Cathode spots in DC arc and glow discharges: self-organization phenomena

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The existence of multiple modes of current transfer to electrodes of gas discharges is rather the rule than the exception. In particular, it has been known since the early 1950s that steady-state current transfer to cathodes of high-pressure DC arc discharges can occur in the diffuse mode, where the current is distributed over the front surface of the cathode in a more or less uniform way, or in the spot mode, where most of the current is localized in a small area (cathode spot). Similarly, it has been known for many decades that steady-state current transfer to cathodes of DC glow discharges can occur in the abnormal mode or in the mode with a normal spot. Recently, also modes with steady-state patterns of more than one spot have been observed (e.g., [1] and references therein).

Diffuse and spot modes of steady-state current transfer to cathodes of high-pressure arc discharges are of considerable scientific interest and of critical importance for design of a number of technical devices, such as high-intensity discharge (HID) lamps. The existence of different modes has been under intensive theoretical investigation for several decades; however, self-consistent theoretical models started to emerge only in the 1990s, after it has been realized that different steady-state modes of current transfer represent self-organization phenomena and as such are intimately related to existence of multiple steady-state solutions existing at the same discharge current, that must be admitted by an appropriate theoretical model. By now, such multiple solutions have been found and investigated in detail and a universally recognized theory has been developed along these lines and validated by detailed experiments; e.g., review [2] and references therein. As far as cathodes of DC glow discharges are concerned, 2D simulations (e.g., [3] and references therein) revealed only one steady-state solution, which describes the abnormal discharge at high currents and the normal discharge at lower currents. This solution is qualitatively different from the classic von Engel and Steenbeck (1D) solution (it predicts the normal mode where the unstable mode associated with the falling section of the CVC is predicted by the von Engel and Steenbeck solution), and such difference suggests that the whole picture is still incomplete: other solutions should exist for the same discharge current. Another indication in the same direction is the existence of patterns with more than one spot [1]. Such multiple solutions have just started to appear [4].

Although physical mechanisms of current transfer to hot (arc) and cold (glow) cathodes of DC discharges are very different, the overall patterns of self-organization leading to appearance of multiple modes are remarkably similar. This allows one to develop a unified treatment of both phenomena. Such treatment is a subject of the present work.

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