§11. Sputtering of Plasma Facing Materials by Irradiation with CW High Flux Ion Beam

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We have developed a new ion source device with triode spherical electrodes (HiFIT, High Flux Irradiation Test device) for ion irradiation experiments to plasma facing materials, see Fig.1.

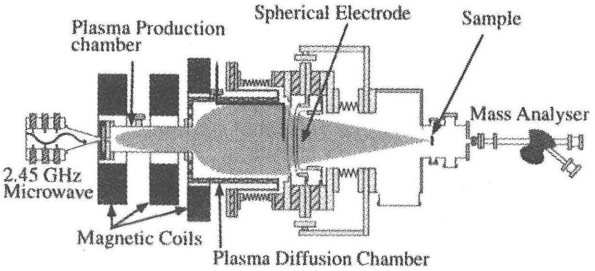

Fig. 1. Schematic view of HiFIT (High Flux Irradiation Test stand).

High-density source plasma is produced by ECR discharge with 2.45 GHz microwave in a plasma production chamber. Maximum magnetic field of about 2.2 kG can be applied. To obtain uniform plasma on spherical electrode (effective diameter of 15 cm), high-density plasma is diffused into a plasma diffusion chamber where permanent magnets are attached outside to form line cusp field. Discharge gas was fed near the microwave-input window. The gas pressure in the plasma diffusion chamber can be reduced to about 1.5 mTorr for hydrogen discharge.

Broad ion beam is focused geometrically by multi-aperture triode spherical electrode whose effective diameter and radius of curvature are 15 cm and 60 cm, respectively. Maximum acceleration and deceleration voltages are 6 keV. For relatively high energy ion beam extraction ($V_{acc} > 1$ keV), deceleration voltage V_{dec} is kept lower than acceleration voltage V_{acc}, while for low energy beam extraction (Vacc < 1 keV), much higher V_{dec} than V_{acc} is applied to obtain high flux beam.

Maximum beam flux on-axis   measured by calorimeter at the focal point as a function of beam energy (or V_{acc}) is shown in Fig. 2 for hydrogen discharges with the gas pressure of 10 mTorr.

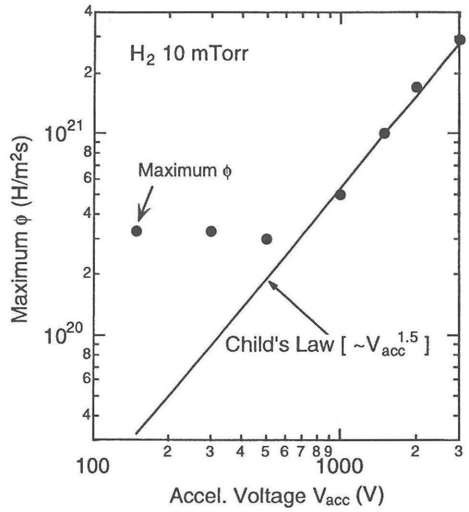

Fig. 2. Maximum beam flux on-axis at a focal point   as a function of V_{dec}.

For the acceleration voltage V_{acc} more than about 1 keV, maximum   is roughly proportional to $V_{acc}^{3/2}$, so called Child's law. This indicates that application of V_{dec} has almost no effects on enhancement of beam flux. In the beam energy less than 1 keV, however, maximum   is almost constant regardless of the beam energy. In these cases, deceleration voltage V_{dec} is much higher than acceleration voltage V_{acc}, for example, V_{dec} of -2100 V was applied in V_{acc} of 300 V. According to the single aperture ion beam experiment with similar aperture dimensions, beam flux increased rapidly with V_{dec} over V_{dec}/V_{acc} of about 4[1]. This multi-aperture ion beam experiment seems to qualitatively agree with the single aperture results.

For tokamak experiments, many plasma facing materials (tungsten, beryllium, graphite etc.) would be used to fulfil the requirements for steady-state reactors depending on the location such as divertor, baffle plate, etc. These materials are subject to erosion and form codeposition layers on relatively low flux area. It is important to know the characteristics of these layers such as conditions for erosion and deposition, and hydrogen retention. We plan to perform this mixed material irradiation experiments with hydrogen and methane beam. It was found that ion beam species extracted from the mixed plasma of hydrogen and methane contained CH_x and C_2H_x and very small amount of C_3H_x. The ratio of carbon atom flux to total atom flux was measured by a magnetic mass analyser. The ratio, for example, is about 1.7 % with the discharge gas pressure ratio of 0.04 (CH_4/H_2).

References

[1] Y. Ueda et al, Rev. Sci. Instrum. 65 (1994) 2587.