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Magnetic presheath structure in the sheet plasma with radial electric filed

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Abstract

Two-dimensional potential structure in the transition layer between plasma and an oblique end plate was investigated in a magnetized sheet plasma with the radial electric field. The scale length of the magnetic presheath is extending to the direction of the magnetic filed line, i.e. plasma flow, and is not the normal direction of the end plate. It is found that the potential structure is unsymmetrical at the upper and lower sides of the end plate. The formation of the magnetic presheath is sensitive to the profiles of the radial electric field, the electron density, and the electron temperature in the plasma.

1.Introduction

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 changes of the electric field, the density and temperature gradients. Such imbalance is expected to give remarkable effects on plasma parameters; the edge potential 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 [1-3]. The effect of the magnetic field on the plasma presheath was studied by Chodura in the collisionless limit. Plasma quasi-neutrality and a Boltzmann distribution for the electron density were assumed in order to determine the electric field. Chodura found that in order to satisfy the usual Bohm condition at the sheath plasma edge, a new layer was required. In the first presheath region the ions are accelerated to supersonic velocities parallel to the magnetic field lines, which may be oblique with respect to the wall. In the second presheath region, which has the thickness of approximately the ion Larmor radius, the ion velocity vector is rotated so that the velocity normal to the wall is supersonic at the entrance to the sheath.

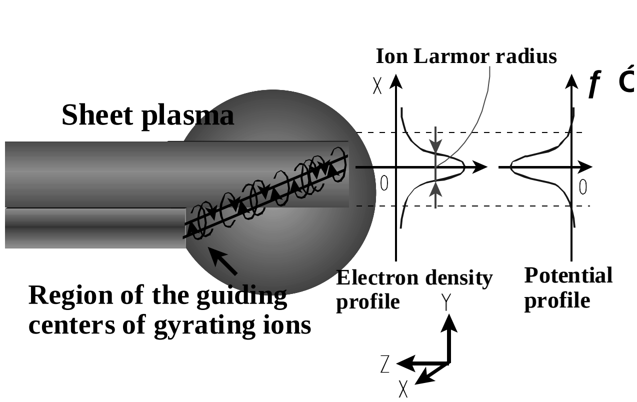

Fig.1 Schematic drawing of the magnetized sheet plasma.

The collisionless presheath in the case of an electric field E parallel to the wall and normal to the magnetic field B was also analyzed by Hutchinson [4]. He found that the Chodura condition at the magnetic presheath edge was transformed into a condition that took into account ion drift in the ExB direction. It is found that an oblique magnetic field provides two presheath mechanisms; one is due to the ion polarization drift and another is due to finite ion-gyroradius effects. Although a lot of work has been done in order to understand the properties of the potential formation at the plasma–wall boundary with tangential electric field in a plasma, very little is known about the mechanism of that formation in front of an oblique end plates with various angles. These processes of the plasma-wall boundary are very complex.

To investigate the effect of the plasma-wall boundary with the oblique end plate, we have demonstrated in a magnetized sheet plasma [5] by using a TP-D type discharge apparatus. By definition as shown in fig.1, sheet plasma should have the unique characteristics:(i) the guiding centers of all gyrating ions lie in the vicinity of the midline 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 $_i$, 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, two-dimensional potential structure in front of the oblique end plate is investigated in the rotation round x-axis whose direction is that of the thickness of sheet plasma.

2.Experimental apparatus

Schematic drawing of the plasma at end plate and measuring system are shown in Fig.2. The sheet plasma device is divided into two regions: the sheet plasma source region and the experimental region. The sheet plasma source is composed of a LaB_6 cathode, an anode combined with a floating electrode system having a rectangular hole, through which a discharge path forms, and a rectangular magnetic coil system. The dimension of the anode slit is 1. 5 mm in thickness and 30 mm in width. In the experimental region, the strength of the uniform magnetic field was formed by ten rectangular magnets. 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 at about 10^{-4} 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 1 Torr.

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

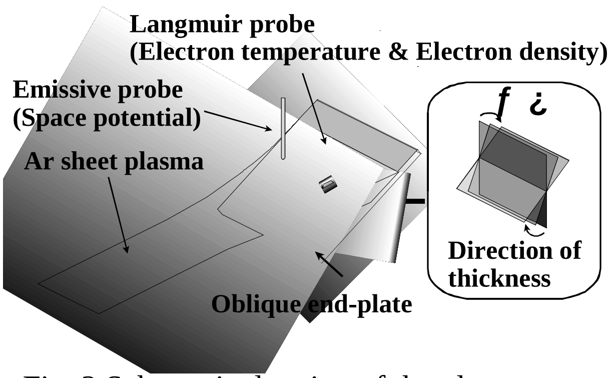

Fig. 2 Schematic drawing of the plasma at the oblique end plate and measuring system.

the oblique end plate. The end plate rotates around 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 angel between the magnetic field and electric field at the rotation round y axis is denoted as .. The oblique end-plate located perpendicularly against z is expressed in .= 0˚.

The electron density and the electron temperature were determined by Langmuir probe. The plasma potential, $._p$, 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 to confirm that the floating potential closely matches the plasma potential. This technique has an accuracy as good as 0.2V which is limited by the emitting wire temperature of 0.2eV. Positions were resolved to 0.1cm by using a mechanical probe driver. The potential measurements are performed in the z-axis directions of the magnetized sheet plasma.

