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PLASMA-BEAM PROCESSES

Emission Current Formation in Plasma Electron Emitters

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Abstract—A model of the plasma electron emitter is considered, in which the current redistribution over electrodes of the emitter gas-discharge structure and weak electric field formation in plasma are taken into account as functions of the emission current. The calculated and experimental dependences of the switching parameters, extraction efficiency, and strength of the electric field in plasma on the accelerating voltage and geometrical sizes of the emission channel are presented.

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1. INTRODUCTION

In the mid-20th century, the development of electron beam technologies stimulated the study of devices alternative to thermal-emission guns in which gas discharges were used to generate high-energy electron beams [1]. The largest practical advances were achieved in the study of three main methods for generating high-energy electron beams, i.e.,

(i) electron beams produced in a high-voltage discharge (HVD),

(ii) ion–electron emission in a high-voltage glow discharge (HVGD), and

(iii) electron emission from low-voltage discharge (LVD) plasma followed by electron acceleration [1].

The relation of the beam current to other parameters (voltage, pressure) in devices with HVD is presented by the theory of high-voltage discharge with a hollow cathode and a main potential drop in the anode region of the discharge gap [1]. Similar dependences in devices with HVGD are presented by the theory of high-voltage discharge with a main potential drop in the near-cathode region [1].

To describe the processes of electron current switching from LVD to the accelerating gap, the plasma probe theory was adapted by Zharinov and Kovalenko [2] for the first time. In this paper, the two-electrode model of a plasma generator with electron emission from plasma to the accelerating gap through an anode hole was considered. It is assumed that charged particle motion in plasma is collisionless. The ratio of the density of the thermal electron current j_T to the current density j_a to the anode was assumed to be much greater than unity in order of magnitude, which corresponds to the horizontal shape of the current–

reach unity at the plasma emission surface area S_e much smaller than the anode area S_a. Moreover, the condition was formulated, under which acceleration of electrons emitted from plasma can be implemented,

$$G\frac{S_e}{S_e+S_a} \le 1, \text{ where } G \approx \frac{j_T}{j_a}. \qquad (1)$$

An important methodological significance of this study by Zharinov [2] is that it was first noted the need to consider the state of near-wall layers in the emitting plasma generator (see condition (1)) when analyzing the efficiency of electron current switching to the emission channel.

In the paper by Ul'yanov and Filippov [3], it was proposed to consider the current redistribution to plasma generator electrodes in the plasma emitter due to restructurization of near-wall layers, taking into account corresponding switching coefficients. However, switching mechanisms in ion and electron plasma emitters can differ significantly.

For practical LVDs, the shape of their I–V characteristics usually differs significantly from the horizontal one, i.e., the plasma emissivity is not infinite. In this case, we can assume that electron extraction from plasma can cause its perturbation and the restructurization of near-wall layers bounding it at plasma generator electrodes. Moreover, in the case of LVDs, emitting plasma generators contain a larger number of electrodes than the simplest gas-discharge gap (cathode and anode), and electrons are emitted through an emission channel whose geometrical sizes have a decisive effect on electron emission. Therefore, each par-