MAGNETIC PRESHEATH IN FRONT OF AN OBLIQUE END-PLATE IN A MAGNETIZED SHEET PLASMA

Akira Tonegawa, Masataka Ono[*], Shigeyasu Sakamoto[*], Masahiro Shibamoto, Kazutaka Kawamura[**], Kazuo Takayama[**], Tuguhiro Watanabe[***], Hajime Ssuzuki[***] and Nobuyoshi Ohyabu[***]

Department of Physics, School of Science, Tokai University
[*]*Department of Nuclear Engineering, School of Engineering, Tokai university*
[**]*Research Institute of Science & Technology, Tokai University, 1117 Kitakaname, Hiratsuka,259-1292, Japan*
[***]*National Institute for Fusion Science, 322-6 Oroshi, Toki Gifu 509-5292, Japan*

Abstract

To investigate the effect of an oblique end-plate on the transition layer between a plasma and an absorbing wall, we measured the space potential, the electron density, and electron temperature at the end-plate in a magnetized sheet plasma as the two-dimensional boundary-like plasma. The end plate rotates round x axis which is in the direction of the thickness of sheet plasma, or round y axis which is in the direction of the width of sheet plasma. The scale of the length and the potential drop of the magnetic presheath at the rotation round y axis are larger than those at the rotation round x axis.

1. Introduction

The transport of charged particles along with the magnetic field lines dispersed at the walls is important for the researches on the laboratory plasma, divertor plasma and so on. In particular, when a conducting wall is placed at an angle to the magnetic field, the particle diffusion toward the wall deviates markedly from the uniformity by the effects of the electric field, the density and the temperature gradients. Such imbalance is expected to give a remarkable effects on plasma parameters, the edge potential [1-3] and particle flow along the magnetic field. In the magnetic field intersecting the surface at a shallow angle, Chodura showed that the transition layer has a double structure composed of the magnetic presheath and the Debye sheath. Using a kinetic analysis by K.Sato et. al., it is found that an oblique magnetic field provide two presheath mechanisms; one is due to the ion polarization drift and another is due to finite ion-gyroradius effects. These processes at the plasma-wall boundary are very complex.

In order to investigate the effect of the plasma-wall boundary with the oblique end-plate, we have demonstrated in producing a magnetized sheet plasma [4] by using a TP-D type discharge apparatus. By definition, sheet plasma should have the unique characteristics:(i) the guiding centers of all gyrating ions lie in the vicinity of the midplane of a plasma and (ii) the plasma thickness in a direction perpendicular to a dc magnetic field is as thin as twice the mean ion Larmor radius. One can consider the sheet plasma as a "two-dimensional boundary-like" plasma which still preserves an overall charge neutrality. The study of the thin plasma column, whose thickness is the order of the ion Larmor radius L_i, is important from the view points, such as the effect of dc electric fields on particle dynamics and the finite ion Larmor radius effect and so on.

In this paper, we measured the space potential, the electron density, and electron temperature at the end-plate in a magnetized sheet plasma to investigate the effect of an oblique end-plate on plasma parameters. In particular, the change of the format-ion of the space potential in front of the oblique end-plate is investigated in two kinds of the rotation round x axis which is in the direction of the thickness of sheet plasma or round y axis which is in the direction of the width of sheet plasma.

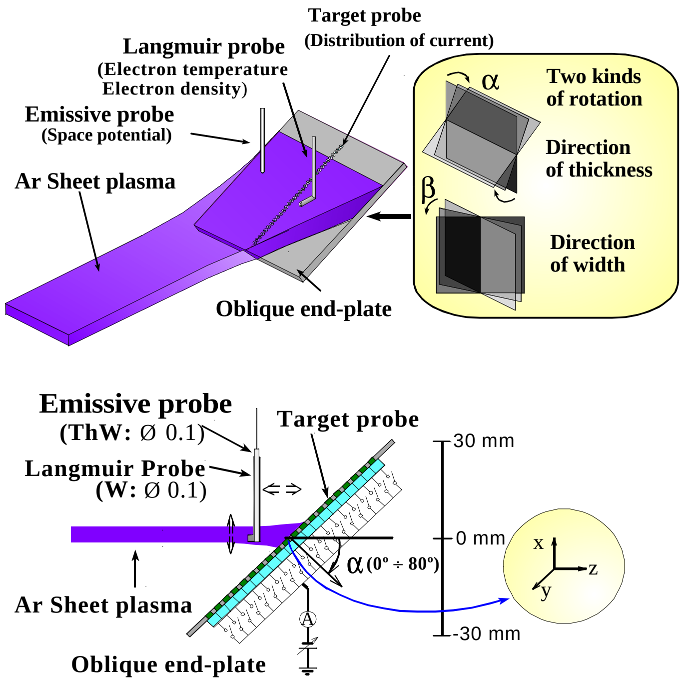

Fig. 1. Schematic drawing of the plasma at the oblique end-plate and measuring system.