3.Experimental Results

The equipotential contours for different angles of the end-plate in a magnetized sheet plasma are shown in fig.3 at the rotation round x-axis: (a).= 0˚and (b).= 80˚. The experimental conditions as follows: the discharge current is 10 A, the strength of the magnetic field is about 0.36 kG, the argon gas flow rate for sheet plasma production is 9 sccm. When the angle of the end-plat .is changed 0˚and 80˚, the floating potential of the end-plate changes from –38 to –43.2 V. When the oblique end-plate is placed at .= 0˚, the $._p$ shows a sudden drop in front of the end-plate. For . = 80˚, the profile of $._p$ is composed of two parts at the transition layer: a slowly falling part which is called "magnetic

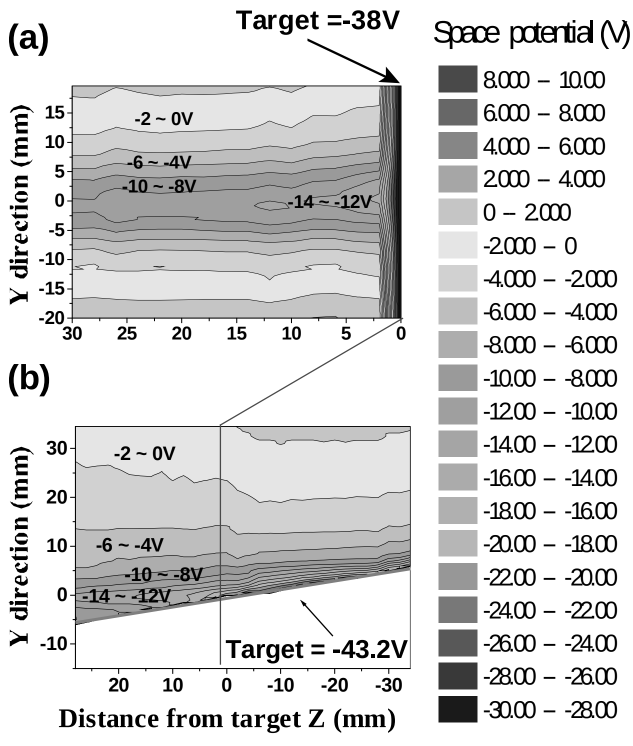

Fig.3 Equipotential contours of the space potential for different angles of the end-plate: (a).= 0˚and (b).= 80˚.

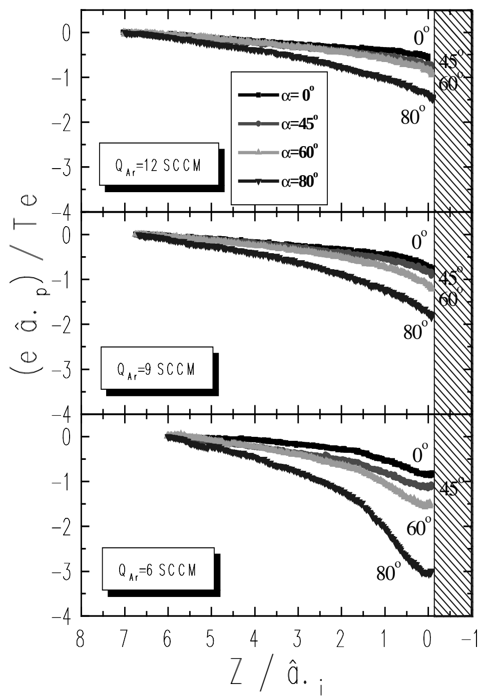

Fig.4 The z profiles of space potential for different gas pressure at various angle.

presheath" succeeded by the sharp fall of the electrostatic sheath region at the wall. The motions of ion guiding centers in a steady-state sheet plasma are restrained in the vicinity of the midline 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.

The z profiles of the space potential for different argon gas pressure at the angle of . = 80 ° are shown in fig.4: (a) Q_{Ar}=12 sccm, (b) Q_{Ar}=9 sccm, and (c) Q_{Ar}=6 sccm. The same experimental conditions as those in fig.3 are used. It is found that the potential structure is unsymmetrical at the upper and lower sides of the end plate. The potential drops of the magnetic presheath increases with decreasing the argon gas flow ratio and with increasing the electron temperature. This potential drop is of the order of T_e / e. The total potential drop between plasma and wall is insensitive to angle .. The scale of the magnetic presheath is several times as larger as the ion Larmor radius.

Two-dimensional potential structure in front of the oblique end plate deviates markedly from the uniformity by the changes of the electric field, the density and temperature gradients. Also, the scale length of the magnetic presheath is extending to the direction of the magnetic field line, i.e. plasma flow, and is not the normal direction of the end plate. In the case of the rotation round x-axis, the orbit of ions trapped at the radial electric-potential well in the sheet plasma is extremely modified by the ExB drift by the electric-field in front of the oblique end-plate. It is found that the potential formations at the magnetic presheath edge with a tangential electric field have to take into account ion drift in the ExB direction.

4.Conclusions

We have investigated the two-dimensional potential structure in the transition layer between plasma and an oblique end plate, was investigated in a magnetized sheet plasma with the radial electric field. The scale length of the magnetic presheath is extending to the direction of the magnetic field line, i.e. plasma flow, and is not the normal direction of the end plate. The potential drop is several times that of T_e / e. The scale length of the magnetic presheath is several times as larger as the ion Larmor radius. The formation of the magnetic presheath is sensitive to the profiles of the radial electric field, the electron density, and the electron temperature in the plasma.

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