Microcrater formation model under cathode spot plasma of a vacuum arc

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A semiempirical hydrodynamic model based on the cellular structure of the cathode spot of a vacuum arc has been developed to describe the formation of a microcrater on the cathode under dense cathode spot plasma. In the context of a 2D axisymmetric problem statement of charge, heat, and mass transfer in a cathode, the formation of a crater on a copper cathode has been simulated. It has been shown that for the cell current ranging between 1.6 and 7 A and the time of current flow through a cell ranging between 15 and 60 ns, the crater diameter is 3–7 µm. In these cases, the current density at the center of a cathode spot cell is ~10^{12} A/m^2, and the average current density in a cell, determined using the crater diameter, is ~10^{11} A/m^2. The obtained results are in agreement with experimental data on the crater size, cathode spot lifetime, and cathode spot current density at near-threshold arc currents.

1. Introduction

According to numerous observations, any vacuum arc track on a cathode has a substructure of microcraters. Based on these observations, the ecton mechanism of the operation of a cathode spot (CS) was proposed [1]. The CS comprises an active area of a cathode, heated to above its melting temperature, and the adjacent dense CS plasma. The ecton model assumes a cyclic operation of individual CS cells having micrometer spatial dimensions and lifetimes of several tens of nanoseconds. Recently, some advances have been made in the theoretical study of the role of the liquid-metal phase in the initiation and operation of a CS cell [2–4].

2. Model description and Results

In the context of a 2D axisymmetric statement of the problem of the charge, heat, and mass transfer in a cathode, a semiempirical hydrodynamic model has been developed to describe the formation of a microcrater and the initial stage of the formation of liquid-metal jets in a cell of the cathode spot of a vacuum arc. The model includes experimentally obtained characteristics of the cathode spot plasma interacting with the cathode, such as the pressure exerted by the plasma on the cathode and the power dissipated in the cathode. The crater formation has been simulated for a copper cathode at a constant CS cell current. It has been shown that for the cell current ranging between 1.6 and 7 A and the time of current flow through the cell ranging between 15 and 60 ns, the crater diameter is 3–7 µm. The simulation predicted the maximum current density in the cell center equal to (1–3)·10^{12} A/m^2 for all calculation variants where the formation of a micrometer-size crater took several tens of nanoseconds. The mean current density in the cell determined in terms of the crater diameter is an

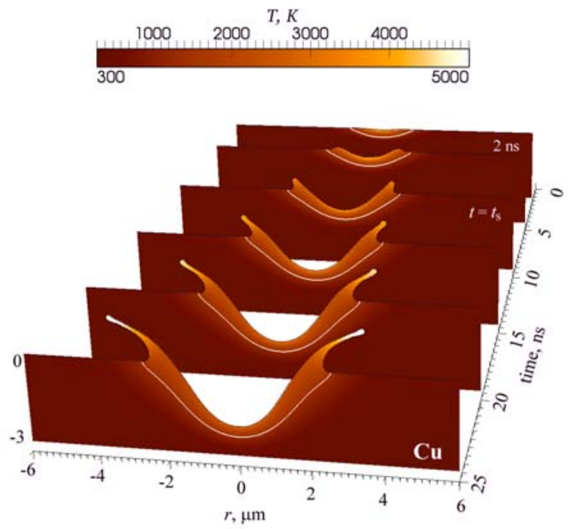

Fig. 1. Results of the numerical simulation of the micro-crater formation (Cu, i_c = 3.2 A, r_0 = 0.8 μm).

order of magnitude lower, ~10^{11} A/m^2. These results are in agreement with experimental data [1] on the crater size, cathode spot lifetime, and cathode spot current density at near-threshold arc currents.

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3. References

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