§15. Characteristics of High Power RF Ion Source Using Large Area Multi-antenna

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1, Introduction

We have proposed a multi-antenna type (tandem) rf driven ion source (MATIS) for neutral beam injection (NBI), and studied the basic characteristics[1-3]. It is composed of a large volume cusp plasma chamber made of a metal wall, and Faraday-shielded multiple current conductors as an internal multi-antenna. The Faraday shield naturally prevents from ion sputtering on the antenna. So far, the ion current density of 0.14 A/cm2 was attained with a uniformly dense hydrogen plasma at a rf power of 170 kW[3] which corresponded to much higher input power. The Faraday shielded antenna unit in the MATIS source has two areas for improvement: the efficiency of the rf plasma coupling, and the threshold RF power required ignite a plasma. As the rf power efficiency, especially for the powerful steady-state plasma source, is an important factor to the source design, the efficiency improvement to MATIS is a required subject and it is expected to be as high as possible like the case of an optimized filament driven source. In the present research, a new multi-antenna unit is fabricated and tested. The basic principle of the antenna design is to realize a close coupling configuration of the multi-antenna with the Faraday shield, in order to efficiently couple near rf fields to the plasmas.

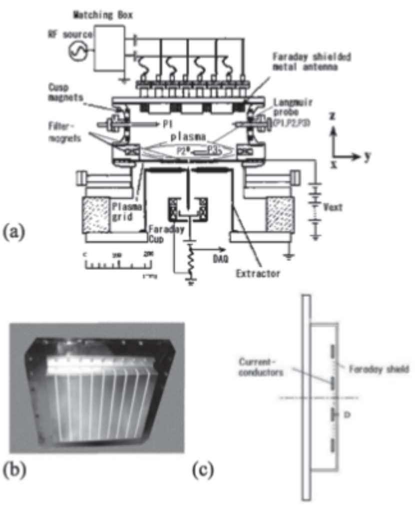

Fig. 1(a) schematic diagram of a multi-antenna type rf ion source. (b)photograph of Faraday-shielded multi-antenna. (c) cross-sectional sketch of the antenna.

2, Faraday shielded multi-antenna rf ion source

The structure of a close coupling multi-antenna type rf driven ion source (CC- MATIS) is shown in Fig.1(a). The all-metal antennas are installed inside the vacuum vessel with Faraday screen. Faraday shielded multi-antenna source produced a high-density plasma (< 170kW, 9MHz, 10ms pulse duration), however, the rf power efficiency for plasma production was fairly low, therefore we developed the new antenna system to improve the coupling between antenna and plasmas. New antenna was designed to increase the RF inductive field at the plasma edge. Four current conductors of the multi-antenna are composed of stainless steel plates (25x200x3t mm), which are electrically connected in parallel. To improve the coupling of the antenna field to the plasma surface, the distance between plasma and the current conductors (D in Fig.1(c)) is reduced to 0.65cm while in the former antenna case, D is ~2cm. Protecting from high voltage rf break down and plasma production inside the FS, fine ceramic powder is filled in the FS.

2, Rf plasma production by CC- MATIS

When the net rf power at a given pressure increases gradually while adjusting the matching network (in Fig. 2), a dense plasma begins to be produced beyond approximately 100 kW of net power, which corresponds to the threshold power for the inductive mode of operation at high densities. The ion saturation current density J+sat increases with the increase of the net power. A maximum value of the obtained J+sat with 0.66 Pa is at the 5.5 A/cm^2 level at 157 kW, though the data points are scattered. This maximum in CC-MATIS becomes higher compared to that in the previous MATIS. The threshold power in CC-MATIS seems to be at the same power level in MATIS (see Fig. 2 , too). It is observed that the gas pressure dependence of J+sat under a given power is weak, and that J+sat seems to have a weak maximum at around 1 Pa.

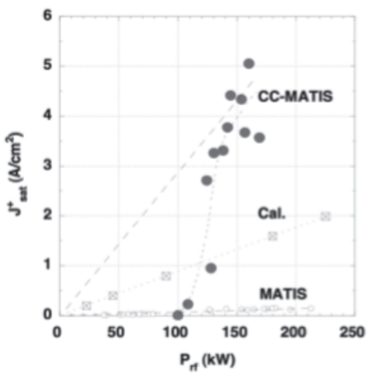

FIG. 2 Rf power dependence of J+sat in CC-MATIS and MATIS, and by calculation using a simple analytical model.

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[3] Y. Oka, T. Shoji et al., in *2nd Int. Sym. on Negative Ions, Beams and Sources*, Hida-Takayama, 16-19th Sep. (2010)