DOI: 10.34854/ICPAF.52.2025.1.1.214

CALCULATION OF CHARGED PARTICLE FLUXES ONTO THE METAL FROM A PLASMA AT A NEGATIVE POTENTIAL OF THE METAL *)

Ivanov V.A., Tereshchenko M.A., Konyzhev M.E., Kamolova T.I., Dorofeyuk A.A.

Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, 119991 Russia, ivanov@fpl.gpi.ru

The effect of plasma on metals is used in a number of technological processes, such as cleaning metals from surface contaminants, structure modification of the surface layers of the metal, and formation of a durable microrelief of the metal surface. For stable reproducibility of these processes, methods for calculating the flows of electrons and ions from the plasma onto the metal are required, at different values of the electric potential Ψ_0, since the established balance of particle flows near the metal surface leads to the emergence of a region of charge separation and an electric field, the value of which determines the occurrence of such strong phenomena as explosive emission and the formation of microplasma discharges [1, 2]. The objectives of the work are to determine the main processes in a plasma that form flows of charged particles onto the metal and to calculate the values of flows both onto the metal and in the entire charge separation region near the metal, as well as in unperturbed plasma. Non-isothermal homogeneous plasma along the metal surface is considered, along the normal to the surface of which (the *OX* axis) the charge separation region is formed, where the flows are calculated. The calculations take into account the force F_e, acting on electrons with temperature T_e due to the presence of an electric potential gradient $\Psi(x)$ in the plasma, and the force F_g, caused by the plasma density gradient $n_e(x)$, while particle collisions in the plasma are not taken into account:

$$F_e = -e\frac{\partial \Psi}{\partial x}; \quad F_g = -\frac{T_e}{n_e}\frac{\partial n_e}{\partial x} . \tag{1}$$

In the absence of both ionization of the background gas and recombination of charged particles, an equation for the average velocity of the electron flow u_e, is obtained, taking into account the processes in the plasma layer adjacent to the metal:

$$u_e\frac{\partial u_e}{\partial x} = -\frac{e}{m_e}\frac{\partial \Psi}{\partial x} - \frac{T_e}{m_e n_e}\frac{\partial n_e}{\partial x} . \tag{2}$$

When the plasma particle flux is maintained at a constant level $\frac{\partial}{\partial x}\left[n_e(x)u_e(x)\right] = 0$, and when $T_e >> m_e u_e^2$, from the equation (2) at a fixed metal potential Ψ_0 the following relation follows: $n_{em}/n_{e0} = \exp\left(-e\Psi_0/T_e\right)$, where n_{em} is the electron density near the metal surface, n_{e0} is the density of undisturbed plasma. The magnitude of the electron flow from the plasma to the metal $(n_e u_e)_m$ will be determined by the expression:

$$(n_e u_e)_m = n_{e0}\left(\frac{T_e}{2\pi m_e}\right)^{1/2} \exp\left(-\frac{e\Psi_0}{T_e}\right) . \tag{3}$$

References

[1]. A.S. Sakharov and V.A. Ivanov, “Field emission as a mechanism for initiating microplasma discharges on a metal in a plasma flow”, Usp. Prikl. Fiz. 4 (2), 150 (2016) [in Russian]. https://advance.orion-ir.ru/UPF-16/2/UPF-4-2-150.pdf

[2]. V.A. Ivanov, M.E. Konyzhev, M.A. Tereshchenko, A.A. Dorofeyuk, T.I. Kamolova and S.N. Satunin Electric field on the surface of a metal electrode with dielectric film in plasma // Plasma Physics Reports, 2024, Vol. 50, No. 7, pp. 856-865. DOI: 10.1134/S1063780X24601056

*) abstracts of this report in Russian