# §17. 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.

As shown in Fig.1, the experiments were done in a cylindrical stainless steel vessel of 16 cm in diameter and 116 cm in length connected by a glass tube of 36 mm inner diameter and 200 mm in length in argon pressure of 3 mTorr. A schematic diagram of an experimental apparatus and an axial profile of magnetic flux density **B** with three different divergent configurations in the glass tube are predicted in Fig. 1. These profiles are called “focus”, “flat“and “diverge” types, respectively. Here, the focus type provides profile that **B** tends to increase gradually and then saturates, the flat type is a roughly uniform one and the diverge type **B** is decreasing in the tube. A radio frequency (RF 13.56 MHz) power generator is connected to a helical external antenna mounted on the glass vessel. The location of $z$ = 0 cm is the end of the glass vessel attached to the side of the grounded stainless steel vessel.

As shown in Fig.2, when the magnetic field is switched off, $n_e$ is almost uniform with keeping a high value ($n_e \cong 5\times10^{10}$ cm$^{-3}$) for -13 < z < -1 cm corresponding to the antenna location. In the cases of both focus and flat types, axial profiles of $n_e$ are quite similar to each other. It is seen in these profiles that $n_e$ gradually increases from $2\times10^7$ to $4\times10^{10}$ cm$^{-3}$ from $z$=-15 to 25 cm. Here, electrons in the glass tube are strongly magnetized because of a big value of electron hole parameters (product between electron cyclotron frequency and collision time) of about 270 ~ 340 around the closed end of glass tube. Precisely speaking, the magnetic fields of these types decreases near the closed end of glass tube (z=-20 cm) causing $-\nabla_{\|}\mathbf{B}$ drift as approaching the tube end.

In the case of the diverge type, it is seen in Fig.2 that $n_e$ around $z$ = -14 cm is higher by about two order magnitude in comparison to that in the cases of other types. For the diverge type, a spatial profile of the plasma potential $V_S$ estimated by the probe predicted that $V_S$ decreased from about 8 to -11 V for -16 < z < -3 cm, increased from -11 to 5 V for -3 < $z$ <4 cm and then remained roughly constant of 5-7 V for $z$ > 4 cm. Due to the potential difference ($=V_S$ (z =-3cm) - $V_S$ (z =-16cm) $\cong$ -11V-8V=-19V) between $z$ = -16 and -3 cm, electrons in this region would be accelerated towards the closed end of the glass tube to realize a bigger ionization around this region. Since the magnetic field strength amounted to the highest value (around $z$ = -17 cm), the ionized electrons tend to move towards the $-\nabla_{\|}\mathbf{B}$ drift against the potential barrier as mentioned above. In addition to this fact, the magnetic field of the diverge type is stronger than that of other types in the region of z≤-10cm. This would cause a higher density in comparison to other type’s ones. For $z$ > -3 cm, the $n_e$ profile in the case of the diverge type is similar to ones corresponding to the focus and flat types.

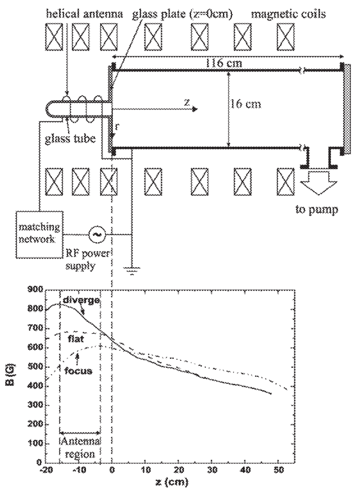


Fig.1 Experimental apparatus

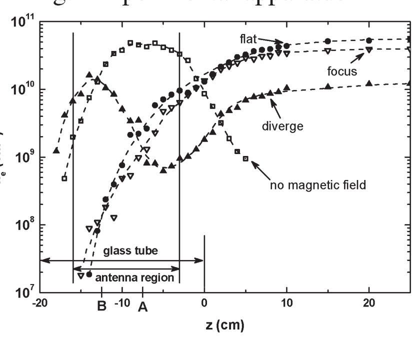


Fig.2 Axial profiles of $n_e$ at various magnetic field configurations