§6. Development of Cesium-free Deuterium Negative Ion Source with Grid Bias Method

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The purpose of the present study is as follows: one is to investigate the possibility of controlling plasma parameters, in particular T_e, with grid bias method in rf-driven plasmas[1]; and the other is to realize negative ion production in rf plasmas and to discuss the difference in T_e control and H^- production between the mesh grid bias method and the magnetic filter method[1, 2].

Figure 1 shows a schematic diagram of rf negative ion source. The source chamber (21 cm in diameter) made of stainless steel is divided by a mesh grid (MG) into two parts, i.e., a source region and an extraction region. In the experiment, three different meshes are used, i.e., No. 1 (7 mesh/in.), No. 2 (30 mesh/in.), and No. 3 (50 mesh/in.). Details are shown in ref. 1. The rf power (13.56 MHz) is supplied to a stainless circular disk antenna with 12 cm diameter. Hydrogen (H_2) gases are used under a pressure of 3 mTorr. rf power is varied from 100 to 400 W. Comparing with the usual magnetically filtered multicusp ion source, in Fig. 1, the magnetic filter (MF) flange (i.e., the rod-type filter) is set instead of the MG flange. The present MF is composed of four rods where diameter of the rod is 10 mm and the distance between two rods id 54 mm. In the present experiment, magnetic field intensities of the MF are 60 and 100G. The negative ion currents are directly detected by a magnetic deflection-type ion analyzer. The plasma grid has a single hole (10 mm in diameter) through which negative ions were extracted from the ion source.

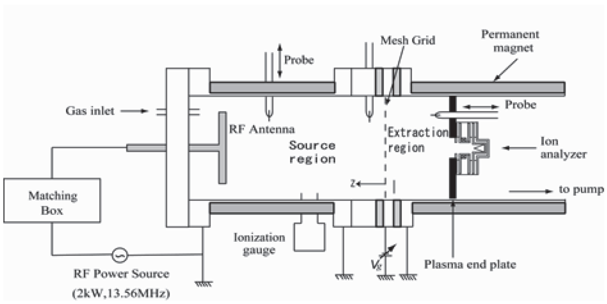

Fig. 1. Schematic diagram of the experimental apparatus.

Figure 2 shows axial distributions of plasma parameters (i.e., n_e and T_e) controlled by both the mesh grid (MG) bias method and the MF method. For the MF method, in the extraction region, $T_e \simeq 4$ eV. The value of T_e is high for negative ion production. Although T_e is decreased by increasing the field intensity of the MF, at the same time, n_e is also decreased more drastically.

In the MG bias method, however, high energy electrons pass the mesh (set at $z = 0$ cm) and enter into the extraction region. As is shown clearly, n_e increases in its value with z and reaches the maximum value and then decrease while T_e decreases in its value and keeps nearly equal to or lower than 1 eV. This is suitable condition for negative ion volume production. Therefore, the MG bias method is more suitable to optimize plasma conditions for negative ion volume production, compared with the MF method.

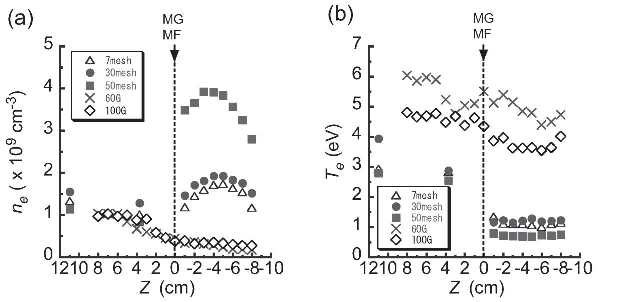

Fig. 2. Axial distributions of plasma parameters: Electron density n_e (a) and electron temperature T_e (b) for three different mesh grids and two different MF fields. The end plate is set at z_{end} = -10.5cm. Experimental conditions: P_{rf} = 200 W, $p(H_2)$ = 3 mTorr, and grid biasing voltage V_g = -50V.

Figure 3 shows the rf power dependence of I_{H-}. Pressure and the position of plasma end plate z_{end} are optimized for two cases (i.e., MG bias method and MF method), respectively. With increasing power, I_{H-} increases linearly. I_{H-} in the MG bias method is much higher than that in the MF method. It is clear from plasma parameter. Within the present experimental conditions, plasma production and control in the extraction region are well done for negative ion production when No. 3 mesh is set due to its high transmittance.

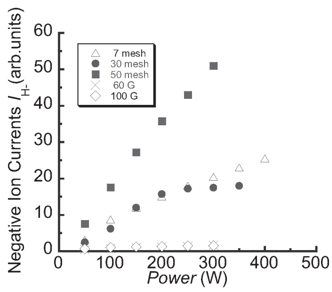

Fig. 3. Extracted negative ion currents as a function of discharge power for three different mesh grids and two different magnetic filters. Experimental conditions: $p(H_2)$ = 3 mTorr, V_g = -50V, and z_{end} = -5cm (7mesh/in.), z_{end} = -6cm (30 mesh/in.), z_{end} = -7cm (50 mesh/in.), for grid bias method. $p(H_2)$ = 2 mTorr, z_{end} = -4cm for the magnetic filter method, and extraction voltage V_{ex} = 1 kV.

1) Okada, J. et al., Rev. Sci. Instrum. **79**, (2008) 02A502.
2) Jyobira, Y. et al., Rev. Sci. Instrum. **79**, (2008) 02A508.