§7. Development of RF Plasma Source for Negative Ion NBI

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Intensive studies of the high power neutral beam injection (NBI) heating utilizing negative ions have been actively executing in NIFS. As to the future plasma source in NBI, key issues are easier plasma production with a good stability, higher plasma density and higher ionization, and developments of large or compact plasma sources. In addition, developing a neutral beam source with the high particle flux is important in the charge-exchange recombination spectroscopy. The present objective is, first, characterizing a high-density, compact plasma source, using a helicon wave scheme [1] in the range of radio frequency. Then, developing a negative ion source with, e.g., hydrogen gas, will be carried out to apply to the advanced NBI in NIFS.

The main device parameters of the compact helicon plasma source with the strong magnetic field [2,3] are as follows: the discharge chamber uses a quartz tube, which has an outer (inner) diameter of 10 (9.5) cm and 90 cm axial length. The magnetic field B can be applied up to 10 kG, whose main strong field region extends to ~ 30 cm in the axial direction. Here, iron yokes were added to increase the field.

Two parallel copper plates with 3 cm in the axial direction each used as the rf antenna, were wound around the quartz tube at the midplane. Here, the spacing between plates was 6 cm. By changing the electrical connection (parallel and anti-parallel current directions), the excitation of the axial wavenumber spectrum can be changed [4,5]. The rf frequencies in this experiment were 7 and 14 MHz with a fill pressure of 1-33 mTorr (with pulsed as well as continuous operation modes). In order to estimate the antenna loading, a directional coupler monitoring the incident and reflected powers was used in addition to measure the antenna voltage and current. A Langmuir probe was scanned radially at the midplane.

Here, we present the results on the plasma performance using various gas species [2,3]. In Ar discharges, we could obtain the electron density n_e more than 10^{13} cm^{-3} with the input rf power P_{rf} of less than 1 kW. Here, with the increase of B, n_e was higher in the high field region before the so-called density jump due to the better radial confinement. However, this jump became weaker with the increase of B.

Figure 1 and 2 show examples of the plasma density n_e vs. P_{rf} (rf frequency is 7 MHz) with Xe (He) pressure of 10 mTorr and B of 1.36 kG (0.48 kG). The density jump to the range of 10^{13} cm^{-3} was observed in Xe discharges with less than 0.5 kW of P_{rf} (Fig. 1). To the contrary, in the He discharges (Fig. 2), a monotonic increase of n_e was found with P_{rf}, and n_e itself was much lower, e.g., ~ 10^{11} cm^{-3} with P_{rf} of 1kW, than Ar and Xe discharges. We have also found that the maximum density was obtained when the excitation frequency was near the lower hybrid frequency from the dependence of n_e on the magnetic field, by changing the gas species and the rf frequency.

In conclusion, the experiments on the plasma production with n_e up to the range of 10^{13} cm^{-3} were successfully carried out using a compact, high magnetic field device, changing gas species. The more detailed characterization in a wide range of operating parameters will be done, which is expected to contribute to the advanced NBI system in NIFS.

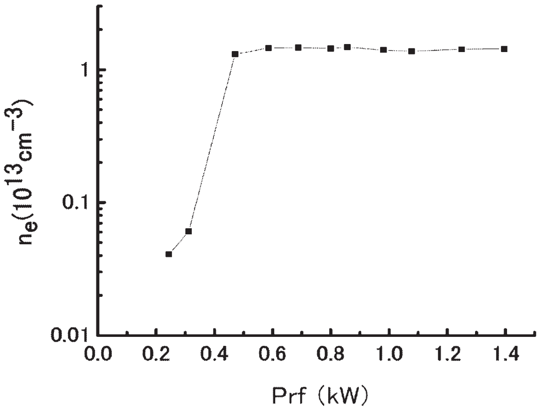

Fig. 1. Electron density as a function of rf power (Xe).

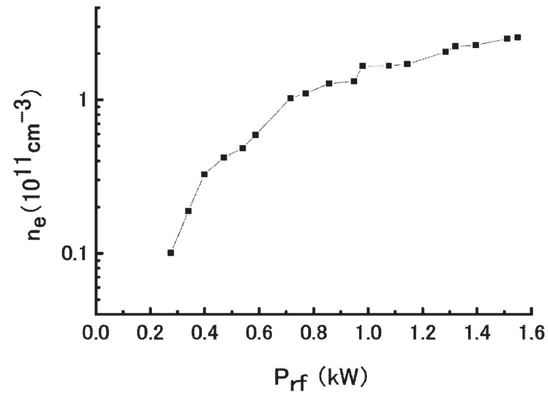

Fig. 2. Electron density as a function of rf power (He).

Reference

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