§14. Development of Very Small Diameter, RF-Produced, High-Density Plasma for Unitization of Negative Ion NBI

Shinohara, S., Kuwahara, D., Nakagawa, T.
(Tokyo Univ. of Agriculture & Technology),
Hada, T. (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. 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. It is also important to develop a small plasma source for unitization.

The present objective is to develop and characterize a very small diameter, high-density, helicon plasma source with a relatively low magnetic field by the use of the helicon wave scheme, aiming at the realization of the development of the negative NBI (unitization). Therefore, optimization of the helicon sources and the hydrogen gas operation is also important after the source development.

We have developed the Small Helicon Device (SHD)[2-4]: 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 can be changed: hydrogen, helium and argon). Here, we have tried a helicon plasma production, changing gas species to see the ion velocity behavior naturally accelerated in the presence of the divergent magnetic field. 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) was used, considering the helicon wave dispersion relation and other production schemes. Plasma parameters were measured by Langmuir probes, and plasma light emissions are monitored by two monochromators.

First, in the case of 2 cm inner quartz diameter tube, which is a very small source, we could obtain the electron density of ~ 10^{19} m^{-3} in argon plasma.[2-4] Next, we have investigated the ion velocity dependence on the RF power, changing gas species (also the magnetic field and gas flow rate), as shown in Fig. 1.[5] For the argon discharges, it was possible to obtain the density of 10^{19} m^{-3}, but lower than 10^{18} m^{-3} for helium and hydrogen discharges partly due to the higher ionization potentials than argon. From the Mach probe measurements, the maximum axial velocities were ~ 2, ~ 10 and ~ 30 km/s for argon, helium and hydrogen discharges, respectively.

In conclusion, we have succeeded in the very small diameter (2 cm) plasma production with the electron density (10^{17}-10^{19} m^{-3}), using the SHD, and the lighter ion showed its higher velocity. We will continue these studies to be applied to the real ion source requirements.

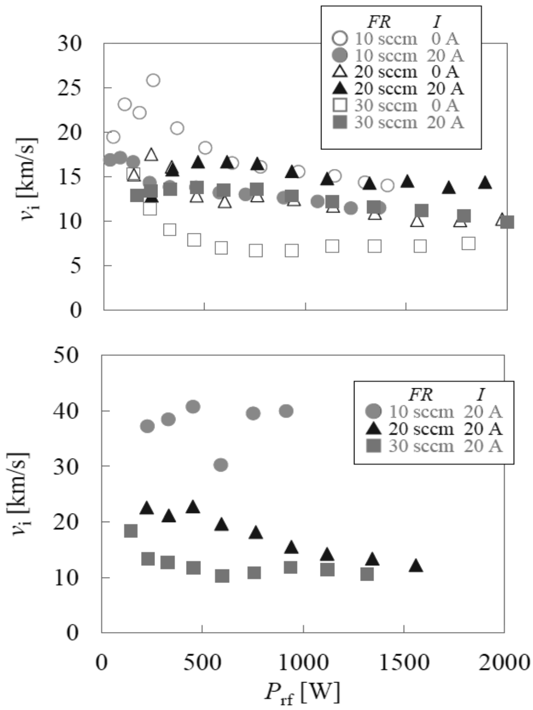

Fig. 1. Dependence of ion velocity on RF power, changing gas species: He (top panel) and H (bottom panel)

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