Simulation of Triode High Voltage Glow Discharge Electron Sources With Taking Into Account The Anode Plasma Parameters

I.V. Melnyk [1]

[1] *National Technical University of Ukraine "Igor Sikorsky KPI", Electronic Faculty, Electronic Devices Department, Kyiv, Ukraine*

This paper is devoted to describing the algorithm of simulation of triode high voltage glow discharge electron sources with including into consideration the parameters of anode plasma, such as the temperature and mobility of plasma electrons. For calculation of anode plasma parameters estimated relations for high voltage glow discharge have been used. The distinctive feature of proposed methodic of calculation is using of iterative algorithm, which allows to provide the calculations till obtaining the equilibrium between the force of electric field in the cathode-fall region and the force formed by the pressure of electron gas in anode plasma. Obtained results are very important to the experts in the industrial application of modern electron beam technologies.

1. Introduction

High Voltage Glow Discharge Electron Sources (HVGDES) are widely used in industry today for realizing complex technological operations of modern electron beam technology [1 – 3]. For effective control the stability of current of high-voltage glow discharge in such electron sources with low time-constant additional low-voltage discharge is used [4]. In the paper [4] the methodic of calculation of High Voltage Glow Discharge (HVGD) time parameters, based on defining of anode plasma distance through estimation the level of gas ionization by the fast beam and slow plasma electrons, as well as on the equation of discharge self-maintained, have been proposed. But main disadvantage of this method is necessity of using for such calculations important data about the temperature of electron gas in anode plasma and about mobility of electrons in it.

The improved iteration methodic of calculation of anode plasma parameters is proposed in this report.

2. Method of iterative calculation of the temperature and mobility of electron gas

For calculation the temperature of electron gas and mobility of electrons in anode plasma such estimative equations were used [5]:

$$T_e = \frac{eU_{ac}}{2k}\left[1+\sqrt{1+\frac{\pi e^2 m_i}{6m_e}\left(\frac{U_{ac}d_{cp}}{p_{a0}\overline{Q_{ea}}}\right)^2}\right], \qquad (1)$$

$$d_{cp} = \frac{p_{a0}\overline{Q_{ea}}}{U_{ac}}\sqrt{\frac{6m_e}{\pi e^2 m_i}\left(\left(\frac{2kT_e}{eU_c}-1\right)^2-1\right)}, \quad \mu_e = \frac{ap_{a0}d_{cp}}{U_{ac}}+b\,.$$

where T_e – temperature of electrons, μ_e – its' mobility, U_{ac} – acceleration voltage, d_{cp} – distance from the cathode to anode plasma, p_{a0} – residual pressure in the discharge gap, k – Boltzmann constant, $\overline{Q_{ea}}$ – average cross-section of dissipation of electrons on the atoms of residual gases, U_c – control voltage, a, b – empiric constants [4, 5].

Iterative calculation of plasma boundary position by the equation (1) and by the equations, obtained in paper [4], was provided, till the value of cathode-plasma distance dcp became equal in the both variant of calculations. Obtained calculation results for energetic efficiency of electron sources with considering nitrogen as operation gas for different values of control voltage are presented at Fig.

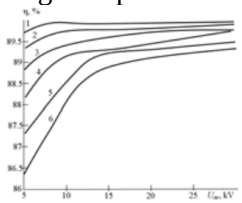

Fig. Calculated dependences of energetic efficiency of HVGDES on different acceleration voltage and control voltage: 1 – U_c = 80 V, 2–U_c = 70 V, 3 – U_c = 60 V, 4 – U_c = 50 V, 5 – U_c = 40 V, 6 – U_c = 30 V; p_{a0} = 0,5 Pa

3. Conclusion

Obtained results are mostly similar to presented in paper [4], difference nearly 15 – 20% is observed for the small and high values of control voltage. Therefore the main advantage of proposed iteration methodic is absence the reference to empirical data about the thermodynamic parameters of electron gas in anode plasma from the manuals [1, 5], which can be incorrect usually and must be strongly verified

3. References

[1] Novikov A.A. "High Voltage Glow Discharge Electron Sources With Anode Plasma", Moscow, "Energoatomizdat", 1983 (in russian).

[2] Feinaeugle P., Mattausch G., Schmidt S., Roegner F.H., Society of Vacuum Coaters, 54-th Annual Technical Conference Proceedings, Chicago, pp. 202–209, 2011.

[3] Mattausch G., Zimmermann B., Fietzke F., Heinss J.P., Graffel B., Winkler F., Roegner F.H., Metzner C., "Elektrotechnica and Electronica (E+E)", vol. 49, № 5-6, pp. 183–195, 2014.

[4] Melnik I.V., Radioelectronics and communication systems, Vol. 56, # 12, pp. 51 – 61, 2013.

[5] Raizer Yu.P. "Physic of Gas Discharge", Moscow, Nauka, 1987. (in russian).