§19. Development of a High Frequency Negative Ion Source for the NBI System

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In the present negative ion sources of NBI systems, the source plasma is generated by dc arc discharge where a hot filament act as a cathode. The lifetime of the ion source is limited to several hundred hours due to erosion and fatigue of the cathode filaments and damage to the filaments by anomalous arc discharge. Thus, a long-lifetime ion source is required for future NBI systems. Microwave-discharge and rf-driven ion sources are promising as long-lifetime ion sources because they have no filaments.

In this project, following three articles are studied:

(1) Production and control of ECR plasmas (2.45 GHz) and RF plasmas (13.56 MHz).

(2) Application of these high frequency plasmas for negative ion sources in NBI systems.

(3) Mechanism of reduction of electron temperature with the use of magnetic filter.

Here, on production of ECR plasmas, experimental results of new production method are reported[1,2]. A schematic diagram of the ECR hydrogen negative ion source is shown in Fig.1. The plasma source chamber (210 mm in diameter and 300 mm in length) made of stainless steel is a conventional multicusp volume source equipped with both a magnetic filter (set at z = 20 cm) and a plasma grid (set at z = 22 cm). The microwave power is launched into the circumference of a chamber by an annular slot antenna.

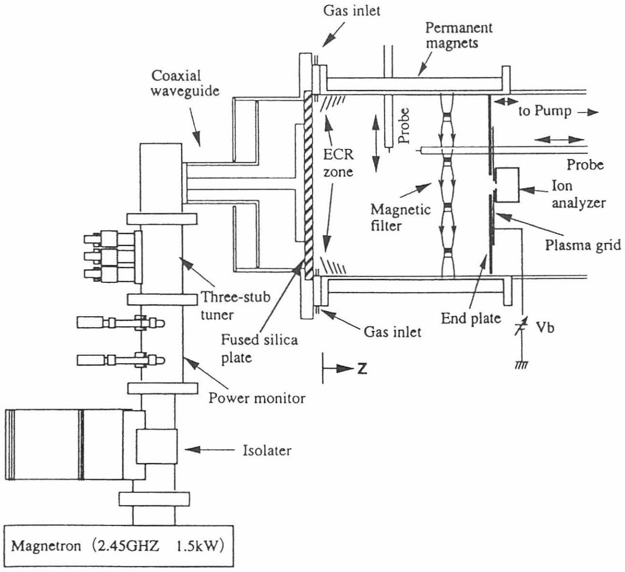

Fig. 1. Schematic diagram of the ECR negative ion source with the line-cusp resonance magnet.

We test the two types of magnetic field structure for the ECR field. The line cusp of permanent magnets provide both the resonance magnetic flux density of 875 G for 2.45 GHz inside the chamber (i.e., the annular region 10-15 mm from the chamber wall) and confinement of the produced plasmas (see Fig. 1).

The ring-cusp samarium-cobalt permanent magnets are located just outside the chamber with facing same polarities at a separation of 4 mm, where the chamber is inserted between the fused silica plate and the source chamber in Fig.1. These permanent magnets provide the resonance magnetic flux density of 875 G for 2.45 GHz inside the chamber i.e., the annular region 15-20 mm from the chamber wall.

Figure 2 shows the dependence of extracted H^- currents on P_{μ}, where extraction voltage V_{ex} = 600 V, For reference, the H^- currents in dc plasma is also plotted. The H^- currents in dc plasma is higher than those in ECR plasmas. For H^- production, *Te* and *ne* of ECR plasmas in the second chamber are not controlled well by the magnetic filter. In addition, plasma production effiency, and also production of fast electrons, are not necessarily high compared with dc plasma production. Therefore, the optimization of plasma parameters for the H^- production is under study.

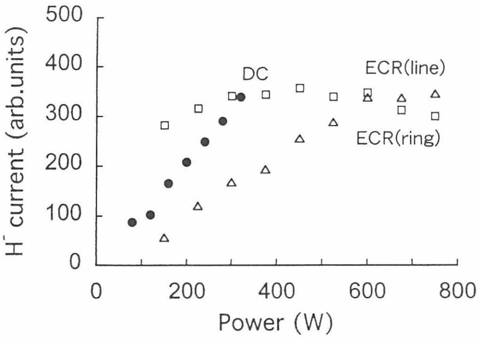

Fig.2. Extracted H^- currents, vs P_{μ}, ●: dc plasmas (3mTorr), △: the line-cusp (3mTorr), □: the ring-cusp (1.5 mTorr).

The role of the magnetic filter (i.e., preferential reflection of high-energy electrons) is not well clarified although it is widely used to reduce *Te*. Furthermore, effect of the magnetic filter in ECR plasmas is different from that in DC plasmas. Namely, in ECR plasmas, *Te* is not reduced well with the use of the same magnetic filter. This point is now under study.

References

1) Fukumasa, O. and Matsumori, M.: Jpn. J. Appl. Phys. **38** (1999) 4581.
2) Fukumasa, O. and Matsumori, M.: Rev. Sci. Instrum. **71** (2000) 935.