§14. Development of High-Density Helicon Plasma Source with Large Diameter and Low Aspect Ratio for Negative Ion NBI

Shinohara, S. (Institute of Eng., Tokyo Univ. of Agriculture & Technology),
Hada, T. (Interdis. Grad. Sch. Eng. Sci., Kyushu Univ.),
Kaneko, O., Tsumori, K.

Utilizing an arc filament method, high power neutral beam injection (NBI) heating with negative ion sources has been actively executing in NIFS. As to the advanced, future plasma source in NBI, one of critical issues is easier plasma production by an rf wave such as a helicon wave [1] with a high stability, high plasma density and high ionization. It is also important to develop a large area plasma source with a short axial length. In addition, a low magnetic field operation is desirable due to the small effect on the ion source as well as the small necessary power supply and light weight.

Here, the present objective is to characterize large area, high-density, low-field plasma sources [2-6] by shortening the axial plasma length (changing also the material of the termination plates), leading to a small aspect ratio A, by the use of the helicon wave scheme.

Experiments are carried out using the Large Helicon Plasma Device (LHPD) [2-6], the largest helicon volume in the world of 2.1 m^3. Here, using the vacuum chamber inner radius of 74 cm, the high-density plasmas are produced by applying an RF wave of 7 MHz to the spiral antenna with a fill pressure P (argon) of 0.75-10 mTorr and the magnetic field of < 150 G. The axial plasma length z_E is limited by the movable termination plate. Plasma parameters (rf wave structures) are measured by Langmuir probes (magnetic probes). Typical electron density n_e and electron temperature are 10^{12}-10^{13} cm^{-3} and 3-5 eV, respectively.

Figure 1 shows the dependence of n_e on the input rf power P_{inp}, changing the end plate material, which limit z_E of 34.5 cm. With the increase in I_s (coil current near the antenna), the threshold power, less than a few kW, to have a density jump to helicon mode on the order of 10^{12} cm^{-3}. There is a tendency that the insulation material causes the higher density and more peaked radial profile with the same rf power.

Figure 2 shows the relationship between the total number of electrons N_e in the whole plasma region divided by P_{inp} and z_E. Regardless of the end plate material, N_e / P_{inp} increases with z_E, which is consistent with the classical scaling predicted by ours [1].

In conclusion, the largest diameter (74 cm), high-density (10^{12}-10^{13} cm^{-3}) helicon plasmas with short axial length down to 4.7 cm, corresponding to A = 0.075, are produced. Good plasma production efficiency is obtained, which is consistent with the expected scaling. Based on these studies, optimum conditions to meet the real ion source requirements must be considered.

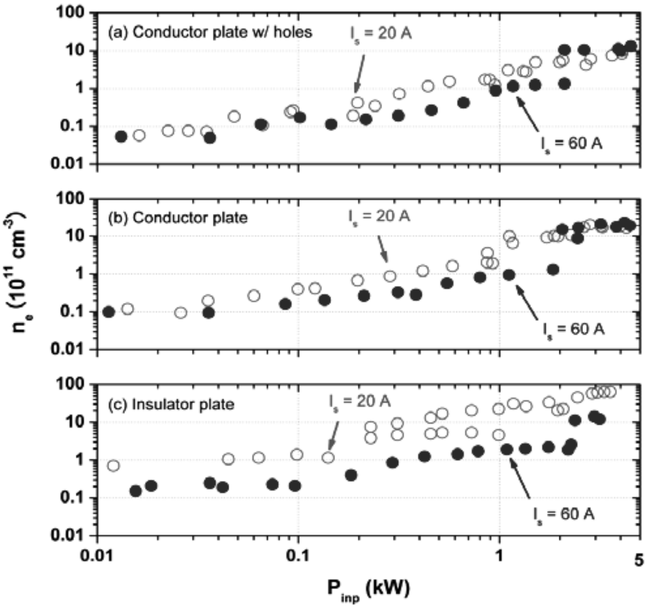

Fig. 1. Electron density n_e as a function of rf power P_{inp}, changing end plate material.

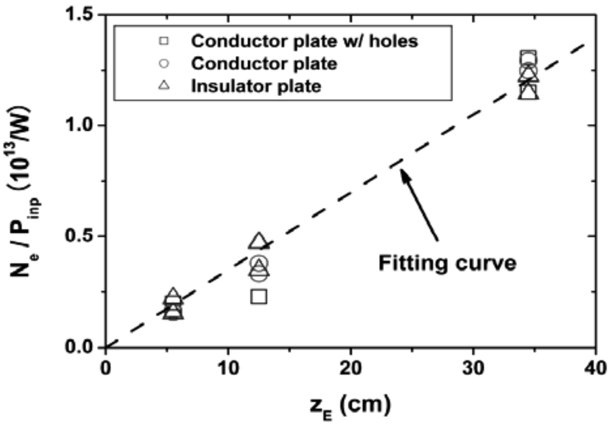

Fig. 2. Dependence of total number of electrons N_e divided by rf power P_{inp} on the axial length z_E.

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