§23. Increase in Plasma Density by Suppression of Electrostatic Coupling and its Application to Inductive RF Negative Ion Sources

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In a negative ion source for neutral beam injection (NBI) of experimental nuclear fusion devices, a hot cathode DC discharge has been widely used. Instead of the DC discharge, a RF inductive discharge has been recently studied because of no usage of filaments which limit the lifetime of the ion source due to erosion and fatigue. In the inductive discharge, the discharge powers are provided to the plasma with electromagnetic (inductive) coupling and electrostatic (capacitive) coupling. In order to improve power efficiency to produce plasmas, the electrostatic coupling should be suppressed because it causes large power loss by ions at the discharge antenna due to appearance of self-bias voltage on the insulator covering the discharge antenna. In the present study, we have developed a new method to reduce the electrostatic coupling based on capacitance termination of antenna, and applied it to the inductive RF negative ion source of NIFS.

In a stainless steel vacuum vessel, 30 cm x 30 cm in cross section and 20 cm in depth, a hydrogen plasma is generated by coupling 6 kW 2 MHz RF powers through an insulated antenna. The antenna coil is floated in the DC sense by series-connected blocking capacitors C_1 and C_2. The capacitor C_2 terminates the antenna to the ground through a residual inductance L_r of ~1.6μH. The discharge is turned on during 200 ms with the period of 10 s. Plasma parameters such as electron density and electron temperature are measured by Langmuir probe. The antenna voltages V_1 and V_2 are also measured by a 1:1000 high voltage divider, and the averaged antenna voltage $<V_{ant}>$ is defined as $(V_1+V_2)/2$. The value of C_2 is varied from 1.3 nF to ∞ (electrically short) at fixed C_1 of 8 nF to control the antenna voltage ratio of V_1:V_2.

Figure 1 shows the electron density n_e and the averaged antenna voltage $<V_{ant}>$ as a function of C_2. When C_2 is adjusted to 4~6 nF, the electron density shows a maximum value. At that time, the averaged voltage $<V_{ant}>$ is minimized, suggesting that the impedance of the residual inductance L_r is compensated by that of C_2. Such a good correspondence between the voltage minimum peak and the density maximum peak suggests that the observed density increase is attributed to the reduction of electrostatic coupling between the plasma and the antenna.

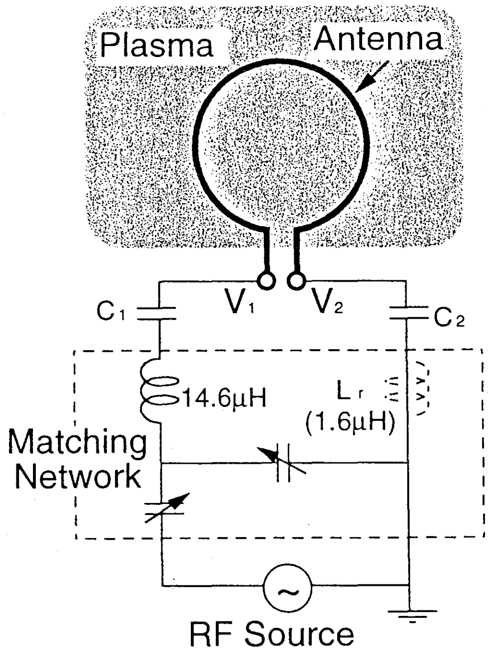

Fig. 1. Experimental Apparatus

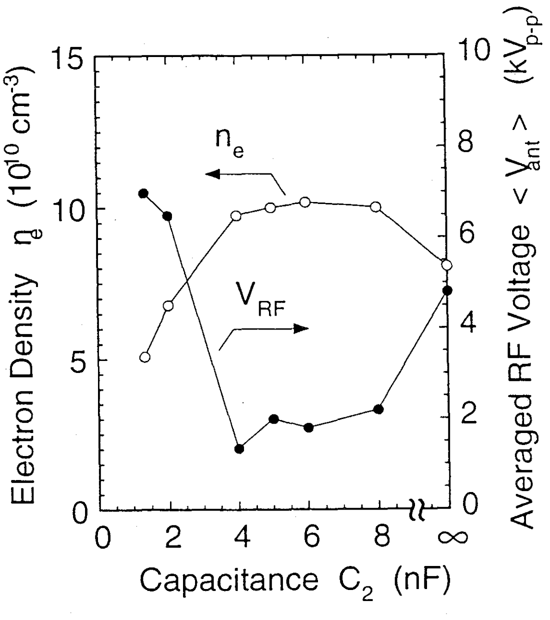

Fig. 2. Electron density n_e and averaged antenna voltage $<V_{ant}>$ as a function of C_2.