# §13. Research and Development of Small Diameter, High-Density RF Plasma Source, Aiming at Unitization of Negative Ion NBI

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As to 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. 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.

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 is typically argon). Here, we have tried a helicon plasma production using a wide range of RF excitation frequency (7, 12, 50 and 70 MHz with an input power of less than 1 kW), considering the helicon wave dispersion relation and other production schemes. Here, a two-loop antenna was used. Plasma parameters were measured by Langmuir probes, and plasma light emissions are monitored by two monochromators.

In the case of 0.5-2 cm inner diameter tube, which is the smallest helicon source in the world, we could obtain the electron density of $10^{18}$-$10^{19}$ $m^{-3}$ in an excitation frequency range of 7-60 MHz (argon plasma) [2-4]. Next, we have investigated the density dependence on the RF power, changing gas species, as shown in Fig. 1. Here, the plasma diameter was 2 cm with a mass flow rate of 20 sccm and coil current of 20 A. 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 smallest diameter (down to 0.5 cm) plasma production with the electron density ($10^{17}$-$10^{19}$ $m^{-3}$), using the newly developed device SHD. Changing the gas species on plasma performance was also tried. We will continue these studies to be applied to the real ion source requirements.

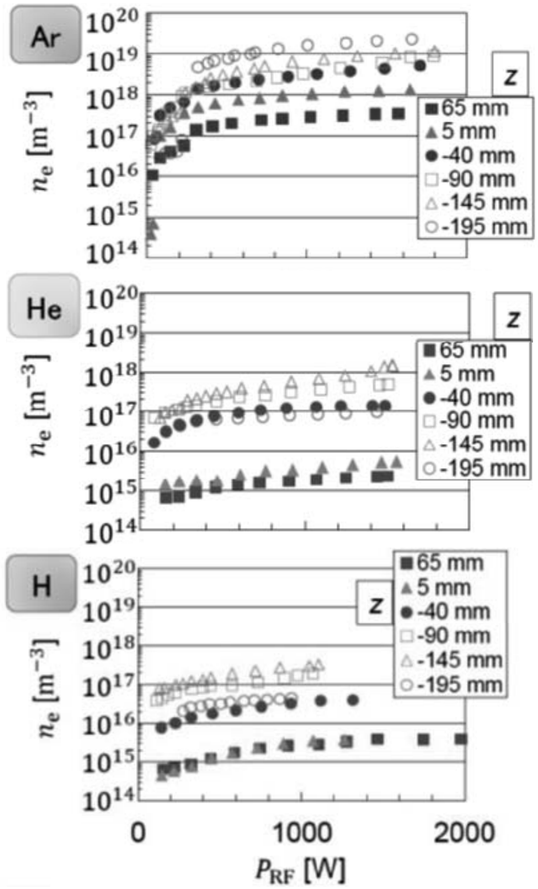


Fig. 1. Dependence of electron density on RF power, changing gas species.

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