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Preliminary Design of a New Beam Line at 1.7-MV Tandem Accelerator of KOMAC

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1. Introduction

A few MeV class proton and ion beam can be used for power semiconductor fabrication [1], nuclear material radiation hardness test [2], ion beam analysis [3-4], neutron production [5], etc. The 1.7 MV pelletron-type tandem accelerator (NEC 5SDH-2) was reinstalled at KOMAC (Korea Multi-purpose Accelerator Complex) two years ago after moving from KIGAM (Korea Institute of Geoscience and Mineral Resources). The beam irradiation service was started from last September. Ion beam analysis systems, PIXE and RBS are on test operation and they will be offered to the users before the end of this year. To meet users' up-to-date requirements, the improvement of the beam line for the beam irradiation was decided. The preliminary design results are presented.

2. Methods and Results

The design parameters and components of the beam line are described in this section. For the effective and high-quality beam service, beam line design has to be performed based on the users' requirements, i.e. the beam irradiation parameters, type of particle, energy, fluence, irradiation area, uniformity, etc. requested by users. The beam line is composed of a steerer, a beam profile monitor, a faraday cup, a slit, a X-Y scanner, gate-valve, and beam transport pipe.

2.1 Irradiation Parameters

The irradiation parameters reflected to the beam line component design have to be optimized because there are limits of budget, size, space, etc. The parameters of the tandem accelerator and beam line at present are summarized in Table 1.

Table I: Parameters of Tandem Accelerator and Beam Line.

Accel. Voltage	0.1~1.7 MV
Max. Energy	3.4 MeV for proton
Ions	Proton, D, He, Cl, Fe, Al, etc.
Voltage Stability	< 1 kV
Beam Current	10 μA max.
Irrad. Area	10 cm X 10 cm max. for 3 MeV proton
Irrad. Uniformity	± 10 %
Fluence Accuracy	± 15 %

For the application in the field of semiconductor, the irradiation parameters are as follows;
- Ions: Proton
- Irradiation area: 6" or 8" wafer size
- Energy: 1~2 MeV
- Uniformity: >90%
- Dose: 1E13~1E14 /cm^2

Proton beam irradiation can be contributed to the property improvement of power semiconductor devices by controlling the minority carrier lifetime and creating a field-stop layer.

2.2 Beam Line Design

The beam line is composed of steerer, Beam profile monitor, Faraday cup, slits, and scanner as shown in Fig. 1. The arrangement of the beam line components is changed and the total length is increased to maximize the irradiation to meet users' requirements.

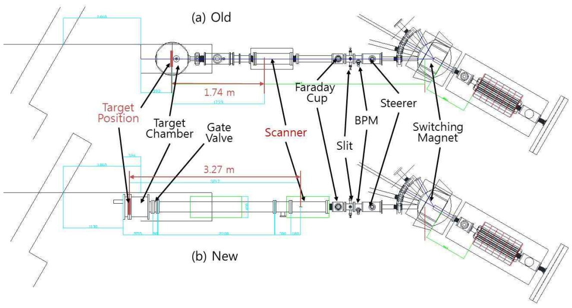

Fig. 1. Irradiation beam line of 1.7 MV tandem accelerator.

To enlarge the irradiation area, the distance between the scanner and the target has to be increased. As shown in the figure, the distance is changed from 1.74 m to 3.27 m. The deflection angle of a charged particle by one pair of plates is given in following equation.

$$A = \frac{V \times l \times q}{2 \times d \times E} \text{[Radians]} \quad [1]$$

Where, V: potential between plates [Volts]
l: length of plates [cm]
q: charge on the particle [e]
d: separations of plates [cm]
E: Energy of charged particle [eV]

For the raster scanner (NEC, ERS-7), plate length and separation are 30.5 cm and 3.8 cm. As a result of calculation, the deflection angle can be 0.026 radians for 3 MeV proton and maximum irradiation area can be 16 cm at the target when the distance from the scanner and target is 3 m and potential between plates is 20 kV. The scanner is shown in Fig. 2. The scanning frequencies for X- and Y-directions are 517 and 65 Hz. The scanner is originally designed for use with an NEC silicon wafer ion implantation system. The scanner can deposit up to 3 MV doubly charged ions across 6 inch diameter silicon wafers. [6]

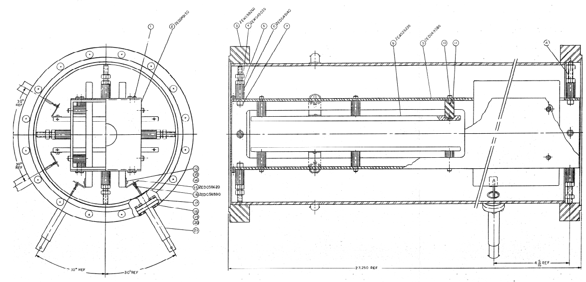

Fig. 2. Electrostatic raster scanner, ERS-7 model of NEC.