2. Experimental apparatus

Schematic drawing of the plasma at end-plate and measuring system are shown in Fig. 1 (a) and (b), respectively. The sheet plasma device is divided into two regions: the discharge region and the experimental region. The discharge region is TP-D (Test Plasma produced by Directed current) type plasma source which was originally developed at Institute of Plasma Physics in Nagoya University. This plasma source is composed of a cathode, an anode combined with both a floating electrode system having a hole of rectangular cross-section, through which a discharge path forms, and rectangular magnetic coil system. The dimensions of the anode slit is 1.5 mm in thickness and 30 mm in width. The strength of the uniform magnetic field in the experimental region formed by ten rectangular magnetic. Since the anode slit also used to evacuate differentially the two regions of the device, the neutral pressure in the experimental region can be kept low (~1 Torr). The plasma is generated inside the discharge region by using a dc discharge between the hot cathode coated with electron-emitting oxide and the anode electrode at argon neutral pressure of about 10^{-4} Torr.

The oblique end-plate was placed at 70 cm away from the anode slit along the axis of the device in an uniform-magnetic-filed (0.15 ÷ 0.35 kG). The end-plate is kept the floating potential of -20 -40 V. In the transition layer, the direction of the magnetic field is parallel to the plasma flow (z direction) and the electric field is perpendicular to the oblique end-plate.

The end-plate rotates around x axis or y axis. The electric field forms in the normal direction to the oblique end-plate. The angle between the magnetic field and the electric field mentioned above is changed 0°, 45°, 60° and 80°. The angle between the magnetic field ant electric field at the rotation round x axis denotes as α and that round y axis denotes as β. The oblique end-plate located perpendicular to z is expressed in $\alpha = \beta = 0°$.

The electron density and the electron temperature were determined by Langmuir probe. The plasma potential, φ_p, is measured with an emissive probe (0.1 mm diam, 2 mm long) heated with dc power supply. The emissive probe characteristic is traced out so as to confirm that the floating potential closely matches the plasma potential. The potential measurements are performed in the radial and axis directions of the magnetized sheet plasma.

3. Experimental Results

The potential profiles for the various angles of the end-plate in a magnetized sheet plasma are shown in Fig. 2 at the rotation round x axis. The space potential and the length from the oblique target is normalized the electron temperature T_e and the ion Larmor radius ρ_i, respectively. The angle of the rotation α is 0°, 45°, 60° and 80°. The experimental conditions as follows: the discharge current is 10 A, the strength of the magnetic field is about 0.36 kG. When the argon gas flow rate for sheet plasma production is 12, 9, and 6 sccm, the electron temperature is changed from 3 to 6 eV. At the same time, the floating potential of the end-plate changes from -20 to 40. When the oblique end-plate perpendicular to z, i.e. $\alpha = 0°$ is placed, the φ_p shows a sudden drop in front of the end-plate. For $\alpha \neq 0°$, the profile of φ_p is composed of two parts at the transition layer: a slowly falling part which is called "magnetic presheath" succeeded by the sharp fall of the electrostatic sheath region at the wall. With increasing angle the potential drop in the presheath increases. The potential drop of the magnetic presheath increases with decreasing the argon gas flow ratio. This potential drop is of the order of T_e / e. The total potential drop between plasma and wall is insensitive to angle α. The scale of the magnetic presheath increases as α increases from 0° to 80° and is several times as larger as the ion Larmor radius.

