§15. Electron Density Measurement of Negative Ion Source by Means of Surface Wave Probe

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It is well-known that co-extracted electron current is remarkably reduced by seeding Cs in H^- ion sources. However, the mechanism of the phenomena is not clearly understood due to difficulties in measuring electrons near a plasma grid, where the strong magnetic field is formed. A Langmuir probe is widely used in measurement of the electron density, but it is quite difficult to determine the electron density in the magnetized plasma precisely by the Langmuir probe. One of the most potential candidates for measuring the electron density in the extraction region is a surface wave probe, which can obtain the local electron density and is available in the magnetized plasma. The principle of this method is based on the resonant spectroscopy, whose resonance relates to the electron density.

The surface wave probe had not been applied to the studies of negative ion sources. Hence, to confirm the availability of the surface wave probe, the electron density measurements were carried out with a test chamber where the pure-volume hydrogen plasma was produced by arc discharge. Figure 1 shows a schematic illustration of the experimental setup. The surface wave probe consists of an alumina tube and a semi-rigid cable whose inner conductor is exposed at the end. Radiofrequency power is applied to the semi-rigid cable at the frequency of 50 MHz to 1.5 GHz and the ratio of the reflected power P_{ref} to the applied power P_{in} is detected by a network analyzer. The electron density is estimated from the resonant frequency where the applied power is strongly absorbed by the electrostatic wave standing at the interface between the dielectric tube and the plasma. The reflection coefficients ($\log_{10} P_{ref}/P_{in}$) of the applied radiofrequency power are shown in figure 2. The absorption signals are observed and the resonant frequency increases with the discharge power. The electron density n_e is obtained from the following equation.

$$n_e = 1.2 \times (\frac{\omega}{F})^2 \times 10^{10} \quad [cm^{-3}] ,$$

where ω is the resonant frequency and F is a constant derived from the dispersion relation and depends on the geometrical configuration of the cable.

Figure 3 shows the dependence of the electron density in the field-free region measured by the surface wave probe (SWP) and the Langmuir probe (LP) on the arc power. The electron density increases with the arc power and the experimental results by these probes correspond with each other. This confirms the availability of the surface wave probe for measuring the electron density in the negative ion source. Accordingly, the surface wave probe has been installed in a large H^- ion source and the electron density measurement near the extraction region will be carried out.

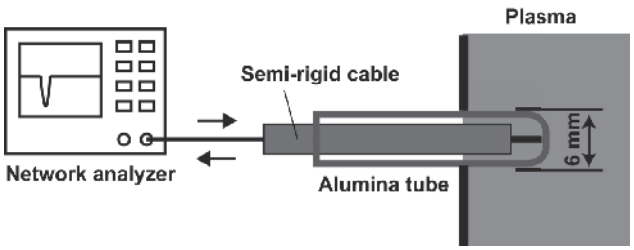

Fig. 1. Schematic illustration of experimental setup.

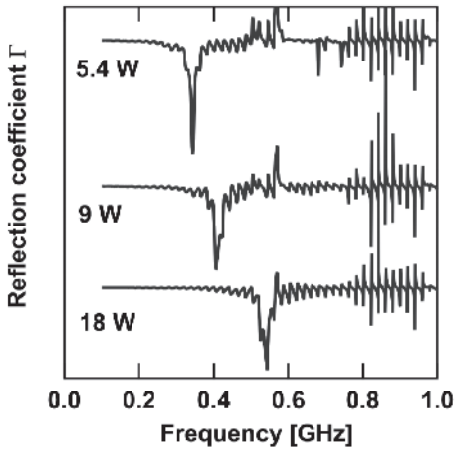

Fig. 2. Reflection coefficient of applied radiofrequency power at some discharge conditions.

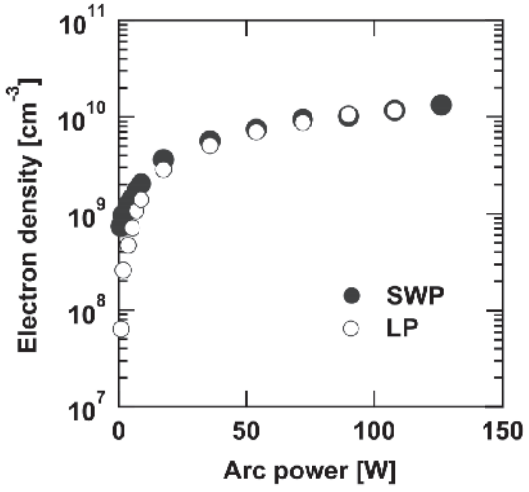

Fig. 3. Dependence of electron density measured by surface wave probe (●) and Langmuir probe (○) on arc power.