§23. Study on Control of Density Profile in Large Area Plasma Source

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In NIFS, high power neutral beam injection system (NBI) utilizes negative hydrogen ions for their good neutralization efficiency instead of positive ions. However, the production of negative ions is less efficient than that of positive ones, which makes the ion source very large. One of the problems in large plasma sources is spatial inhomogeneity of the plasma production that is supposed to be partly due to the magnetic field and electric field induced by the plasma potential. Nevertheless, the role of the electric field, which is also important for enhancing plasma confinement in fusion machines, on the plasma performance has not been investigated in detail. In this work, we examined how the plasma density and bulk plasma flow changed in a magnetized plasma by applying a voltage on the metal plate in order to apply the obtained understandings to a future ion source.

The experiment was performed using Ar gas plasma (45.7 cm in diameter and 170 cm in axial length), produced by RF using a four-turn antenna, with a pressure of P = 0.3 – 30 mTorr [1] (see Fig.1). A voltage biased plate was made of stainless steel (20 cm × 20 cm, with 0.1 cm thickness) with an insulator plate on one side. Here, the plate surface was parallel to the axial magnetic field (B $\leqq$ 1000G). Plasma parameters were measured by the Langmuir probes including the Mach probe for the plasma flow measurement.

The radial profiles of ion saturation current I_{is}, floating potential and plasma flow (parallel to a plate surface and perpendicular to $\boldsymbol{B}$) were measured, changing B, P and biased voltage V_b (-50 ~ 50 V) on the various vertical positions from the plate. Near the plate surface, as shown in Fig. 2, plasma density was lower and the spatial inhomogeneity with a shifted profile was enhanced, which was consistent with the Mach probe measurement and $\boldsymbol{E} \times \boldsymbol{B}$ direction. Typical Debye length λ_D was ~ 0.2 mm, but the vertical length from the plate to affect the plasma was longer than λ_D by more than two orders of the magnitude and was comparable to a magnetic sheath of c_s / ω_{ci} (c_s: ion sound velocity, ω_{ci}: ion cyclotron angular frequency).

This clear spatial inhomogeneity was observed under the conditions of the lower P, the higher V_b and near the plate. However, this trend was found even at the high pressure of 30 mTorr ($\omega_{ci} \times \tau_{in}$ (ion-neutral collision time) ~ 0.2), where the $\boldsymbol{E} \times \boldsymbol{B}$ flow was estimated to be smaller by a factor of ~ 25 compared with a collisionless case. In addition, changing a polarity of B or V_b reversed the radial distribution of I_{is}. Without an insulation on the metal plate, the obtained results were nearly the same, but the I_{is} was larger near the edge of the plate.

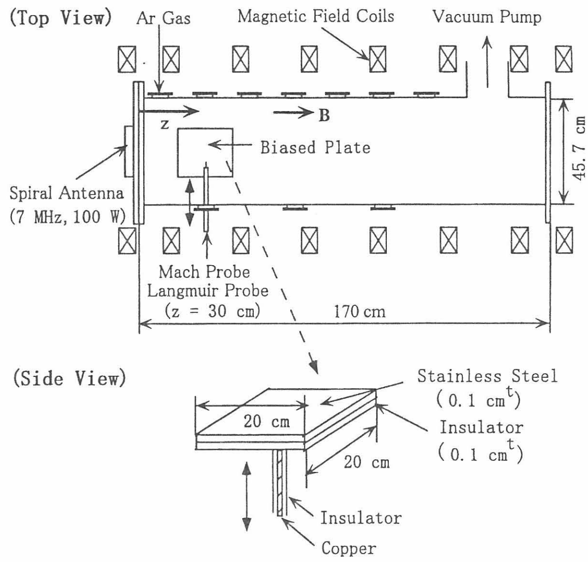

Fig. 1. Schematic view of experimental setup

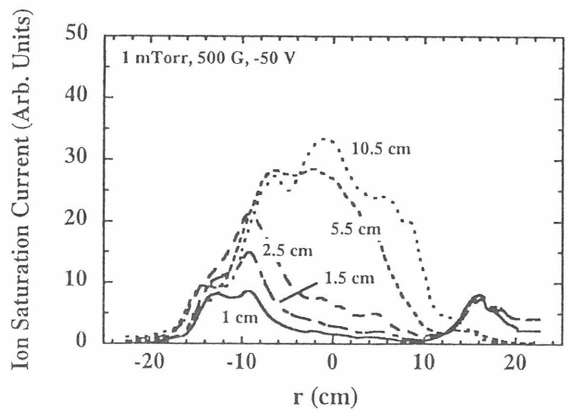

Fig. 2. Radial profiles of ion saturation current I_{is}, changing a distance from the plate (1 mTorr, 500G, - 50V)

Reference

[1] S. Shinohara, S. Takechi, N. Kaneda and Y. Kawai, Plasma Phys. Control. Fusion **39**, (1997) 1479.