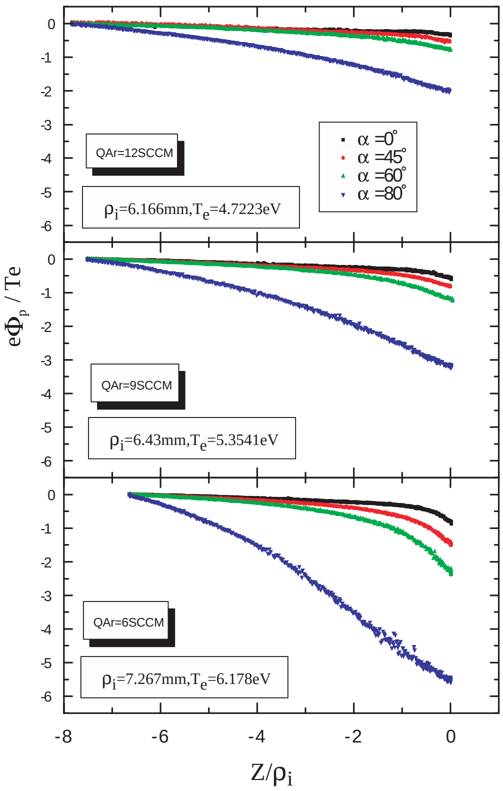

Fig. 2. The potential profiles for the various gas flow Ratio at the rotation to the plasma direction of the thickness. The angle of the rotation α is 0°, 45°, 60° and 80°.

Fig. 3 shows the potential profiles at the various angles of the end-plate in a magnetized sheet plasma during the rotation round y axis.

The angle of the rotation β is 0°, 45°, 60° and 80°. The experimental conditions is same as Fig. 2. The scale length and the potential drop of the magnetic presheath increases with increasing the angle β. In particular, the space potential rapidly decreases at β = 80° and the scale of the magnetic presheath is five times as large as the ion Larmor radius. Both scale of the length and the potential drop of the magnetic presheath at the rotation round x axis are larger than those of at the rotation round y axis.

The motions of ion guiding centers in a steady-state sheet plasma are restrained in the vicinity of the midplane of the plasma. This situation can be viewed that ions are trapped in a radial electric-potential well based on the charge separation between an electron "sheet" confined along an axial magnetic field and the ions themselves gyrating around this electron sheet. In the case of the rotation round x axis, the orbit of ions trapped by the radial electric-potential well in the sheet plasma is modified by the effect of the ion E×B drift by the electric-field in front of the oblique end-plate. The formation of the magnetic presheath is influenced by the radial electric-potential well in the sheet plasma.

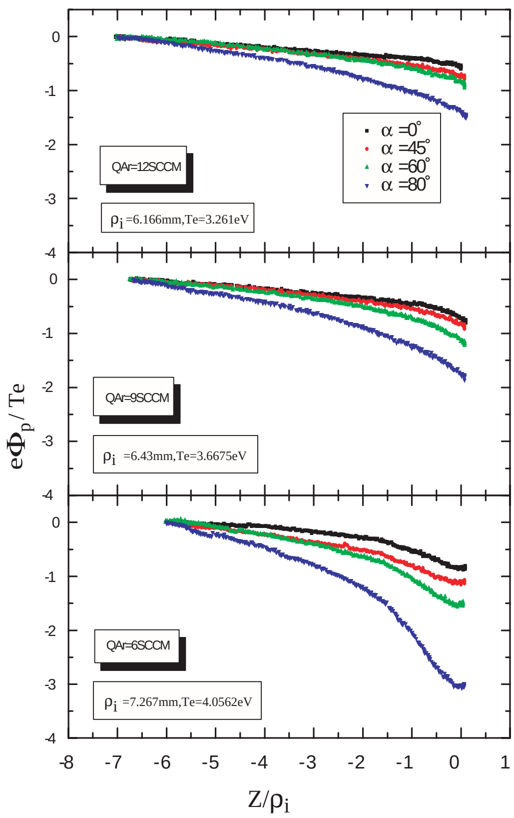

Fig. 3. The potential profiles for the various gas flow ratio at the rotation to the plasma direction of the width. The angle of the rotation β is 0°, 45°, 60° and 80°.

4. Conclusions

We have investigated the effect of an oblique end-plate on plasma parameters by using the sheet plasma designated as the two-dimensional boundary-like plasma. The end-plate rotates round x axis or y axis. The magnetic presheath scales is several times as larger as the ion Larmor radius. The potential drop at this transition layer is of the order of T_e/e. In particular, the scale of the length and the potential drop of the magnetic presheath at the rotation round x axis are larger than those at the rotation round y axis. The formation of the magnetic presheath is sensitive to the angle at the oblique end-plate.

References

[1] R. Chodura: Phys.Fluids **25** (1982) 1628.

[2] R. Chodura: *in* Physics of Plasma-Wall Interaction in Controlled Fusion. Eds. D.E. Post and R. Behrisch, Plenum Press, New York, 1986, p.99.

[3] K. Sato, H. Katayama and F. Miyawaki: Plasma Phys. (*to be published*)

[4] K. Sunako, K. Nanri, T. Noguchi, E. Yabe and K. Takayama: Nucl. Instr. and Meth. B**111** (1996) 151.