§3. In-situ Measurements of Secondary Electron Emission Coefficient in Plasma-Surface Interaction

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High energy particles such as neutrals, ions and photons produced in a fusion reactor are exhausted through diverter area, then a large heat load is applied to the diverter plate. In this meaning, there are strong plasma-surface interaction on a surface of the diverter. As one of the interactions, there is secondary electron emission, and its secondary electron emission coefficient (SEEC) has been measured for various target materials and incident ions. However, in most cases, such a measurement has been carried out with beam experiments in a ultra high vacuum environment for a pressure lower than 10^{-6} Torr which is much different from actual plasma environment. Therefore, new measurement technique is necessary to obtain the actual secondary electron emission coefficient in the plasma environment. Recently, a scintillation-based novel technique for high energy secondary electron measurements in PIII has been developed [1]. In the previous study, we extend the technique by replacing the scintillation detection with a semiconductor diode detector for more precise measurements, enabling one to obtain ion-induced secondary electron current. In this report, we investigate the secondary electron emission coefficient (SEEC) derived from the measured secondary electron current, and time variations of the SEEC during the process.

In the present experiment, one turn loop antenna is set in a 35-cm-diam. and 50-cm-long cylindrical stainless steel chamber, and a 13.56 MHz inductively-coupled plasma is generated at argon pressures of 1.3 Pa by supplying the antenna with RF powers up to 600 W. Under typical conditions, the electron density is 1.1×10^{17} m^{-3} and the electron temperature is 2.3 eV. 10 µs-long high voltage pulses up to 6 kV are applied to a spherical copper target inserted into the plasma with a repetition rate of 10 pps. In order to measure the high-energy secondary electrons, a thermoelectrically-cooled Si-PIN diode are used. As showin in Fig. 2, when the high-energy electrons are incident on the diode detector, hole-electron pairs are created. Since an inverse bias is applied to the detector, the resultant charges are extracted to a charge amplifier whose output voltage is proportional to the total amount of the created charges. The secondary electron current Ise obtained by differentiating the integrated output voltage enables one to discriminate high energy electrons (>2 keV) from background low-energy electrons in the plasma. The absolute calibration revealed that the detector has a sensitivity of ~0.2 mA/mm2 with a fast response time shorter than ~0.1µs.

As shown in Fig. 1, immediately after applying the target pulse voltage V_t of -6 kV at t=0, the target current I_t flows with a peak component for 0<t<2 µs followed by a constant component (t>3 µs). The secondary electron current I_{se} measured by the diode detector also has a waveform similar to I_t. However the peak of I_{se} is significantly lower than that of It because I_{se} obtained by the high energy electron measurement essentially does not include displacement current. Therefore the present technique is available for the selective measurement of the secondary electron current. Taking account of the detector sensitivity, the solid angle of the detector, and the spatial profile of the plasma density around the target, a current ratio of I_t/I_{se} gives the SEEC γ during the ion implantation as ~5 by $I_t/I_{se}= 1+\gamma^{-1}$. Repeating such a measurement, time variation of the SEEC are examined during the PIII process. The SEEC is approximately ~2 just after starting the process. However the SEEC gradually increases and reaches a steady state of ~5. This will be caused by impurities contained in the plasma such as oxygen.

References

[1] K. Nakamura et al: Plasma Sources Sci. & Tech. 6, 86 (1997).

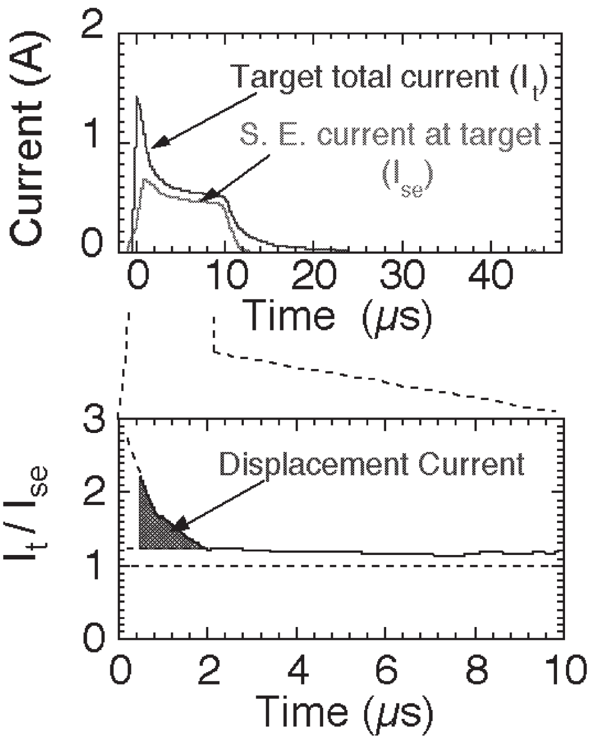

Fig. 1 Time variations of target total current I_t and secondary electron current I_{se}