§12. Radio Frequency Excitation of Plasmas for a Plasma-Sputter-Type Negative Ion Source

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A plasma-sputter-type heavy negative ion source delivers a beam of gold negative ions (Au^-) into the Large Helical Device (LHD) to yield information on fluctuation of local plasma potential.[1)] Beam quality of the extracted Au^- is critically important to realize a signal-to-noise ratio large enough to detect the probe beam escaping out of the LHD. An ion source equipped with a larger sputtering target produces enough Au^- beam current for the proposed diagnostics to measure the plasma potential.[2)]

Factors affecting the quality of Au^- beam include plasma homogeneity, proper Cs coverage on the plasma-sputter-target, and configuration of static electromagnetic field near the ion source extractor. Gradual change of electron emissions from discharge filaments in the ion source can alter recycling of Cs in the ion source, which affects the Cs distribution in the ion source and the corresponding distribution of negative ion emission from the target. Excitation of ion source plasma by AC electromagnetic fields may stabilize the ion source operation through more homogeneous plasma irradiation of the sputtering target for a longer duration. Thus, a study to excite a stable ion source plasma with an electrical power of radio frequency (RF) at 13.56 MHz has been initiated.

Figure 1 shows the structure of the test ion source. A dc power supply keeps the electrical potential of the sputter target several hundred volts negative with respect to the ion source chamber wall. An RF power is supplied to the sputtering target through a dc insulation realized with a thin capton foil. An RF break inserted between the sputtering target and the dc power supply diminishes an RF power flow to the dc power supply

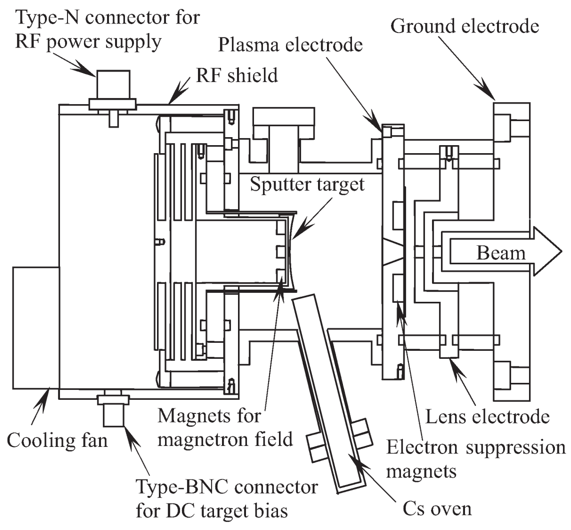

Fig. 1. A schematic illustration of an RF driven surface -production-type heavy negative ion source.

The sputtering target houses a pair of magnets to produce field geometry of a planar magnetron. The surface of the sputtering target has a spherical shape with the radius of curvature to form a focal point at the beam extractor. Another pair of magnet is installed in the extraction electrode to minimize extraction of plasma electrons from the ion source. The body of the ion source is cooled by a forced air cooling.

The source is installed on a small test bench equipped with a magnetic deflection type momentum analyzer.[3)] A performance of the ion source with an O_2 plasma has been tested with a Cs free condition for Cu sputtering target. Figure 2 shows a typical momentum spectrum of the charged particles in the extracted beam. Together with impurity ions of H^-, O^- and $C_nH_m^-$, peaks of negative ions of atomic copper and diatomic copper are found in the spectrum. The RF power less than 100 W stably maintained the oxygen plasma for more than several hours with the pressure less than 10^{-3} Pa at a position down stream of the extractor.

The developed source has a unique characteristic of negative bias control independent of RF power. The dc self bias due to RF power can be as high as 800 V,[4)] and may produce enough sputtering flux without additional dc bias. The source was operated without an additional dc bias to the sputtering target. Comparison of the momentum spectrum data with and without the dc input showed a RF self bias about 300 to 400 V for less than 100 W RF input power.

The present source design is readily adaptable to the test stand of ion source development for LHD beam probe system. The current development targets include optimization of the strength of the electron suppression magnets, control of the source pressure to realize easy plasma start-up, and proper spacing from the tip of the Cs oven nozzle to the target. Completion of these modifications will follow the source operation at energy higher than 20 keV with Au sputtering target.

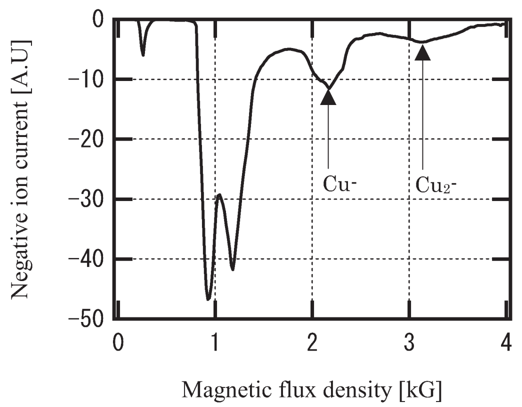

Fig. 2. Typical mass spectrograph of a beam extracted from the RF source operated with pure O_2 gas.

1) Nishiura, M. *et al.*, Rev. Sci. Instrum., 77, 03A537 (2006).
2) Nishiura, M. *et al.*, Rev. Sci. Instrum., 79, 02C713 (2008).
3) M. Wada *et al.*, Rev. Sci. Instrum., 79, 02B501 (2008).
4) H. Kakati *et al.*, J. Appl. Phys., 100, 083303 (2006).