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# Enhanced plasma density downstream of an rf plasma source by enlarging an open source exit

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Having a high plasma density downstream of a magnetically expanding inductively-coupled rf plasma source, which is typically produced in a cylindrical insulator cavity, is a key technology applicable to space propulsion and plasma processing, e.g., a helicon thruster [1] and a plasma sputtering [2]. When applying a static magnetic field to the inductively-coupled source, enhancement of the plasma density inside the source cavity has been observed in a number of experiments, due to wave-plasma interaction or plasma confinement. When applying a moderate magnetic field strength less than a few hundreds of Gauss, major losses of the plasma particles and energy are those on the radial source wall; a numerical model has shown that 80 percent of the energy escapes to the wall [3].

Here a stepped-diameter insulator source cavity is applied to a helicon source in order to have a high density plasma downstream of the source, where an inner diameter near the open source exit is enlarged compared with the upstream diameter and convergent-divergent magnetic field is applied near the source exit to inhibit the plasma loss to the wall by separating the plasma from the wall. The effect of the structure has been observed in the thruster development [4]. Here the application to the plasma sputtering device is presented.

Figure1(a) shows the schematic of the stepped-diameter insulator cavity being tested here, which has different diameters of 30 mm on the left and 50 mm on the right. A three-turn rf loop antenna is wound around the smaller diameter part and powered from a broad-band rf amplifier operated in the frequency range of the 25-30 MHz, where the impedance matching is tuned by varying the frequency [5]. Since a recent experiment has shown the enhanced density by introducing the operating gas from the downstream of the source [6], argon gas is introduced from the interface between the two different diameter regions. The source is attached to a 114 mm cubic chamber evacuated by a turbomolecular pumping system. The argon gas pressure is maintained at 0.6 Pa with the gas flow rate of 8 sccm. The device also has a sputtering target structure including a permanent magnet behind the target material (not shown here) [7]. A solenoid is centered at $z$= -15 mm to apply a magnetic field, which converges along the axis inside the source and expands in the downstream chamber. The plasma density is estimated from an ion saturation current of a Langmuir probe located at 4.5 cm downstream of the source exit.

The measured plasma density for the present source cavity is plotted by filled circles in Fig.1(b) as a function of the solenoid current $I_B$, together with those obtained for 30-mm and 50-mm diameter cylindrical source cavities. The plasma density for the stepped-diameter case is 3-5 times as high as the other cases, showing the enhancement of the density downstream of the source by modifying the cavity structure and the gas injection port. Sputtering process is also tested here to develop the compact sputtering device. A maximum sputtering rate of about 150 nm/min is obtained for the copper target. Furthermore, the sputtering of the ferromagnetic materials are also tested. Efficient sputtering of a thick ferromagnetic target is difficult for a conventional magnetron method, while the presently tested device can provide the similar deposition rate of the ferromagnetic materials to other target materials. The detailed results will be shown in the presentation.

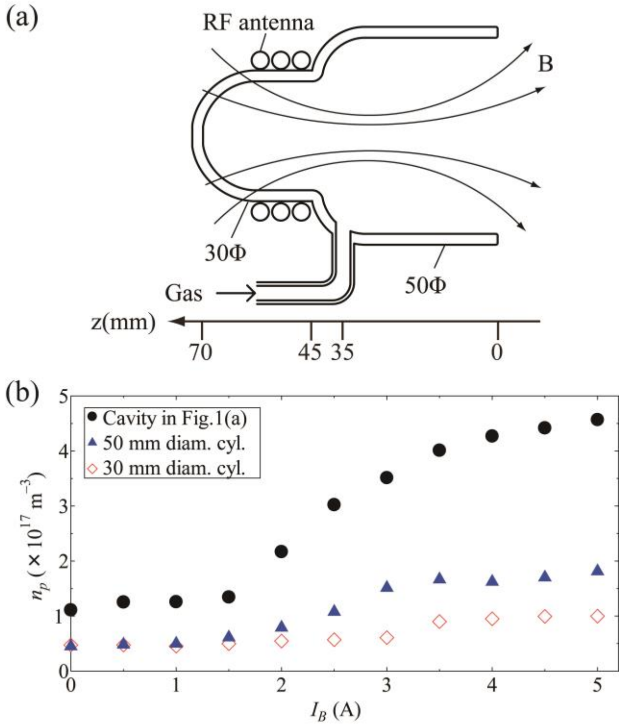


Fig. 1: (a)Schematic of the insulator cavity tested here and (b)plasma density measured downstream of the cavity for three different cavity structures as a function of the solenoid current $I_B$.

References

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