter and 300 mm in pole length. The Radius of inner tube was 60 mm. The number of turns of each electromagnet coil was 700 turns. The gap distance between magnetic qudrupole was 130mm. In this system, the focal length of MQD for 300keV nitrogen ion beam was 23.6cm at applying a field gradient of 3.46 T/m (coil current : 7A).

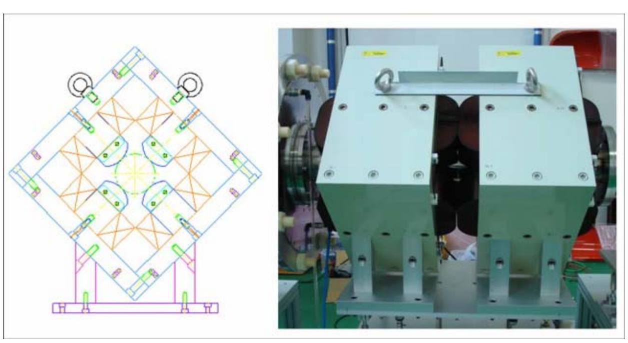

Figure 8: Drawing and photograph of MQD.

Electrostatic Scanner

We designed and manufactured vertical and horizontal electrostatic scanner for large area ion irradiation using high voltage AC. The drawing and photograph of acceleration tube are shown in fig. 9. We need ±20kV AC Voltage for 15cm×15cm beam irradiation at a distance of 1m on target. Each frequency of AC voltage was 100Hz(for x-axis), 1kHz(for y-axis). Gap distance between electrodes was 10cm. The dimension of electrode was 30×12cm.

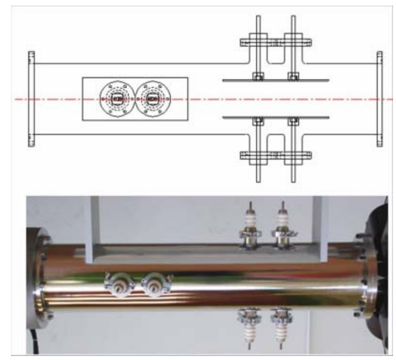

Figure 9: Drawing and photograph of electrostatic scanner.

CONCLUSION & DISCUSSION

We successfully designed 300keV ion implanter for high nitrogen ion beam current up to 5mA and ion energy up to 300keV and beam size on target up to 15cm x 15cm. The optimum condition of nitrogen ion implantation process is as followings:

- 20keV 10mA (ion source)
- 10kV at intermediate electrode (Einzel lens)
- 2548Gauss at 7300AT (MSM)
- 280keV (Acceleration Tube)
- 3.46 T/m-7A (MQD)
- ±20kV (Scanner)

Also, we manufactured several component of 300kV ion implanter system and will construct 300kV ion implanter system. In addition, we will confirm the emittance by matrix calculation comparing with the result by PARMILA or PBO LAB simulation code.

REFERENCES

[1] J. K. Hirvonen, C. A. Carosella and G. K. Hubler, Nucl. Instrum. Meth. 189 (1981) 103.
[2] H. Loh, R. W. Oliver and P. Sioshansi, Nucl. Instrum. Meth. B34 (1988) 337.