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

Shinohara, S., Shindo, M., Matsuyama, S. (Interdis. Grad. Sch. Eng. Sci., Kyushu Univ.),
Kaneko, O., Tsumori, K.

In utilizing negative hydrogen/deuterium ions with good neutralization efficiency in the high power neutral beam injection system (NBI), the production of negative ions is less efficient than that of positive ones, which makes the ion source very large. One of the problems of the large plasma source 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 effect of the electric field on the plasma performance has not been investigated in detail. Here, 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 develop to a future large area ion source.

The experiment was performed using Ar gas plasma (45 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 and the axial magnetic field $B \leqq$ 1000G [1]. Typical electron density n_e and temperature T_e were < 10^{10} cm^{-3}, 3 – 8 eV, respectively. 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. Plasma parameters were measured by the Langmuir probes including the Mach probe for the plasma flow measurement.

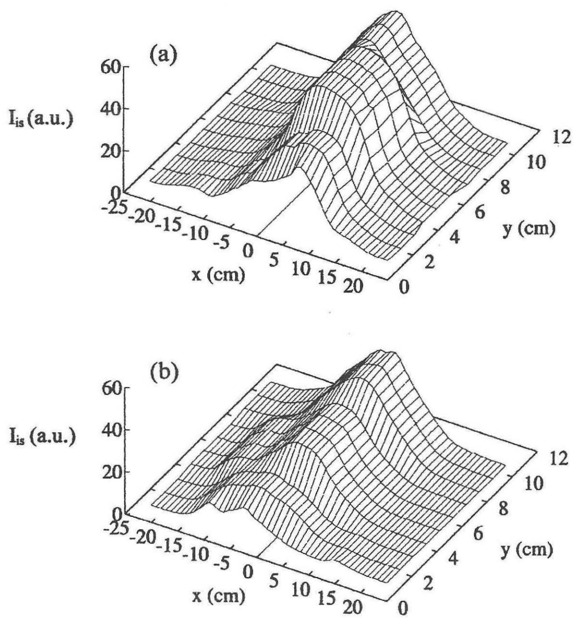

Fig. 1. Two-dimensional profiles of ion saturation current: V_b = (a) 50 V, (b) –50 V (P = 10 mTorr, B = 500 G, with an insulator)

Dependences of n_e, plasma flow (x direction, which is parallel (perpendicular) to the plate surface (magnetic field)) and floating potential V_f on the biased voltage V_b were investigated. Figure 1 shows a typical example of two-dimensional spatial profiles of ion saturation current I_{is}. For the positively (negatively) biased case, plasma density moved to the positive (negative) x direction. This asymmetry became weaker with increasing a distance (y direction) from the plate. With the increase in the magnetic field and/or the decrease in the pressure, this tendency became stronger. In addition, the density distribution was inverted by changing a polarity of the magnetic field.

Figure 2 shows distributions of R, the ratio of I_{is} collected from two opposite directions, measured by the Mach probe. If R is larger (smaller) than 1, the plasma flows to the positive (negative) x direction. Applying the positively (negatively) biased voltage with the magnetic field along the positive z direction, the plasma flowed to the positive (negative) x direction. This flow velocity was larger with the lower pressure and higher magnetic field and also near the plate. The $\boldsymbol{E}\times\boldsymbol{B}$ drift was found even under a high pressure of 30 mTorr. Here, $f = 1 / [1 + 1 / (\omega_{ci}\, \tau_{in})^2]$ was 0.04 (flow velocity $v = fE/B$、 E : electric field、 τ_{in} : ion-neutral collision time).

In conclusion, magnetized plasma distribution was investigated by applying a biased voltage on the metal plate. In order to develop a large area ion source, we must consider boundary conditions and electric field near the boundary because of the importance of the $\boldsymbol{E}\times\boldsymbol{B}$ drift.

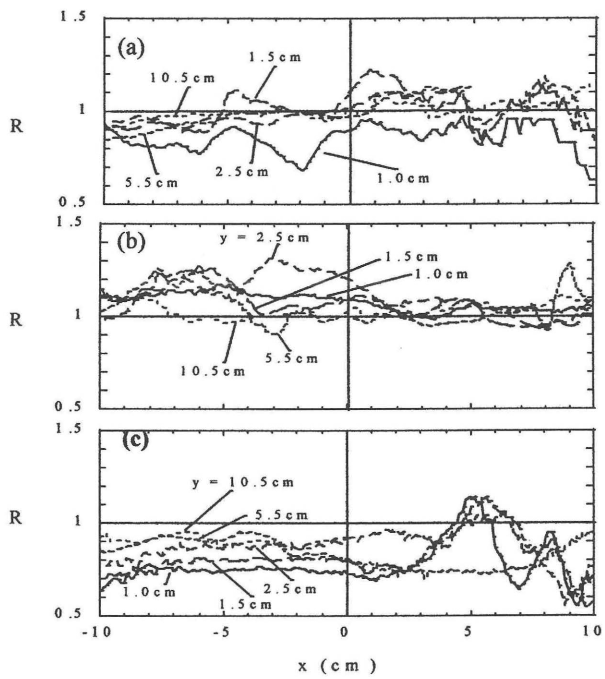

Fig. 2. Plasma flow distribution defined as R : (a) P = 10 mTorr、 B = 500 G, V_b = -50 V (with an insulator), (b) P = 10 mTorr, B = 500G, V_b = 50 V (with an insulator), (c) P = 1 mTorr, B = -500 G, V_b = 50 V (without an insulator).

Reference
1) S. Matsuyama, S. Shinohara and O. Kaneko: Trans. Fusion Technol. 39, (2001) 362.