§16. Basic Process of Solid Hydrogen Ablation by Plasma

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Interaction between plasma and solid is one of the important themes, which should be studied in the sense of plasma science. On the other hand, from the viewpoint of performance of nuclear fusion plasmas, pellet injection experiments have been actively carried out in many toroidal studies in the sense of the control of density profile, obtaining high density or improved confinement, and diagnostic purposes. However, it is, so far, an empirical scaling and the essential part of solid hydrogen ablation by plasmas, such as the interaction between pellet and plasma, have not been clarified. For instance, observation of so-called "Tail Mode", which may be the result of charge exchange equilibrium state and the plasma rotation by the potential, might be affected by the density profile of the edge plasma. Thus, the study on pellet plasma interaction is one of the most interesting issues to be investigated as the fundamental plasma science.

In this research, an accumulation of data on the interaction between plasma and solid hydrogen is planned by measuring the fundamental process of pellet injection into an inductively coupled plasma (ICP). ICP is possible to get high-density of 10^{12}cm^{-3} and uniform density profile at low pressure of a few mTorr. This plasma is considered to be utilized as target plasmas to simulate edge plasmas. In this report, we present fundamental characteristics on spatial structure in ICP.

The experiments were done in a cylindrical stainless steel vessel of 16 cm in diameter and 116 cm in length. Figure 1 shows a schematic diagram of experimental apparatus and axial profile of magnetic flux density. A radio frequency (RF 13.56 MHz) power is input to a water-cooled 3 turn antenna mounted on a glass vessel (a glass tube of 36 mm in diameter and 200 mm in length combined with a glass plate of 165 mm in diameter and 10 mm in thickness) under a slightly divergent magnetic flux density with a maximum value of B_m = 600 G. The distance z = 0 cm is at the end of the glass vessel attached to the left side of the grounded stainless steel vessel.

Figure 2 shows axial profile of n_e and T_e at the gas pressure of 3 mTorr and the position of z = 5 cm and r =0 cm. Here, n_e and T_e measurements were done by a Langmuir plane probe with 0.5 mm diameter faced to the plasma source and was perpendicular to the magnetic field line. The use of such a faced plane probe in the magnetic field would improve the validity of the measurement because the shadow caused by the probe could not appear unlike the cylindrical and plane probes faced to back-side. It is seen that n_e gradually increases from 5×10^9 to 4×10^{10} cm^{-3} with increasing distance z from -5 to 25 cm, while T_e decreases drastically from 6 to 3 eV with increasing distance z from -5 to 4 cm and then gradually decreases. Spatial profile of the plasma potential Vs estimated by the Langmuir probe predicted that Vs changed from 2.5 to 10 V for -4< z < 1 cm and then decreased drastically to 6.2 V at z=5 cm, and then increased gradually to 8 V at z=25 cm. Electrons with Te≈6eV at the plasma source can penetrate through the potential barrier of about 3V (≈Vs(z=0cm)=9.5V-Vs(z=5cm)=6.2V). The inelastic mean free path λ_{ed} for electron-neutral direct ionization and λ_{ec} for electron-metastable cumulative ionization were estimated to be about 11 cm and 10 cm, respectively [2]. Te profile of Fig.3 provides energy-relaxation length in the region of z=0 to 5 cm as roughly 9cm. Thus, ionization by electrons could be also realized in the downstream. This might be one of the reasons why the electron density gradually increase in the downstream as shown in Fig.3. Besides this mechanism, the wave propagation effect [3] which did not identified in this work would be also another candidate to provide this result.

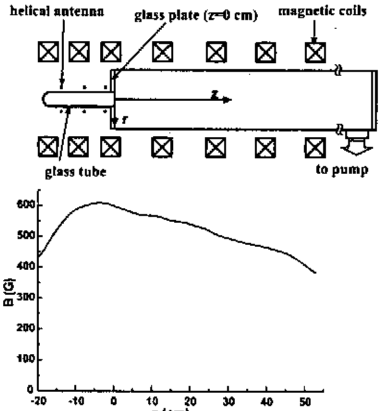

Fig.1. Experimental apparatus

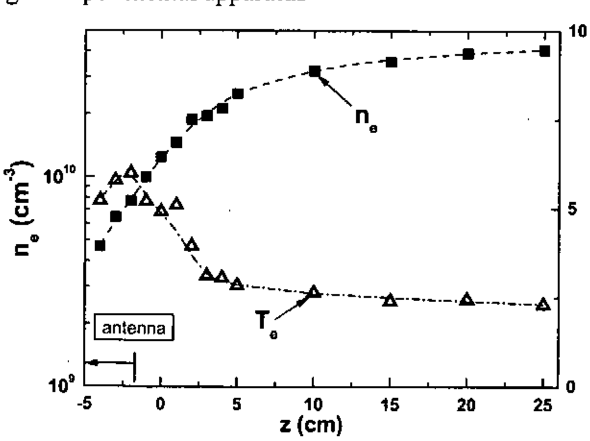

Fig.2 Axial profile of density n_e and temperature T_e of electrons

Reference
1) Brown, S. C., *Basic Data of Plasma Physics,* (MIT, Cambridge, 1966).
2) Chen, F.F. I.D.Sudit and M.Light, Plasma Sources Sci. Technol., 5(1996)173.