§21. Electric Field at a Plasma-Facing Wall for a Two-Temperature Electron Distribution

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The electric field E_w at a plasma-facing wall (PFW) for a two-temperature Maxwellian distribution of electrons at the sheath entrance (TTED) is obtained from the Poisson equation:

$$\bar{E}_w^2 \equiv \frac{E_w^2}{n_{se}T_{ec}/\varepsilon_0} = \Lambda_{iw} - \Lambda_{ew},\ \Lambda_{jw} \equiv -\frac{2|q_j|}{n_{se}T_{ec}} \int_0^{\phi_w} d\phi\, n_j(\phi). \quad (1)$$

Here n_{se} and T_{ec} are the electron density at the sheath entrance and electron temperature of the cold component. The electron contribution Λ_{ew} is expressed by using the wall potential drop ϕ_w:

$$\Lambda_{ew} = \frac{2}{n_{se}T_{ec}} \sum_{k=c,h} n_{ek}T_{ek}\{1 - e^{e\phi_w/T_{ek}} \frac{1}{1+\mathrm{erf}(\sqrt{-e\phi_w/T_{ek}})} - \frac{2\sqrt{-e\phi_w/T_{ek}}}{\sqrt{\pi}[1+\mathrm{erf}(\sqrt{-e\phi_w/T_{ek}})]} e^{e\phi_w/T_{ek}}\} \quad (2)$$

The contribution from ions Λ_{iw} with a shifted Maxwellian distribution at the sheath entrance is expressed as follows:

$$\Lambda_{iw} = \frac{8\nu_{ese}^2 T_i}{Z_i T_{ec}[1+\mathrm{erf}(\nu_{ese})]} \frac{\nu_{ese}}{\sqrt{\pi}} \int_0^{\infty} d\xi\, \xi\, (\sqrt{\xi^2 + \alpha_{ese}} - \xi) \exp[-\nu_{ese}^2(\xi-1)^2], \quad (3)$$

where
$$\nu_{ese} \equiv \frac{c_{s,DET}}{\upsilon_{thi}} = \sqrt{\frac{1}{2}(\frac{Z_i\lambda_{es}T_{ec}}{T_i} + \gamma_i)},$$

$$\alpha_{ese} \equiv \frac{-Z_i e\phi_w}{\nu_{ese}^2 T_i} = \frac{-2Z_i e\phi_w}{Z_i\lambda_{es}T_{ec} + \gamma_i T_i},$$

$$\text{and}\quad \lambda_{es} \equiv n_{se}/(n_{esc} + n_{esh}\frac{T_{ec}}{T_{eh}}). \quad (4)$$

When the ion temperature T_i approaches to zero, the ion part, Eq. (3), approaches a value of

$$\Lambda_{iw}\big|_{T_i=0} = 2\lambda_{es}[\sqrt{1 - \frac{2}{\lambda_{es}} \frac{e\phi_w(T_i=0)}{T_{ec}}} - 1]. \quad (5)$$

Here $\phi_w(T_i = 0)$ is the potential drop in the case of $T_i = 0$ and the TTED.

In the case where the effect of the ion temperature is neglected, the normalized wall electric field, which depends on the hot electron component, is shown in Fig.1,for the cases of (*a*) a lower electron temperature of the hot electron component (LET), $T_{eh}/T_{ec} = 3.0$, and (*b*) a higher one (HET), $T_{eh}/T_{ec} = 20.0$. The much larger wall drop gives us an approximate form of the electron component Λ_{ew} ,

$$\Lambda_{ew} \sim 2(n_{ec}/n_{se}) + 2(n_{eh}/n_{se})(T_{eh}/T_{ec})$$
$$= 2 + 2\,[(T_{eh}/T_{ec}) - 1]\,(n_{eh}/n_{se}), \quad (6)$$

which comes from the first terms of the cold and hot components in Eq. (2). In this case, the terms including the wall potential drop are neglected. This approximate form is proportional to n_{eh}/n_{se} and has the dependences shown in Fig. 1 (*a*) and (*b*). The ion part $\Lambda_{iw}|_{Ti=0}$, where $T_i = 0$, represents the dependence of the wall potential drop. In the case of HET, the maximum of the electric field occurs at higher (n_{ec}/n_{se}), which is a result of the functional dependence on n_{eh}/n_{se}, i.e. $\Lambda_{ew} \propto (n_{eh}/n_{se})$ [Eq.(5)] and $\Lambda_{iw} \propto \sqrt{-\phi_w(T_i=0)} \propto \sqrt{\ln(n_{eh}/n_{se})}$ at the higher n_{ec}/n_{se}.

The normalized changes of the electric field due to the effect of finite ion temperature are shown in Fig. 2, where n_{eh}/n_{se} is 0.1, $T_i/T_{ec} < 1.0$ for (*a*) LET, $T_{eh}/T_{ec} = 3.0$, and (*b*) HET, $T_{eh}/T_{ec} = 20.0$. The normalized square of electric field at $T_i = 0$ are 2.012 and 11.67 for the case LET and HET, respectively. The changes are complex because the effect of the finite ion temperature changes the wall potential drop, Eq. (3), as well as the ion contribution to E_w. The normalized change of LET, however, is smaller than 2 %. In the case of HET, it is as large as 20 %.

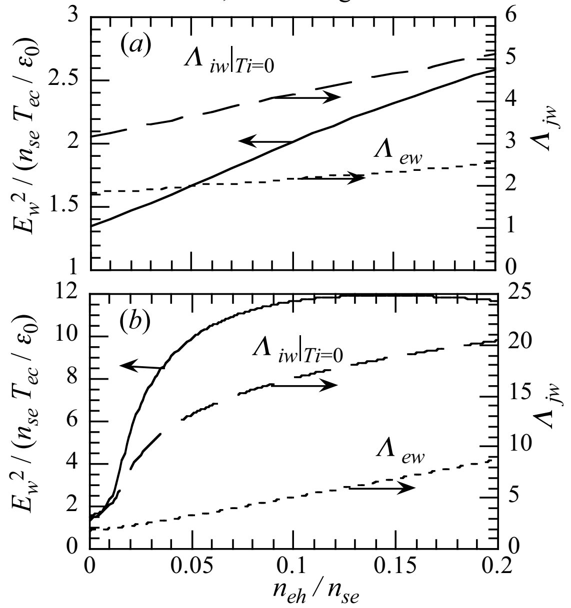

Fig.1 Normalized electric field at PFW. (*a*) LET, $T_{eh}/T_{ec} = 3.0$, and (*b*) HET, $T_{eh}/T_{ec} = 20.0$.

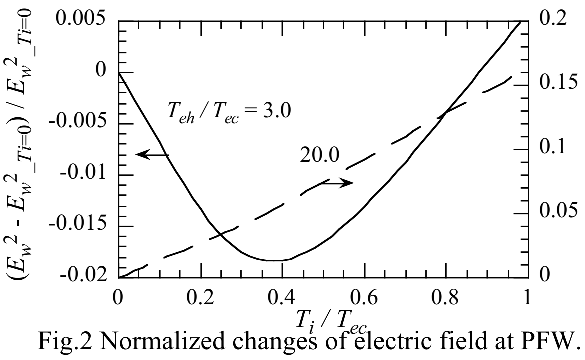

Fig.2 Normalized changes of electric field at PFW. $T_{eh}/T_{ec} = 3.0$, and $T_{eh}/T_{ec} = 20.0$, where n_{eh}/n_{se} is 0.1.