§10. Development of a Compact Volume Production Type 14 GHz Negative Hydrogen Ion Source

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Multiply charged ions are efficiently produced in a high frequency electron cyclotron resonance (ECR) plasma. The reason for observing abundant highly charged ions in an ECR plasma is attributed to high mean energy of plasma electrons accelerated by the microwave power. It is considered possible to increase negative ion production efficiency if one can utilize these high energy electrons to produce vibrationally excited hydrogen molecules in a hydrogen plasma. This is because hydrogen negative ions (H^-) are formed through a two-step process: vibrational excitation of hydrogen molecules by fast electrons, and successive attachment of low energy electrons to the produced vibrationally excited hydrogen molecules.

We have started to investigate if this idea can be applicable to make an efficient negative ion source for use in accelerators, and/or large area H^- source that can be utilized for neutral beam injection system of future fusion reactors. A series of experiments had been initiated to test the performance of a small ion source with the 5 kG ECR magnetic field produced by a pair of permanent magnets.[1] The design had been largely modified at the part of beam forming electrodes as shown in Fig. 1.

A 20 mm diameter 90 mm long alumina tube placed in a tranverse magnetic field serves as a discharge chamber. High temperature plasma produced by 14 GHz microwave field in the central part of the discharge chamber has to diffuse across the transverse magnetic field to reach the extraction hole. Thus the ECR magnetic field also works as the magnetic filter field to reduce electron temperature near the region of the extraction hole. However, two adverse effects due to strong magnetic field are anticipated. These are over cooling of electron temperature, and bending of the beam trajectory at the extractor.

The modification shown in Fig. 1 had realized a reduction of the magnetic field around the extraction hole. A flange made of magnetic material was inserted to cover around the region of the extraction electrode. Surfaces of the magnetic material flange were covered by copper thin layers to avoid direct exposure to 14 GHz microwave. The improvement in the H^- intensity was remarkable and was as high as two orders of magnitude.[2]

Judging from the dependence of H^- ion current intensity against pressure, which had shown a monotonic decrease against pressure, plasma cooling effect due to the magnetic filter field is considered still too strong for H^- ion production. Namely, the design to reduce local magnetic field near the extractor had realized good extraction efficiency, but the field reduction was not enough to mitigate overcooling of electron temperature by the magnetic filter field. Thus, the source is being modified to separate extractor region plasma form ECR plasma with a smaller distance.

The new source design consists of a single magnet with the axis of magnetization aligned parallel to the direction of the beam extraction. The schematic diagram and the picture are shown in Fig. 2. Intensity of H^- current had dropped by an order of magnitude from the previous source design. On the other hand, positive ion current had been enhanced by more than an order of magnitude. The source has the better performance for positive ion extraction, which corresponds to insufficient cooling of plasma electrons near the extractor hole. Thus, the structure of the ion source near the extraction hole is further modified to reduce electron temperature near the extraction hole.

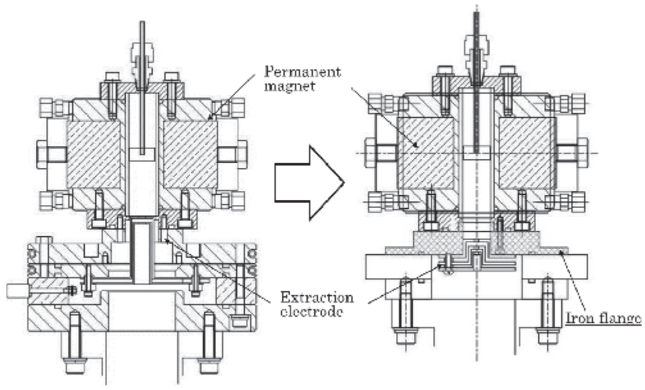

Fig. 1. Change of ion source structure to increase negative ion extraction efficiency.

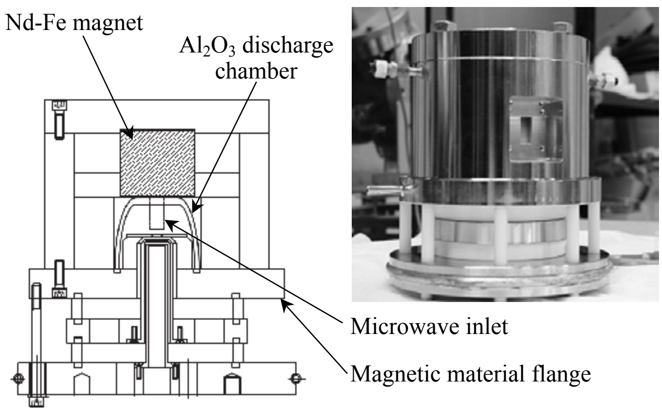

Fig 2. Schematic drawing and the picture of the assembled 14 GHz ECR negative hydrogen ion source.

1) M. Wada, Y. Demura, T. Kasuya, T. Kenmotsu, S. Maeno,T. Nishida, M. Nishiura, K. Shinto and H. Yamaoka, Plasma Fusion Res. 6, 2406100 (2011).
2) M. Wada, T. Kasuya, T. Kenmotsu, S. Maeno, T. Nishida, M. Nishiura, K. Shinto, and H. Yamaoka, Rev. Sci. Instrum. 83, 02A716 (2012).