PHYSICS OF SPOTLESS MODE ON CATHODES OF METAL VAPOR ARCS*

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It is well known that current transfer to cathodes of arc discharges in ambient gases may occur in the spot mode, where most of the current is localized in narrow domains, or current spots, occupying a small fraction of the cathode surface, and in the diffuse, or spotless, mode, where the current is distributed over the front surface of the cathode in a more or less uniform way. The diffuse mode is favored by high average temperature of the cathode surface, which can be achieved by reducing the cathode dimensions.

Spots on cathodes of vacuum, or metal vapor, arcs are known equally well. The spotless mode of current transfer to cathodes of vacuum arcs seems to be known not so well, however its existence has been firmly established by now. Similarly to the diffuse mode on cathodes of ambient-gas arcs, the spotless mode on cathodes of vacuum arcs occurs in cases where the average temperature of the cathode surface is high enough, usually around 2000 K. Being one-dimensional in nature and quasi-stationary, this mode is a much easier object for experimental and theoretical investigation than cathode spots. In addition to being of interest due to potential applications, such investigation will also advance understanding of cathode spots in vacuum arcs. Unfortunately, experimental results on the spotless mode are difficult to explain theoretically.

A fresh attempt to do so is undertaken in this work. The analysis is performed both on qualitative and quantitative levels. It is shown that in the case of chromium cathode the current transfer to the cathode may be ensured by ambipolar diffusion of ions from the quasi-neutral plasma, while the electron emission and, consequently, the energy input into the near-cathode space-charge sheath play minor roles. In essence, this regime is similar to the ion saturation regime of operation of electrostatic probes. In the case of gadolinium cathode, the current transfer may be ensured by thermionic emission. This regime is similar to the usual regime of current transfer to cathodes of arc discharges, except that the ion current is negligible and the cathode is heated by radiation from the plasma. There is a very significant input of energy into the sheath, which gives rise to much higher values of the electron temperature than those in the case of Cr cathode and to the appearance of multiply charged ions, in agreement with the experimental results published recently.

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