Modelling self-organization in dc glow microdischarges with the use of COMSOL Multiphysics

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Abstract
Stationary self-organized patterns of cathodic spots have been observed in DC glow microdischarges in xenon; e.g., [1]. Recently, such patterns have been obtained in the numerical modelling [2]: multiple steady-state solutions have been found for the same discharge current, some of these solutions describing modes with a normal spot and other describing modes with several spots which are qualitatively similar to those observed in the experiment and fit into the general pattern of self-organization in near-electrode regions [3].

A very interesting and important question is why the self-organization was observed in discharges in Xe but not in other plasma-producing gases such as Ar [1]. Another question is as follows. In patterns with many spots observed in the experiment, spots are grouped in concentric rings, and in many cases numbers of spots in outer rings are higher than those in inner ones. However, in the modelling [2] numbers of spots in different rings are equal. It is very interesting to try to obtain in the modelling patterns with unequal numbers of spots in different rings similar to those observed in the experiment.

These questions are dealt with in this work. The key feature of the modelling is the use of a stationary solver of COMSOL Multiphysics, which allows one to decouple questions of numerical and physical stability.

The modelling is performed for a parallel-plane discharge of the height of 0.5 mm and radius of 0.5...1.5 mm in Ar or He. The simplest self-consistent model of glow discharge is used, which accounts for a single ion species and employs the drift-diffusion local-field approximation. For the pressure of 30 Torr, the discharge in Ar and He is obstructed (i.e., the current density-voltage characteristic *U(j)* is rising for all current densities), in contrast to that in Xe, the reason being the difference in cross sections of elastic collisions of electrons with atoms. Unsurprisingly, no multiple solutions have been detected, which means that no self-organization is present. A falling section comparable to that in Xe at 30 Torr appears in the current density-voltage characteristics at the pressure of 75 Torr for Ar and 530 Torr for He. 2D and 3D modelling has shown that multiple solutions describing self-organized patterns indeed exist for these pressures and are similar to those for Xe at 30 Torr found previously.

Distributions of current density over the cathode in several states belonging to one of the modes with azimuthal period of $\pi/3$ is shown in the figure. There are two concentric rings with 6 spots each in state a_2; the azimuthal period is $\pi/6$. In states h - d, three of the spots of the inner ring gradually merge with the nearest spots of the outer ring and the resulting spots are located at the periphery: a pattern with 3 spots in the inner ring and 6 spots in the outer ring appears. The merging happens for alternating pairs of spots and therefore the azimuthal period of the mode is doubled.

In summary, self-organization in microdischarges appears to be a general phenomenon. Numerical modelling describes its most important features even in the framework of the simplest model. One should be able to observe self-organization also in gases other than Xe provided that the experimental conditions, such as pressure, are right.

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References

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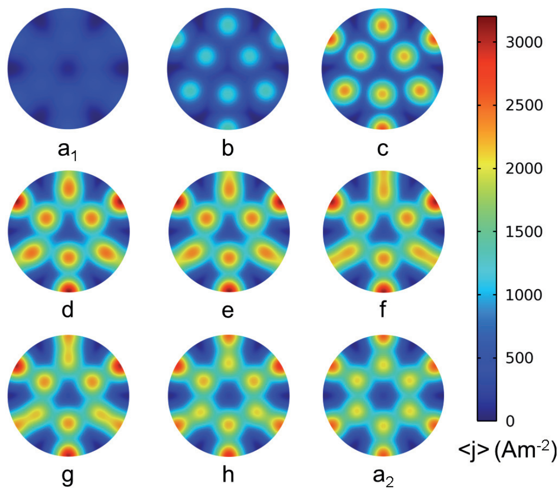

Figure. Distribution of current density over the surface of the cathode in states belonging to a mode with azimuthal period of $\pi/3$. Discharge of the radius of 0.5 mm in He at the pressure of 530 Torr.