§22. Large-Area High-Density Negative Hydrogen Ion Source Using a Helicon-Wave Sheet Plasma

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In the development of hydrogen negative ion sources for neutral beam injection (NBI) heating system of the next generation fusion reactors, the sources yielding higher negative ion current (> 40 A) under long-time operation (＞10-1000 s) are urgently required. As a candidate, rf plasma sources such as helicon plasma and inductively-coupled plasma sources are under consideration because high-density plasmas on the order of 10^{12}-10^{13} cm^{-3} can be easily produced with relatively low rf power, and there are no electrodes, which may cause impurities and require frequent maintenance. In this context, our group has studied the production and loss mechanisms of H^- ions in high-density (~10^{12} cm^{-3}) helicon-wave plasmas. The plasma parameters were spatially controlled by optimizing the applied magnetic field and the efficient production of the H^- ions has been attained at the low-electron temperature region. In this report, as a practical development of H^- ion sources, we have developed a large-area helicon-wave plasma source having a rectangular wave guide mode.

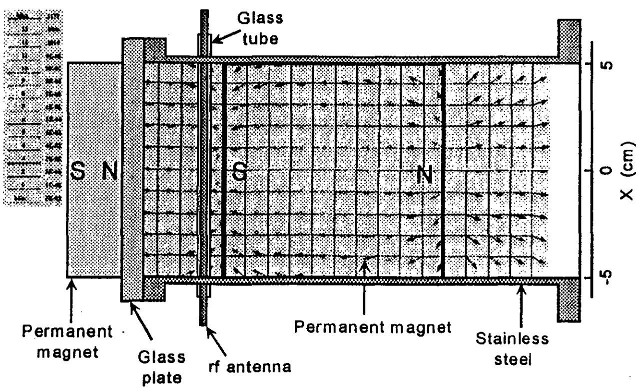

Fig.1 rectangular helicon-wave Plasma source.

Figure 1 shows the schematic view of the rectangular helicon-wave plasma source. A pair of ferrite permanent magnets produces a uniform magnetic field (B) of 0.6 kG in the horizontal direction. First, we investigated basic plasma characteristic with Ar. A sheet plasma of 1 cm in thickness and 4 cm in height was produced by applying an rf power (P_{rf}) to a single line antenna. The dependence of plasma density (n_p) on P_{rf} exhibited density jump which is a characteristic feature of helicon-wave plasmas. We also confirmed helicon wave pro-pagation along B by a magnetic probe.

Next, we investigated the dependence of n_p on the angle between the antenna current (I_{rf}) and B to examine the optimal antenna configuration, as shown in Fig. 2. High-density plasmas having $n_p \sim 5 \times 10^{12}$ cm^{-3} were produced for the case when I_{rf} was parallel to B and even for low gas pressure of 7.5 mTorr. The threshold rf power of the density jump was drastically decreased for this antenna.

In accordance with this result, we made a U-shaped antenna having current component along B and generated hydrogen plasmas. For H_2 gas pressure of 40 mTorr and P_{rf} of 1 kW, a large-area plasma having $n_p \sim 1.3 \times 10^{10}$ cm^{-3} was produced.

As conclusion, the rectangular helicon-wave plasma source is promising for a large-area H^- ion source.

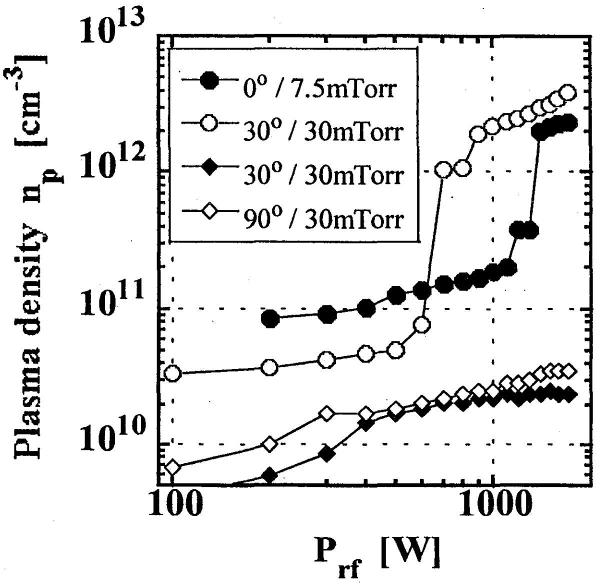

Fig.2 Dependence of n_p on the angle between B and I_{rf}.