SELF-CONSISTENT MODELLING OF SELF-ORGANIZATION ON DC GLOW CATHODES

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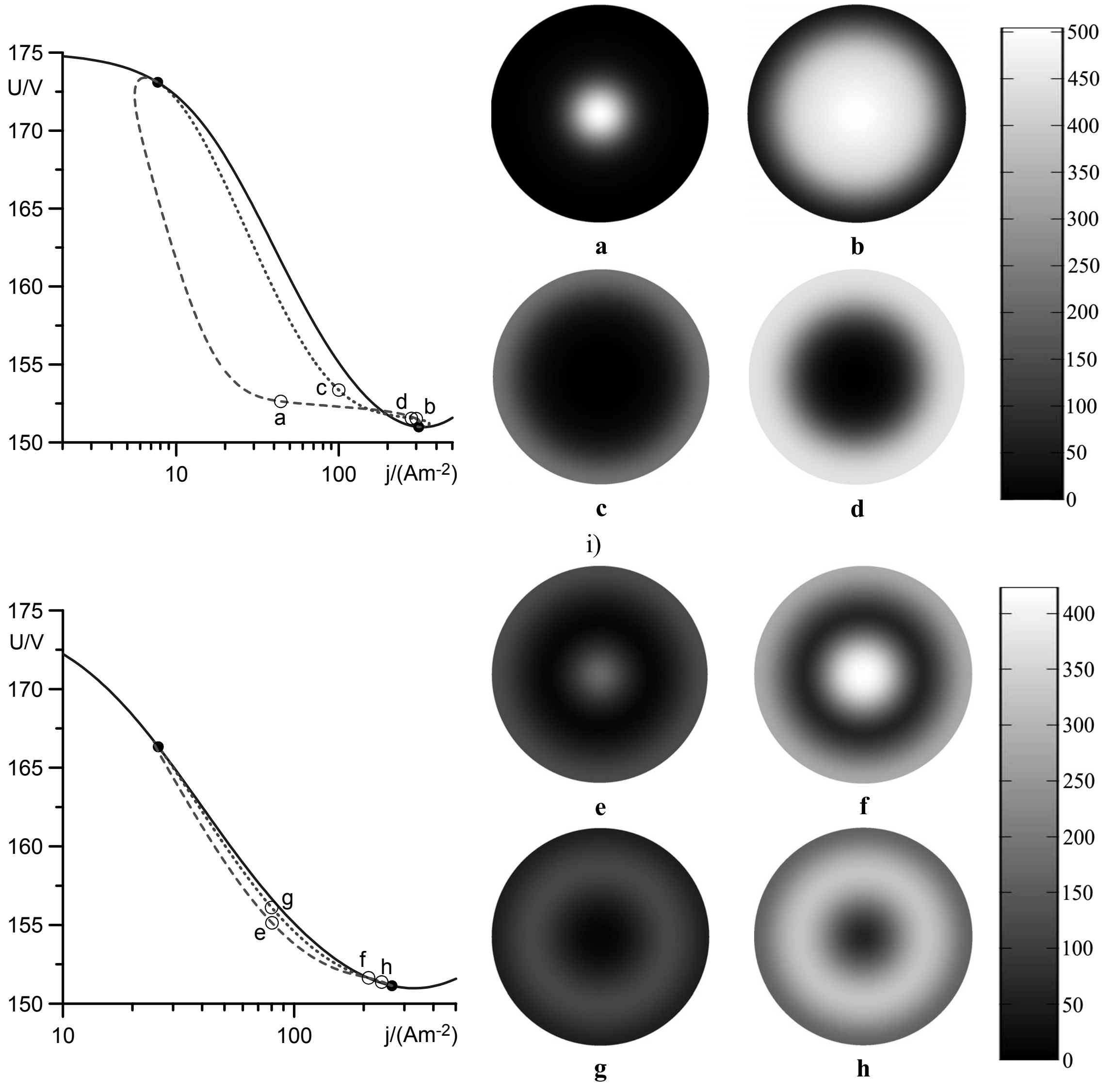
It is well known that current transfer to cathodes of DC glow discharges can occur in the abnormal mode or in the mode with a normal spot. This leads to a suggestion [1] that a self-consistent theoretical model of a near-cathode region in a DC glow discharge admits multiple steady-state solutions describing different modes. As indicated in [2], this hypotheses allows one to explain also recent observations of steady-state patterns of more than one spot, reported in [3-5]. A bifurcation analysis [6] has shown that multiple steady-state solutions must exist even in the framework of the most basic self-consistent model of glow discharge, which takes into account a single ion species and assumes motion of the ions and the electrons to be dominated by drift, neglecting more complex effects as the presence of multiple ion and neutral species with a complex chemistry or a nonlocal electron energy distribution. In the present work, multiple steady-state solutions are calculated for the first time.

In this work the simplest self-consistent DC glow discharge model is treated, which comprises a conservation equation for electrons, a conservation equation for a single ion species, and the Poisson equation. The processes considered for charged particle production and decay are electron impact ionization and dissociative recombination. The temperatures of the charged particles are assumed given and uniform throughout the discharge.

The above stated problem admits 1D, 2D and 3D solutions [1, 6]. In the present work the 1D and several 2D solutions are found by means of the commercial software COMSOL Multiphysics. As an example, we present here axially symmetric results for a xenon 30 Torr cylindrical glow discharge with parallel plate electrodes. The radius and height of the discharge vessel is 0.5 mm.

The figure shows graphs of the current-voltage characteristics (CVC) of the 1D solution and of several 2D solutions. (*j* is the average current density in a circular cross section of the discharge.) The images on the right-hand side of the graphs represent the current density distribution on the cathode surface. The 1D CVC is the well-known Von Engel and Steenbeck solution, see e.g. [7], which describes states corresponding: to the Townsend discharge at very low currents; to the falling part of the CVC, which is unstable and does not realize; and to the abnormal glow discharge regime, for which the CVC is rising. The CVCs for the 2D solutions describe states corresponding to: 1) the normal discharge mode (a, b); 2) the mode with a ring-spot at the edge of the cathode (c, d); 3) the mode with a spot in the center of the cathode and a ring spot at its edge (e, f); and 4) the mode with a ring-spot on the cathode (g, h).



i)

ii)

Fig. 1 Full line: CVC of 1D solution. Dashed line: normal spot mode (i), and mode with a spot in the center of the cathode and a ring spot at its edge (ii). Doted line: mode with a ring-spot at the edge of the cathode (i), and mode with a ring-spot (ii). The images represent the current density distribution over the cathodic surface. The grayscale bar is in A m^{-2}. Full circles: bifurcation points; open circles: points corresponding to the images of the cathodic surface.

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