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METHODS FOR STABILIZING THE ELECTRON BEAM CURRENT IN SOURCES WITH A PLASMA CATHODE AND ANODE BASED ON THE LOW-PRESSURE ARCH DISCHARGE *)

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Electron sources with plasma cathodes are widely used in science and technology [1]. Such sources, regardless of the type of discharge used to generate emission plasma in the plasma cathode, use beam current stabilization systems. In the case of continuous electron sources, the stabilization system makes it possible to achieve the ripple factor of beam current at the level of a few percent. But when switching to pulsed beams with a pulse duration of the order of hundreds of microseconds or even less, the beam current stabilization system is a separate complex technical solution, since it must have the maximum possible depth of the feedback loop and work out instabilities in a time much shorter than the duration of the beam current pulse, i.e., provide a feedback frequency of the order of 1 MHz, which can be very difficult and expensive solution. Stabilization of the beam current for pulsed sources is especially important when it comes to controlling the beam power to form the required temperature field in the surface of the workpiece, for example, when generating modulated electron beams [2, 3].

This paper discusses methods for introducing self-consistent feedback in electron sources [4] with plasma cathodes based on a low-pressure arc discharge with grid stabilization of the emission plasma boundary and a plasma anode with an open plasma boundary. Both the vacuum case and the plasma-filled accelerating gap are considered, the anode plasma in which is generated by the electron beam itself, and the concentration of which depends on the beam generation conditions (accelerating voltage, beam current density, gas pressure, magnitude and configuration of the leading magnetic field, etc.). In this case, one of the destabilizing factors is the change in generation conditions during a submillisecond beam current pulse. Methods for increasing the depth of feedback through the use of operational amplifiers are proposed.

It is shown that the use of negative feedback in such systems with respect to the ion flux into the plasma emitter from the accelerating gap makes it possible to ensure the reproducibility of generation modes and the repeatability of the processes of beam action on the surface of metallic materials.

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References

[1]. E. Oks. Plasma Cathode Electron Sources: Physics, Technology, Applications. WILEY-VCH. (2006). 171 p.

[2]. M. Vorobyov, T. Koval, V. Shin, P. Moskvin, My Kim An Tran, N. Koval, K. Ashurova, S. Doroshkevich, M. Torba. Controlling the Specimen Surface Temperature During Irradiation With a Submillisecond Electron Beam Produced by a Plasma-Cathode Electron Source. IEEE Transactions on Plasma Science. – 2021. – V. 49. – No. 9. – P. 2550 – 2553.

[3]. M.S. Vorobyov, N.N. Koval, P.V. Moskvin, A.D. Teresov, S.Yu. Doroshkevich, V.V. Yakovlev, V.I. Shin. Electron beam generation with variable current amplitude during its pulse in a source with a grid plasma cathode. Journal of Physics: Conference Series 1393 (2019) 012064, doi:10.1088/1742-6596/1393/1/012064.

[4]. N.N. Koval, S.V. Grigoryev, V.N. Devyatkov, A.D. Teresov and P.M. Schanin. Effect of Intensified Emission During the Generation of a Submillisecond Low-Energy Electron Beam in a Plasma-Cathode Diode. IEEE Transactions on plasma science. – 2009. – V. 37, No. 10. – P. 1890 – 1896.

*) abstracts of this report in Russian