Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Development of Metal Ion Implanter and it's Application

Jae Sang Lee*, Chan Young Lee
Proton Engineering Frontier Project, Korea Atomic Energy Research Institute,
150 Duckjin-dong, Yosung-ku, 305-353 Korea
**Corresponding author: jslee8@kaeri.re.kr*

1. Introduction

PEFP(Proton Engineering Frontier Project) has been developed some test facilities using domestic accelerators for the basic experiments and pilot studies of proton & ion beam application technology developments.[1]

Metal ion implanter has been designed and manufactured for studies of surface modification by metal ion beam. The purpose of design is domestic development of the basic technology for the application field using by metal ion beam. The main point of design & manufacture is production, acceleration and transportation of metal ion beam current up to 1mA and ion energy up to 100keV and beam size on target up to 10cm x 10cm.

Metal ion implanter consists of modified Burnas ion source[2], mass separation magnet, slit, acceleration tube, magnetic quadrupole, electrostatic scanner and target. It includes fiber optic links for the monitoring and control of the ion source parameters in the high voltage zone, and a computer system for the characterization of the ion beam and the whole control of an implantation process.[3] Also, this equipment used for diverse application areas, like gem coloring, photo-catalyst, solar cell, lighting LED, medical material, and so on, by modifying the surface characteristics of materials such as polymers, metals, and ceramics.

2. Development of Metal Ion Implanter

An overview of metal 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. The implanter consists of a Modified Burnas ion source, a mass separation magnet, a slit, an acceleration tube, a magnetic quadrupole, an electrostatic scanner, and a target. The controlling and monitoring of components in the high-voltage terminal are accomplished via a serial fiber optic loop to the ground level of the implanter system.

2.1 Ion Source

We developed the Modified Burnas ion source for metal plasma generation and ion beam extraction. The specifications for the ion source include a cobalt ion beam current of up to 10 mA and an ion energy of up to 20 keV. The detailed specifications of ion source are as follows :

Fig. 1. Overview of the metal ion implanter

- Modified Burnas Ion Source (20 kV, 10 mA):
  - Electron emission cathode: tungsten block
  - Source Magnet: 200 G (8 A)
  - Beam dimension at the source outlet : 60×1.5mm
  - Distance between metal plasma chamber and electron suppression electrode: 10 mm
  - Maximum Crucible Temp. : 550℃

The extraction system for the ion source was a three electrode-slit aperture system, including a plasma chamber, an electron suppression, and an extraction electrode. After extraction, the trajectory of the ion beam diverges along the beam axis due to the space charge effect [4]. Thus, it is important to close the gap along the beam line between the ion source and the mass separation magnet.

2.2 Mass Separation Magnet

We designed and manufactured a water cooled-type mass separation magnet (MSM) for ion species separation. The radius of the magnet was 0.4 m, and the beam deflection angle was 90 degree. For vertical focusing of the ion beam, we designed the inlet and the outlet edge angles of the magnetic dipole to be 30 degrees [5]. For separation up to silver ions at 10keV, the value of magnetic field must increase up to 0.37 T. After manufacturing of mass separation magnet, It was able to operate at fields up to 0.5 T under 26,250 Ampere-turns. The uniform range of the magnetic field along the horizontal line was 12 cm.

2.3 Acceleration Tube

We manufactured an electrostatic acceleration tube for ion beam acceleration up to 100 kV. It consists of four cylindrical electrodes and one suppression electrode. For gradually decreasing the field from 100 kV to ground, we installed a divide resistor between electrodes. To prevent surge shock during the operation of the ion implanter, we designed the tube with the outer gap distance between electrodes in atmosphere being 50 mm and the inner gap distance in vacuum being 20 mm.

