§12. Releasing of Spherical Conducting Dust Particle from Plasma-Facing Wall under Biased Potential

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The releasing conditions of a spherical conducting dust particle from a plasma-facing wall under biased potential is analyzed. A Debye sheath is formed near the wall with a strong electric field and a supersonic ion flow toward the wall, which create forces acting on the dust particle attached to the wall. The total force in our consideration includes the repulsive from the wall electrostatic force as well as the attractive drag force due to ion absorption and scattering, and electrostatic image force due to redistribution of charges on the wall. The ion drag force is obtained using the Orbital Motion Limited (OML) theory [1], which gives the absorption cross section of electrons and ions by the dust particle. The electric and the image force on the dust particle depend on the dust charge. The wall surface charge density and the dust radius R_d determine the charge of the dust particle as following

$$Q_d = -\xi_q \pi R_d^2 \varepsilon_0 E_w, \qquad (1)$$

where E_w is the electric field at the wall surface and ξ_q is the form factor taking into account the effect of redistribution of the dust surface electric field. For the case of the conducting sphere placed on the wall in uniform external electric field, it was shown [2] that the value of the form factor is $\xi_q \approx 6.58$. The dust particle is capable to leave the wall when the total force acting on it is directed from the wall. All the forces are functions of the dust radius and the plasma parameters near the wall. Thus, if the plasma parameters are fixed then the releasing condition can be solved in respect to the dust radius. The solution is

$$R_{c1} = \frac{m_i u_{izw}^2}{\xi_q E_w q_i \ln \Lambda_d}\left[-1 + \sqrt{1 + 4\ln \Lambda_d (\alpha - 1)}\right], \qquad (2)$$

where

$$\alpha \equiv \frac{\xi_q (1 - \xi_q / 16) \varepsilon_0 E_w^2}{m_i n_{iw} u_{izw}^2}, \qquad (3)$$

$\ln \Lambda_d$ is the dust Coulomb logarithm, n_{iw} and u_{iw} are the ion density and flow velocity near the wall, respectively. The non-negative solution (2) exists when $\alpha \geq 1$. We called R_{c1} the first critical dust radius. If the dust particle radius $R_d < R_{c1}$ then the particle will leave the wall, in the opposite case $R_d \geq R_{c1}$, the dust particle will be pined to the wall. The values of the plasma parameters near the biased wall as functions of the sheath potential drop φ_{sh} are obtained using the Bohm sheath model, which assumes vanishing electric field and ion flow velocity equals to the ion sound speed $c_{s0} = \sqrt{T_e / m_i}$ at the sheath edge. The dependence of the α parameter on the sheath potential drop is shown in Fig.1a. As we can see, the condition of the first critical dust radius existence is satisfied, when the sheath potential drop larger than the threshold value $\varphi_{sh,th}$ corresponding to $\alpha = 1$. As shown in the Fig.1b, the first critical dust radius increases from zero at the threshold sheath potential drop to a few Debye lengths for deeper sheath potentials. For the potentials lower than the threshold one no physical solutions for the first critical dust radius exist and the dust particles of any size will be pined against the wall with the ion drag forces. Thus, the region above the curve in the Fig.1b corresponds to the pinned dust particles, and the region below the curve corresponds to the particles sizes and the sheath potentials when the dust particles can be released from the wall.

The externally applied voltage to the wall allows to control the sheath potential drop. Therefore, the first critical dust radius and the threshold potential are the functions of the externally applied voltage. It shows the possibility to control the size of the released dust particles or even suppress the dust releasing from the wall when the wall potential is below the threshold value.

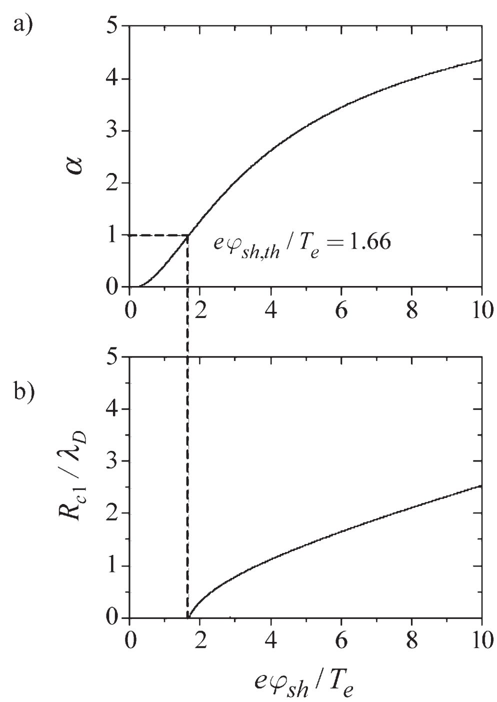

Fig. 1. The dependence of the parameter α (a) and the first critical dust radius R_{c1} (b) on the sheath potential drop φ_{sh} in the Bohm sheath model. Here the parameters $\xi_q = 6.58$ and h $\Lambda_d = 3$.

Reference

1) Allen, J.E., Physica Scripta **45**, (1992) 497
2) Lebedev, N.N., and Skalskaya, I.P., Z. Tech. Phys. **32**, (1962) 375 (in russian)