§12. Electric Field at Plasma-facing Wall in Oblique Magnetic Field

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In order to investigate the phenomena in front of a plasma-facing wall, such as dust dynamics and ion implantation to the wall, the plasma quantities and the electric field, E_w, at the wall are necessary. The spatially changing electric field in the oblique magnetic field create the polarization drift of the plasma ions to the perpendicular direction of the magnetic field, which is the cause of the magnetic pre-sheath [1,2]. In this study the electric field is obtained by solving the Poisson's equation in the whole region of the magnetic pre-sheath (MP) and the Debye sheath (DS). The ion flow inside the magnetic pre-sheath consists of the ion flow along the magnetic field, the ion polarization drift, and the $\vec{E}\times\vec{B}$ drift [2], where the ion Larmor radius is much smaller than the characteristic length of spatial change of the electric field. The local electrostatic potential is obtained from the Poisson's equation:

$$\varepsilon_0 \frac{d^2\phi}{dz^2} = e[n_e(\phi) - Z_i n_i(\phi)]$$
$$= en_{e0}\{\exp(e\phi/T_e)\frac{1+\mathrm{erf}\sqrt{e(\phi-\phi_w)/T_e}}{1+\mathrm{erf}\sqrt{-e\phi_w/T_e}} - \frac{1}{\sqrt{1-\frac{2e\phi}{T_e}(1-\frac{\sin^2\beta}{\omega_{ci}B}\frac{d^2\phi}{dz^2})}}]\} \quad (1)$$

where ϕ_w is the potential at the wall, ω_{ci} and β are the ion cyclotron frequency and the angle of oblique magnetic field from the wall normal and the charge neutrality condition at the MP entrance, $Z_i n_{i0} = n_{e0}$, is used. The last term indicates the effect of the oblique magnetic field. This equation gives the quadratic equation with respect to the second order derivative of the potential:

$$b_0(\frac{d^2\phi}{dz^2})^2 + b_1(\phi)\frac{d^2\phi}{dz^2} + b_2(\phi) = 0\,, \quad (2)$$

where

$$b_0 = \frac{\varepsilon_0 \sin^2\beta}{en_{e0}}\,, \quad (3)$$

$$b_1(\phi) = -[e^{e\phi/T_e}\frac{1+\mathrm{erf}\sqrt{e(\phi-\phi_w)/T_e}}{1+\mathrm{erf}\sqrt{-e\phi_w/T_e}}\sin^2\beta + \frac{\varepsilon_0\omega_{ci}B}{en_{e0}}]\,, \quad (4)$$

$$b_2(\phi) = \omega_{ci}B[e^{e\phi/T_e}\frac{1+\mathrm{erf}\sqrt{e(\phi-\phi_w)/T_e}}{1+\mathrm{erf}\sqrt{-e\phi_w/T_e}} - \frac{1}{\sqrt{1-2e\phi/T_e}}]\,. \quad (5)$$

The local electric field is expressed by using the one of the solutions of Eq. (2):

$$E_z^2(\phi) = 2\int_0^\phi \frac{d^2\phi}{dz^2}d\phi = -\frac{1}{b_0}\int_0^\phi [b_1(\phi) + \sqrt{b_1^2(\phi) - 4b_0 b_2(\phi)}]d\phi\,. \quad (6)$$

In Fig.1, the electric field at the wall are shown as functions of the angle β for the case of the weaker magnetic field or the higher density ($\delta_B = 5.0\times10^{-3}$, solid lines) and the larger magnetic field or the lower plasma density ($\delta_B = 5.0\times10^{-2}$, dashed lines), where the parameter δ_B characterizes of the effect of the magnetic field;

$$\delta_B = \frac{\varepsilon_0 Z_i B^2}{m_i n_{e0}} = \frac{\lambda_{D0}^2}{\rho_{Ls}^2}\,, \quad (7)$$

where λ_{D0} is the Debye length at the MP entrance and ρ_{Ls} is the ion Larmor radius with respect to the ion sound speed. The value of $\delta_B = 5.0\times10^{-3}$ corresponds to the magnetic field of 3 T and the electron density of 10^{19} m^{-3}. The electric field becomes much weaker than in the case without magnetic field. In the case of the higher magnetic field or the lower density, i.e. larger δ_B, the decrease of the electric field compared to that without magnetic field are moderate.

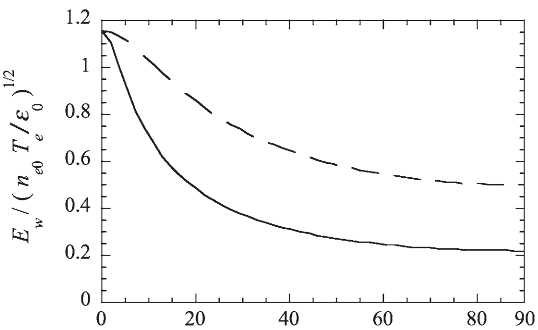

Fig1. The electric field E_w at the wall as functions of the angle of oblique magnetic field from the wall normal for the case of $\delta_B = 5.0\times10^{-3}$ (solid lines) and 5.0×10^{-2} (dashed lines).

1) R. Chodura, Phys. Fluids, **25** (1982) 1628.
2) K. Sato, et al., Contrib. Plasma Phys., **34** (1994) 13.