§7. Effect of Secondary Electron Emission for Probe Measurement

Tsushima, A., Tawaraya, T. (Yokohama Na. Univ.),
Yoshimura, S.

It is known that secondary electron emission yield increases with increasing the energy of an incident electron. This problem should be considered for an electrostatic probe to measure high electron temperatures. In general, the coefficient of secondary electron emission δ is a function of the energy E of an incident electron with the form

$$\delta/\delta_m = f(E/E_m) \; , \qquad (1)$$

where δ_m is the maximum value of the coefficient and E_m is the energy at which this maximum occurs. Then, if a probe electrode is immersed in a plasma with an electron temperature T_e, the effective coefficient $\bar{\delta}$ is a function of T_e only. In particular, using an empirical form[1)] $f(x) = (2.72)^2 x e^{-2\sqrt{x}}$,

$$\bar{\delta}(T_e) = (2.72)^2 \delta_m \frac{k_B T_e}{E_m} \int_0^\infty \xi \; e^{-\xi - 2\sqrt{(k_B T_e/E_m)\xi}} \, d\xi \; . \qquad (2)$$

It is very useful that the effective coefficient does not depend on a bias potential of the electrode or a space potential. Therefore, an electron current density of a probe with a bias potential V_p in a plasma with a space potential V_s is represented by

$$j_e(V_p) = \frac{1}{4} e n_{ec} \left[1 - \bar{\delta}(T_{ec})\right] e^{e(V_p - V_s)/k_B T_{ec}} + \frac{1}{4} e n_{eh} \left[1 - \bar{\delta}(T_{eh})\right] e^{e(V_p - V_s)/k_B T_{eh}}, \qquad (3)$$

where two Maxwellian distribution functions with electron temperatures, T_{ec} and T_{eh} ($T_{ec} < T_{eh}$), and corresponding densities, n_{ec} and n_{eh}, respectively. Note that the electron current density due to the component with T_{ec} is reduced by $1 - \bar{\delta}(T_{ec})$ and that due to the component with T_{eh} is reduced by $1 - \bar{\delta}(T_{eh})$.

Using two probes with tungsten and molybdenum electrodes with a simultaneous sweep bias potential, probe characteristics were obtained in a device similar to a DP machine.[2)] Since the effective coefficient $\bar{\delta}_{\mathrm{W}}$ of tungsten ($\delta_m = 1.36$; $E_m = 650$ eV) and that $\bar{\delta}_{\mathrm{Mo}}$ of molybdenum ($\delta_m = 1.25$; $E_m = 375$ eV) are different, our concern is whether electron temperatures estimated from the probe characteristics of the two probes with tungsten and molybdenum electrodes agree or not and whether density ratios $(n_{eh}/n_{ec})'s$ estimated with the consideration of secondary electron emission effect from those of the two probes with tungsten and molybdenum electrodes agree or not. For the first task, attention to T_{eh} is paid since T_{ec} is so small in our experimental conditions; the two electron temperatures from the two probes agree within an accuracy of 10 %. For the second task, using the relation

$$R = \frac{n_{eh}}{n_{ec}} = \frac{I_{eh}}{I_{ec}} \sqrt{\frac{T_{ec}}{T_{eh}}} \frac{1 - \bar{\delta}(T_{ec})}{1 - \bar{\delta}(T_{eh})} \; , \qquad (4)$$

the relations between $R_{\mathrm{Mo}}/R_{\mathrm{W}}$ and T_{eh} are depicted by closed circles, as shown in Fig. 1, where I_{ec} and I_{eh} are electron saturation currents of the components with T_{ec} and T_{eh}, respectively; R_{W} and R_{Mo} are obtained from the probe with tungsten and molybdenum electrodes, respectively. It is seen that the closed circles agree with $R_{\mathrm{Mo}}/R_{\mathrm{W}} = 1$, which is represented by a solid line. In comparison, without the consideration of secondary electron emission effect, using the relation

$$R = \frac{n_{eh}}{n_{ec}} = \frac{I_{eh}}{I_{ec}} \sqrt{\frac{T_{ec}}{T_{eh}}} \; , \qquad (5)$$

the relations between $R_{\mathrm{Mo}}/R_{\mathrm{W}}$ and T_{eh} are depicted by open circles, as shown in Fig. 1. It is seen that, as expected, the open circles agree with $R_{\mathrm{Mo}}/R_{\mathrm{W}} = [1 - \bar{\delta}_{\mathrm{Mo}}(T_{eh})]/[1 - \bar{\delta}_{\mathrm{W}}(T_{eh})]$, which is represented by a broken curve.

In conclusion, an electron temperature T_e can be estimated from a slope of the semi-logarithmic plot of $I_e(V_p)$ and $I_e(V_p)$ is reduced by $1 - \bar{\delta}(T_e)$, where $I_e(V_p)$ is the electron current of a probe biased to V_p.

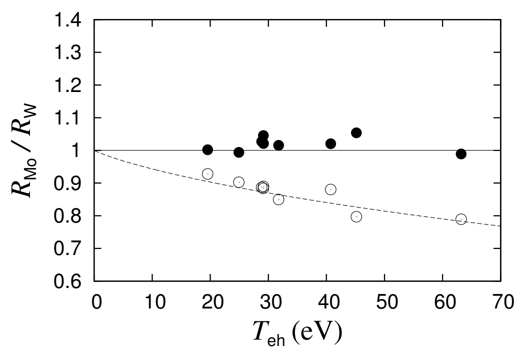

Fig. 1: Relationship between $R_{\mathrm{Mo}}/R_{\mathrm{W}}$ and T_{eh} by closed circles when secondary electron emission effect is considered and by open circles when secondary electron emission effect is not considered. A solid line represents $R_{\mathrm{Mo}}/R_{\mathrm{W}} = 1$ and a broken curve represents $R_{\mathrm{Mo}}/R_{\mathrm{W}} = [1 - \bar{\delta}_{\mathrm{Mo}}(T_{eh})]/1 - \bar{\delta}_{\mathrm{W}}(T_{eh})]$.

1) Langley, R. A., Bohdansky, J., Eckstein, W., Mioduszewski, P., Roth, J., Taglauer, E., Thomas, E. W., Verbeek, H. and Wilson, K. L.: Nucl. Fusion **24** (1984) S9.

2) Tawaraya, T., Tsushima, A., and Yoshimura, S.: *Proc. Plasma Conference 2011* (Kanazawa, Japan, 2011) 22P172-B.