§6. Development of a Compact 14 GHz ECR Plasma Production Unit for a Negative Hydrogen Ion Source

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Research on efficient production of negative hydrogen (H^-) ions in electron cyclotron resonance (ECR) plasma is being continued through utilizing 14 GHz microwave resonant cavity structure. The ECR condition for 14 GHz microwave requires magnetic field intensity as high as 5 kG. Several types of field configurations based on careful designs of the magnetic circuit of the ion source have been attempted to see if they realize efficient production, transport and extraction of H^- ions [1].

The developed structure with the axial magnetic field intensity distribution is shown in Fig. 1. In the upper part of the figure is shown the structure constructed with magnetic material. An annular cylinder of magnetic material has been put into an alumina discharge chamber so as to create magnetic field with the intensity well larger than 5 kG. However, if the spatial distribution of the filed intensity is plotted as shown in the lower part of the figure, one should find the distance between the resonance point and the surface of the alumina discharge cup is below 10 mm [2]. Electrons accelerated by electric field launched in the direction parallel to the magnetic field strikes the wall of the chamber right after the acceleration. This problem is intrinsic to the small size of the ion source.

The reduced size of the ion source induces complexity in design to optimize the magnetic filter field geometry. Integrated intensity of the transverse magnetic field along the distance from the core plasma to the extraction hole has to be properly adjusted to minimize the density of high temperature component of electrons while keeping efficient transport of vibrationally excited hydrogen molecules. The source structure had been modified so that the volume of the ion source discharge chamber, or the distance from the hot plasma region to the ion extractor can be changed. This modification had been accomplished by inserting a thin Mo disk in the annular magnetic material cylinder forming the magnetic circuit for the ECR field.

The result of the optimization test has yielded data as they have been expected in the low pressure range of the ion source. Intensity of the extracted H^- current increased by an order of magnitude by enlarging the discharge voltage, as shown in Fig. 2. However, during the operation of the intermediate size of the discharge chamber, a sudden increase in H^- current against the increase of ion source pressure, which was about 100 times the value indicated in the abscissa of the figure, was observed. The reason for this sudden increase of the beam current has been attributed to a mode jump, or the transition from a low efficiency microwave coupling mode to a high efficiency coupling mode. A further investigation is being conducted to investigate whether the jump is due to more efficient ionization in the source, or more efficient electron cooling for electron attachment to vibrationally excited hydrogen molecules.

Operation of the ion source at higher frequency microwave is desired as the system size can be made smaller on the high voltage stand. However, the system requirement for the very high magnetic field will be a future problem for maintaining the field strength of permanent magnets. Thus, two schemes are being tested; lower frequency microwave excitation in the same magnetic field geometry, and the field tuning that realizes the power coupling at the half frequency sub harmonics for 14 GHz microwave power.

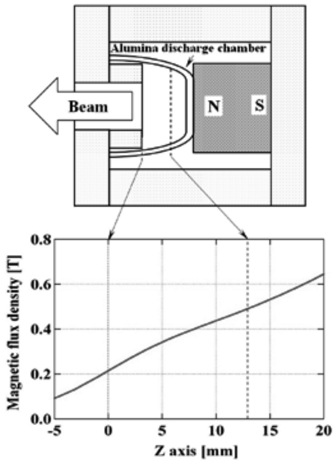

Fig. 1. Structure and the magnetic field intensity distribution of the compact 14 GHz ECR ion source.

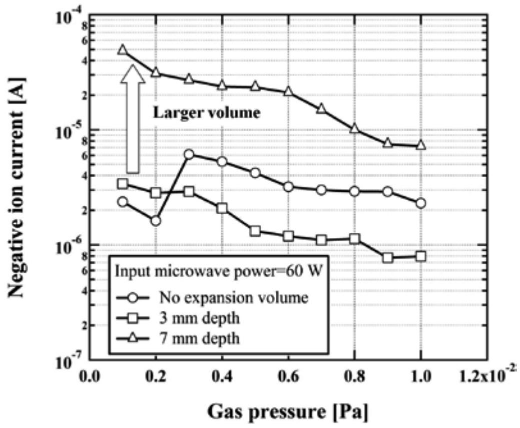

Fig. 2. The size effect upon the negative ion beam current extracted from a compact 14 GHz ECR negative hydrogen ion source.

1) T. Ichikawa, T. Kasuya, T. Kenmotsu, S. Maeno, T. Nishida, M. Nishiura, H. Yamaoka, M. Wada, AIP Conference Proceedings, **1515** , 394 (2013).
2) M. Wada, T. Ichikawa, T. Kasuya, T. Kenmotsu, M. Nishiura, H. Takemura, H. Yamaoka, Plasma and Fusion Res. **8**, 2401035 (2013).