2.4 Magnetic Quadrupole

We designed and manufactured an air-cooled-type magnetic quadrupole for vertical focusing the 100keV metal ion beam at the input aperture of the electrostatic scanner. The field gradient of the quadrupole magnet was operated up to 10 T/m under a 7.85A coil current. In this system, the focal length of the MQ for a 100keV cobalt ion beam was 45 cm, which was the position of the scanner, at applying a field gradient of 1.54 T/m (coil current: 1.2 A).

2.5 Electrostatic Scanner

We designed and manufactured vertical electrostatic scanners for large-area ion irradiation using a high chopping wave voltage. We need a ±10 kV for 10 cm×10 cm beam irradiation at a distance of 1.2 m on target. The frequency of the chopping wave was 1kHz. To prevent the neutral beam on target, we made the gap between the vertically center of beam line and target and tilt the ion beam by controlling the base voltage at scanner. (Fig. 2.)

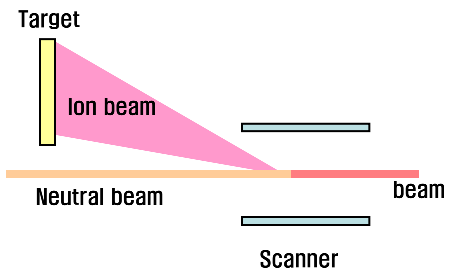

Fig. 2. A schematic of charged particle trajectory by electrostatic scanner

2.6 Beam Characteristics and Application

For the industrial application, large area uniform surface modification is very important due to the cost problem. For the large area metal ion beam treatment, we controlled magnetic quadrupole and electrostatic scanner. The large area beam profile of the cobalt ion on target is shown in Fig. 3. The area that can be used to irradiate on target is about 10cm in horizontal beam profile.

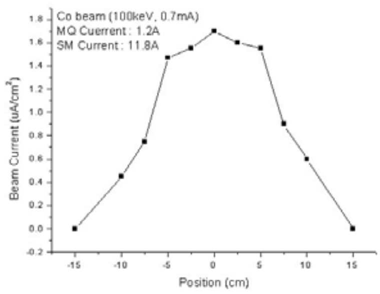

Fig. 3. Cobalt beam profile on target measured by a Faraday Cup

By using this facility, we had some experiments for industrial application. After cobalt and iron ion implantation to sapphire at 100keV and heat treatment, the color of sapphire changed from colorlessness to blue and orange color. (Fig. 4.)

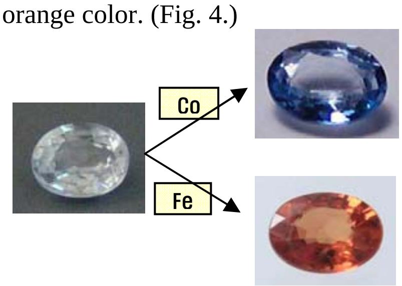

Fig. 4. The Changes of sapphire color by cobalt and iron ion implantation (100keV)

3. Conclusions

We successfully designed & manufactured 100keV metal ion implanter for metal ion beam current up to 1mA and ion energy up to 100keV and beam size on target up to 10cm x 10cm.

This equipment contributes to develop the application technology at gemstone coloring, electronic device, photo-catalyst and so on.

ACKNOWLEDGMENTS

This work is supported by the 21C Frontier R&D program of the Ministry of Education, Science and Technology of the Korean Government.

REFERENCES

[1]] Jae S. Lee, Bo Y. Kim, and Jae H. Lee, J. Korea Phys. Soc., Vol. 47(1), p. 79, 2005.
[2] lan G. Brown, The Physics and Technology of Ion Sources, Wiley-VCH, Weinheim, p. 138, 2004.
[3] Jaime M. Martin and German Gonzalez-Diaz, Nucl. Instr. & Meth B, Vol. 88, p. 331, 1994.
[4] Ishikawa Junzo, Ion Source Engineering, Ionics Press. Inc., Kyoto, p. 177, 1991.
[5] S. R. In, B. J. Yoon, B. Y. Kim, and T. S. Kim, J. Korea Phys. Soc., Vol. 49, p. S320, 2006.