§32. In Situ Measurement of Surface Modification of Plasma-facing Material during the Long Duration Discharge

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In order to investigate surface modification of the first wall, a new plasma-wall interaction (PWI) simulator has been developed[1)]. Properties of the first wall surface continue to change during a long duration discharge due to PWI such as heat load, particle road, radiation damage, erosion and re-deposition. It is necessary to estimate the surface modification in real-time for better understanding of PWI. In the PWI simulator APSEDAS (Advanced PWI Simulation Experimental Device and Analysis System), cylindrical plasma of the diameter of ~5 cm is produced by a helicon discharge where frequency and input power are 13.56 MHz and up to 5 kW, respectively. A set of two coils produces an axial magnetic field of 0.05 T at the plasma center. The feed gas is hydrogen or helium.

Figure 1 shows ion saturation current as a function of RF power in the following experimental condition: feed gas hydrogen, neutral pressure in the vacuum vessel ~ 7 mTorr and magnetic field 0.025T. It was measured by a Langmuir probe at 10 cm away from the target stage. The ion saturation current at the central region of the plasma drastically increased around ~1.7 kW of RF power (i.e. density jump). It is considered that helicon wave is excited in the plasma, and it heats the electrons and sustains the high density plasma. In this operational condition, the microwave frequency ω is satisfied the following condition: $\omega_{ci} << \omega << \omega_{ce}$, and the dispersion relation is

$$c^2 k_z \left(k_z^2 + k_\perp^2\right)^{1/2} = (\omega/\omega_{ce})\omega_{pe}{}^2$$

where c is light speed, ω_{ce} electron cyclotron frequency, ω_{pe} plasma frequency, k_z and $k_\perp$ wave numbers parallel and perpendicular to the magnetic field, respectively. The wavelength along the magnetic field is about 140 mm.

Figure 2 shows radial profiles of electron density, electron temperature and space potential of the hydrogen plasma with the RF power of 3.5 kW. The electron density becomes higher towards the center from the edge of the plasma. On the other hand, the electron temperature and the space potential are almost constant except the central region of the plasma. The higher temperature and the lower space potential at the plasma center seem to be attributed to the existence of fast electrons which are produced by the helicon wave.

Ion flux at the plasma center, which is estimated from the electron temperature and the density, is about 3.6 x 10^{22} m^{-2} s^{-1}. It is enough high to make efficient experiments of the plasma-wall interaction. In APSEDAS, an in situ and real-time measurement system using spectroscopic ellipsometry is also developing to investigate properties of co-deposited layer. And sample stages with an RF bias or a heater will also be constructed. Various kinds of PWI simulation and analysis can be done in APSEDAS.

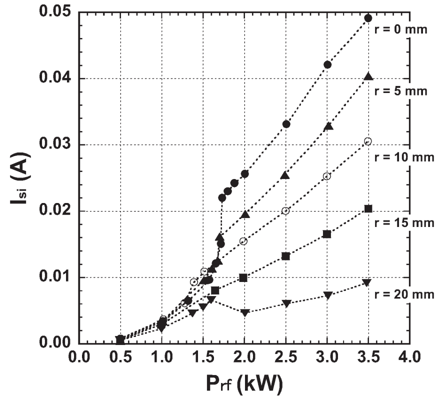

Fig.1 Ion saturated current as a function of RF power.

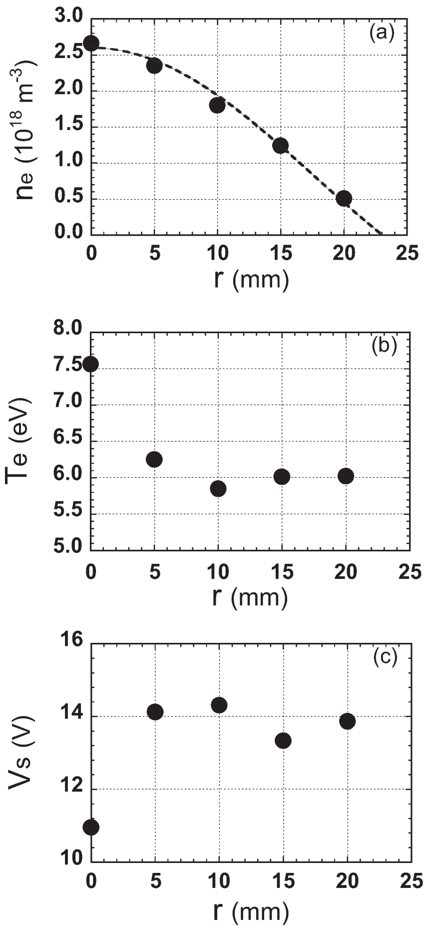

Fig.2 Radial profiles of (a) electron density, (b) electron temperature and (c) space potential in the hydrogen plasma. The RF power is 3.5 kW.

1) M. Sakamoto et al., Reports of Research Institute for Applied Mechanics Kyushu University, No.134 (2008) 61-64.