MODELING NEAR-CATHODE PLASMA LAYER ON CONTACTS OF VACUUM ARCS*

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A model of near-cathode layers in vacuum arcs is developed. The model relies on a numerical solution of the problem of near-cathode space-charge sheath with ionization of atoms emitted by the cathode surface[1] and allows one to self-consistently determine all parameters of the near-cathode layer, including the ion backflow coefficient, as functions of the local surface temperature T_w and the near-cathode voltage U. Evaluation results are given for Cu and CuCr cathodes.

The dependence of the density of energy flux from the plasma to the cathode surface on T_w for fixed U is shown to be non-monotonic with a maximum. This feature stems from the fact that the ion heating of the cathode grows faster than the electron emission cooling at lower T_w and vice versa at higher T_w. This feature is very important theoretically and suggests that spots on cathodes of vacuum arcs may appear due to thermal instability developing in the cathode body and that stationary regimes of cathode spots in vacuum arcs are possible, similarly to what happens in the theory of cathode spots in high-pressure arc discharges.

The developed model may be used for a variety of purposes, including as a module of complex non-stationary 2D and 3D numerical models of plasma-cathode interaction. As a simple example, an analytical evaluation of parameters of stationary spots on copper and chromium is performed in this work. In the case of composite CuCr contacts with large grains, spots with current of several tens of amperes burning on the copper matrix coexist with spots with current of the order of one ampere burning on the chromium grains. This conclusion conforms to high-resolution photographs[2] of high-current arcs between copper-chromium contacts taken at exposure times of 2μs, which revealed cathode spots with the average current of 45A similar to those on pure-copper cathodes, as well as very small and dim spots.

1. M. S. Benilov and L. G. Benilova, “The double sheath on cathodes of discharges burning in cathode vapour”, J. Phys. D: Appl. Phys., vol. 43, No. 34, pp. 345204-1-12, 2010.
2. W. Hartmann, A. Lawall, R. Renz, M. Romheld, N. Wenzel, and W. Wietzorek, “Cathode spot dynamics and arc structure in a dense axial magnetic-field-stabilized vacuum arc”, IEEE Trans. Plasma Sci., vol. 39, No. 6, pp. 1324−1329, 2011.

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