§13. Effect of Gravity on Releasing of Spherical Conductive Dust Particle from Plasma-Facing Wall

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The effect of the gravity on the first critical dust radius is clarified. The gravitational force acting on the dust particle can be arbitrary depending on the wall orientation to the horizontal. We consider two limiting cases: the bottom position of the horizontal wall and its upper position. Then the gravitational force acting on the solid spherical dust particle is $F_g = \pm\frac{4}{3}\pi R_d^3 \rho_d g$, where ρ_d is the mass density of the dust particle, and g is the free fall acceleration. The plus sign means the gravitational force directed toward the wall and the minus sign means from the wall direction. The solutions of the first critical radius accounting the gravitational force was found as

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

where

$$\Delta_g = \frac{8}{3\sqrt{2}\,\xi_q}\left(\frac{1+2e\varphi_{sh}/T_e}{\sqrt{1+2e\varphi_{sh}/T_e + e^{-e\varphi_{sh}/T_e} - 2}}\right)^{1/2}\delta_g , \quad (2)$$

and the dimensionless gravitational parameter δ_g is defined as following

$$\delta_g \equiv \frac{\rho_d g\, \varepsilon_0^{1/2}}{e n_0^{3/2} T_e^{1/2}} . \quad (3)$$

Here n_0 is the plasma density and T_e is the electron temperature. As we can see from (1), the condition for the first critical dust radius existence, $\alpha \ge 1$, is not modified. Hence, the gravitational force does not affect the threshold sheath potential drop.

For the positive direction of the gravitational force, the first critical radius and the region of released dust particles decrease with increasing of the gravitational parameter. As shown in the Fig.1, when the gravitational parameter $\delta_g < 1$ the first critical dust radius is practically unaffected by the gravity and for $\delta_g > 10$ the first critical radius is inversely proportional to δ_g.

In the case of the gravitational force directed from the wall the first critical radius (1) can have two positive solutions depending on the gravitational parameter. In this case, the released dust particles have radii in between the two solutions. In Fig.2a two regions of the released dust particles for the values of the gravitational parameter $\delta_g < 2.302$ are shown that are merged when $\delta_g > 2.302$ (Fig.2c). For the specific value of the gravitational parameter $\delta_g \approx 2302$ the regions of released and pinned dust particles can be clearly seen (Fig.2b), where the indicated forces are dominant. Thus, the releasing of dust particles from the wall was described for any gravity conditions and wall potential values allowing to predict and control the size of released particles. The self-consistent effect of dust shielding in plasma will also be considered in future.

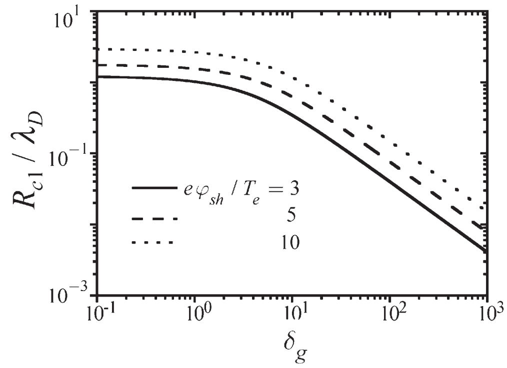

Fig. 1. The dependence of the first critical dust radius on the gravitational parameter δ_g for the gravitational force directed toward the wall.

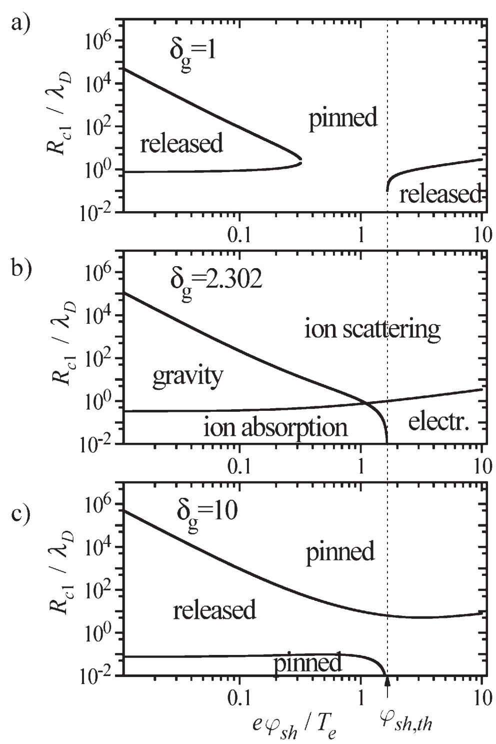

Fig. 2. The first critical dust radius R_{c1} as a function of the sheath potential drop φ_{sh} for the gravitational force directed from the wall.