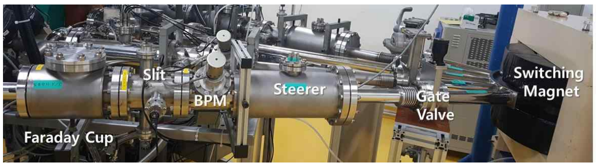

Fig. 3. Picture of beam line components.

Inside the target chamber, a Faraday cup for beam current measurement, a Chromox plate for beam profile monitoring, and sample holder with charge integrator for sample positioning and irradiation dose monitoring are installed as shown in Fig. 3. The target chamber is changed to a new one to increase the irradiation area from 10 cm x 10 cm to 16 cm x 16 cm and new target chamber is shown in Fig. 4.

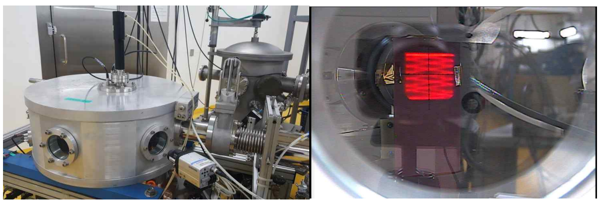

Fig. 3. Target chamber and image on the Chromox plate.

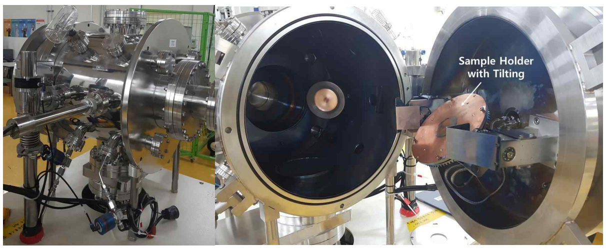

Fig. 4. New target chamber and sample holder.

A vacuum gauge, a Chromox plate and a camera for the beam profile monitoring, and four small faraday cups for the integrated irradiation dose measurement will be installed in the new target chamber. And the installation of a target cooling system will be decided after testing.

3. Conclusions

A new beam line design was performed preliminary to meet users' requirement in the fields of semiconductor fabrications. Comparing to the old one, the maximum irradiation area is increased from 10 cm x 10 cm to 16 cm x 16 cm and target tilting can be possible with a new one. A new beam line will be used for the wafer irradiation for power semiconductor development and other various kinds of irradiation experiments including radiation damage test.

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REFERENCES

[1] V. N. Gubarev, A, Y. Semenov, A. M. Surma, V. S. Stolbunov, Applying Proton Irradiation for Performance Improvement of Power Semiconductors, Power Electronics Europe, Issue 3, 2011.
[2] P. T. Wady, A. Draude, S. M. Shubeita, A. D. Smith, N. Mason, S. M. Pimblott, Accelerated Radiation Damage Test Facility Using a 5 MV Tandem Ion Accelerator, Nuclear Instruments and Methods In Physics Research A, Vol.806, p.109, 2016.
[3] A. Ene, I. V. Popescu, C. Stihi, A. Gheboianu, A. Pantelica, C. Petrej, PIXE Analysis of Multielemental Samples, Rom. Journ. Phys., Vol. 55, Nos. 7–8, P. 806, 2010.
[4] Instrumentation for PIXE and RBS, IAEA-TECDOC-1190, 2000.
[5] L. Irazola, J.Praena, B.Fernández, M.Macías, R.Bedogni, J.A.Terrón, Using a Tandem Pelletron Accelerator to Produce a Thermal Neutron Beam for Detector Testing Purposes, Applied Radiation and Isotopes Vol.107, p.330 (2016).
[6] Installation Manual No. 2HT063334 for Operation and Service of Raster Scanner Electronics, National Electrostatic Corp. (2009).