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GAS DISCHARGE PLASMA DISTURBANCE BY ELECTRON EXTRACTION

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The main physical processes providing the extraction of electron current from gas-discharge plasma were studied by A.V. Zharinov with collaborators /1/. However, these works are not concerned with the disturbance of emission gas-discharge plasma by electron current extraction from it with rather high efficiency $\alpha \sim 1$ (α – the ratio between emission current and discharge current). This work deals with the possible mechanism of emission plasma disturbance.

In the absence of extraction voltage plasma can only be left by high-energy electrons capable of overcoming potential barrier caused be potential drop near the wall (wall potential drop). With the decrease of potential barrier in the extraction area (with the increase of extraction potential) the number of electrons emitted by plasma is increased. With this plasma potential increases and electric fields are formed in plasma volume. As a result the intensity of ionization processes increase that leads to the change (disturbance) of the whole discharge into the state with new values of discharge current and plasma potential. Such a gas-discharge system with an acceleration gap and extraction electrode can be regarded as a unified gas-discharge structure with two energy source – those of discharge power and extraction voltage. The average energy removed by electrons from plasma onto the anode of a discharge chamber (index *a*) and onto the extraction electrode (electron beam, index *em*) can be estimated in the following way: 1) in the absence of electron extraction: W_0; 2) with extraction through the potential barrier W_{1a} and W_{1em}; 3) with extraction from the «open» (without potential barrier) plasma border W_{2a} and W_{2em}

$$W_0 = T_e\left(2 + \frac{e\Delta\varphi_p^0}{T_e}\right)N_0;\ W_{1a} = T_e\left(2 + \frac{e\Delta\varphi_p^1}{T_e}\right)N_{1a};\ W_{1em} = T_e\left(2 + \frac{e\left(\Delta\varphi_p^1 - V_z\right)}{T_e}\right)N_{1em};$$

$$W_{2a} = T_e\left(2 + \frac{e\Delta\varphi_p^2}{T_e}\right)N_{2a};\ W_{2em} = 2T_eN_{2em}.$$

$\Delta\varphi_p^0$, $\Delta\varphi_p^1$, $\Delta\varphi_p^2$ – potential differences in the layer in the absence of extraction through the potential barrier and with extraction from the «open» plasma surface (index 0, 1, 2 correspondingly) that can be determined from the condition of current balance in discharge (S_c, $(1-f)S_a$, fS_a – the areas of cathode, anode and emission plasma surface correspondingly):

$$\Delta\varphi_p^0 = -\frac{T_e}{e}\ln\left[0{,}2\frac{(1+\gamma)S_c+S_a}{S_a}\sqrt{\frac{\pi m_e}{m_i}}\right];\ \Delta\varphi_p^1 = -\frac{T_e}{e}\ln\left[0{,}2\frac{(1+\gamma)S_c+S_a}{1-f+f\exp\left(\frac{eV_z}{T_e}\right)}\sqrt{\frac{\pi m_e}{m_i}}\right]$$

$$\Delta\varphi_p^2 = -\frac{T_e}{e}\ln\left[0{,}2\frac{(1+\gamma)S_c+S_a}{S_a(1-f(V_z))}\sqrt{\frac{\pi m_e}{m_i}}-\frac{f(V_z)}{1-f(V_z)}\right].$$

The number of electrons leaving plasma in the given cases (according to the introduced indexes) can be determined by the equations

$$N_0 = n\upsilon_T S_a\exp\left(-\frac{e\Delta\varphi_p^0}{T_e}\right);\ N_{1a} = \frac{i_a}{e} = n\upsilon_T S_a(1-f)\exp\left(-\frac{e\Delta\varphi_p^1}{T_e}\right);$$

$$N_{1em} = \frac{i_{1em}}{e} = n\upsilon_T fS_a\exp\left(-\frac{e(\Delta\varphi_p^1-V_z)}{T_e}\right);\ N_{2a} = \frac{i_a}{e} = n\upsilon_T S_a(1-f(V_z))\exp\left(-\frac{e\Delta\varphi_p^2}{T_e}\right);$$

$$N_{2em} = \frac{i_{2em}}{e} = n\upsilon_T S_a f(V_z),$$

where the function $f(V_z)$ shows the dependence of emission plasma surface area upon extraction electrode potential when extraction take place from the «open» plasma surface /1/, υ_T – thermal plasma electrons speed.

The removed energy part from the discharge by plasma electrons with any V_z can be presented as the function:

$$\xi = \begin{cases}\xi_1, если V_z < \Delta\varphi_p^1\\ \xi_2, если V_z > \Delta\varphi_p^2\end{cases},\quad \xi_{1,2} = \frac{W_{1,2a}+W_{1,2em}}{W_0} \tag{1}$$

$$\xi_1 = (1-f)\frac{2+\frac{e\Delta\varphi_p^1}{T_e}}{2+\frac{e\Delta\varphi_p^0}{T_e}}\frac{1}{1-f+f\exp\left(\frac{eV_z}{T_e}\right)} + f\frac{2+\frac{e}{T_e}\left(\Delta\varphi_p^1-V_z\right)}{2+\frac{e}{T_e}\Delta\varphi_p^0}\frac{\exp\left(\frac{eV_z}{T_e}\right)}{1-f+f\exp\left(\frac{eV_z}{T_e}\right)} \tag{2}$$

$$\xi_2 = \frac{\left(1-f(V_z)\right)\exp\left(-\frac{e\Delta\varphi_p^2}{T_e}\right)\left(2+\frac{e\Delta\varphi_p^2}{T_e}\right)+2f(V_z)}{\left(2+\frac{e\Delta\varphi_p^0}{T_e}\right)\exp\left(-\frac{e\Delta\varphi_p^0}{T_e}\right)}. \tag{3}$$

It follows from (2) that with $0 < V_z < \Delta\varphi_p$ the inequality $\xi_1 \le 1$ is true and from (3) with $V_z > \Delta\varphi_p^2$ is true $\xi_2 \le 1$. It means that due to discharge change caused by the local electron extraction plasma receives additional energy owing to the