§23. Research and Development of Very Small Diameter, High-Density RF Plasma for Unitization of Negative Ion NBI

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Concerning the advanced, future plasma source in negative NBI required for DEMO reactors, one of the 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. Here, helicon plasmas have been recently attracting much attention because of a flexible operation of the external parameters and log life operation. It is also important to obtain a small but high-density plasma source for unitization.

The present objective is to develop and characterize a very small diameter, high-density, rf or helicon plasma source with or without a relatively low magnetic field, aiming at the realization of the negative NBI (unitization). Therefore, optimization of the rf/helicon sources and the hydrogen gas operation[2)] is also important after the source development.

We have developed the Small Helicon Device (SHD)[2-5]: A stainless steel vacuum chamber has an inner diameter of 16.5 cm with an axial length of 86.5 cm, which is evacuated by a turbomolecular pump with a pumping speed of 200 l/s (base pressure is < 10^{-4} Pa). Two sets of magnetic field coils, made by ourselves, have windings of ~ 400 turns each, and can supply up to 0.086 T each for 30 A coil current. A diameter of plasma source part (quartz tube) can be easily changed, and a mass flow controller (up to 30 sccm) is installed (working gas is argon in this experiment).

Here, we have tried a plasma production, changing a wide range of rf excitation frequency (7-435 MHz) with an input power less than 1.6 kW. Plasma parameters were measured by Langmuir probes, and plasma light emissions are monitored by two monochromators.

First, in the case of 0.5-2 cm inner quartz diameter tube, which is a very small source in a low pressure rf source, we could obtain the electron density n_e of 10^{18} ~ 10^{19} m^{-3} in argon plasma.[3-5] In this experiment, a two-loop antenna with a wide range of RF excitation frequency (7-60 MHz with an input power of less than 1.6 kW).

Next, we have succeeded in the rf plasma production of 0.3 cm diameter, which is the smallest diameter in an low pressure discharge,[2] with n_e more than 10^{18} m^{-3} from the estimation by the monochromator intensity measurements in addition to a Langmuir probe located in the downstream of the production region. Here, a two-loop and four-loop antennas were used.

In order to investigate the dependence of plasma generation power for the case of 0.3 cm diameter, wide ranges of excitation frequency f and a fill pressure P_0 was explored, as shown in Fig. 1. From this, lower f and/or P_0 leads to the lower rf power to initiate the plasma. For example, rf power was only 6.2 W for the case of f = 150 MHz and P_0 = 2 Pa. Since a Langmuir probe size is larger than a production dimeter, it is difficult to measure plasma parameters directly in the production region. However, although the measuring point is downstream of the production region (215 mm away), n_e was measured and it was high of < 10^{17} m^{-3}.

In conclusion, we have succeeded in the very small diameter (down to 0.3 cm, which is the smallest in the world) plasma production with n_e (> 10^{18} m^{-3}), using the SHD. The dependence of rf power for plasma generation on f and P_0 in wide regions was investigated. We will continue these studies to be applied to the real ion source requirements.

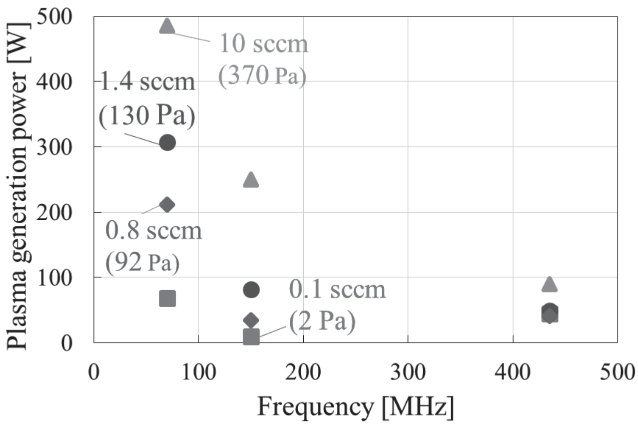

Fig. 1. Dependence of plasma generating RF power on excitation frequency, changing gas pressure.

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