

Self-organization as an intrinsic feature of DC glow microdischarges: predicting self-organization in different gases

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Self-organized patterns of cathodic spots have been observed in DC glow microdischarges in xenon, but not in other gases such as argon. This work is concerned with modelling of DC glow microdischarges in argon and helium. It is found that multiple 2D and 3D solutions for these gases do exist provided that discharge pressure is high enough. The results suggest that self-organization in microdischarges appears to be a general phenomenon that should be observable in gases other than xenon provided that the experimental conditions are right.

Stationary self-organized patterns of cathodic spots have been observed in DC glow microdischarges in xenon [1]. Recently, such patterns have been obtained in the numerical modelling [2, 3]: 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 experiments [1] and fit into the general pattern of self-organization in near-electrode regions [4].

A very interesting question is why the self-organization was observed in xenon but not in discharges with other plasma-producing gases, such as argon [1]. This question is 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 0.5mm and radius of 0.5...1.5mm in xenon, argon or helium. Both the simplest self-consistent model, which accounts for a single ion species and employs the drift-diffusion approximation, and a more complex model which includes non-locality of electron transport and kinetic coefficients and accounts for several ionic species, atoms in metastable states and excimers have been employed.

For the pressure of 30 Torr, the discharge in Ar and He is obstructed (i.e., the current density-voltage characteristic, CDVC, is rising for all current densities), in contrast to that in Xe, the reason being different cross sections of elastic collisions of electrons with atoms. The CDVC for argon and xenon at the pressure of 30 Torr is shown in figure 1(a) computed in the framework of the basic model and in the framework of the detailed model. For both argon and xenon, the CDVC obtained in the framework of the basic model is similar to the one obtained in the framework of the detailed model. Unsurprisingly, no multiple solutions have been detected for argon and helium at 30 Torr, 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, as shown in figure 1(b). Also shown in figure 1(b) are examples of multiple 3D modes computed for argon and helium in the framework of the simple model. The schematics in this figure represent typical distributions of current density over the cathode surface for these modes. In figure 2 are shown examples of computed 2D modes for argon and helium at 75 Torr and 530 Torr (respectively) in the framework of the basic model and with neutralization of the charged particles at the wall of the discharge vessel taken into account.

The 2D and 3D spot patterns are similar to those found [2, 3] in Xe at 30 Torr and the pattern of self-organization is the same. 3D spot patterns are also similar to those observed in experiments [1].

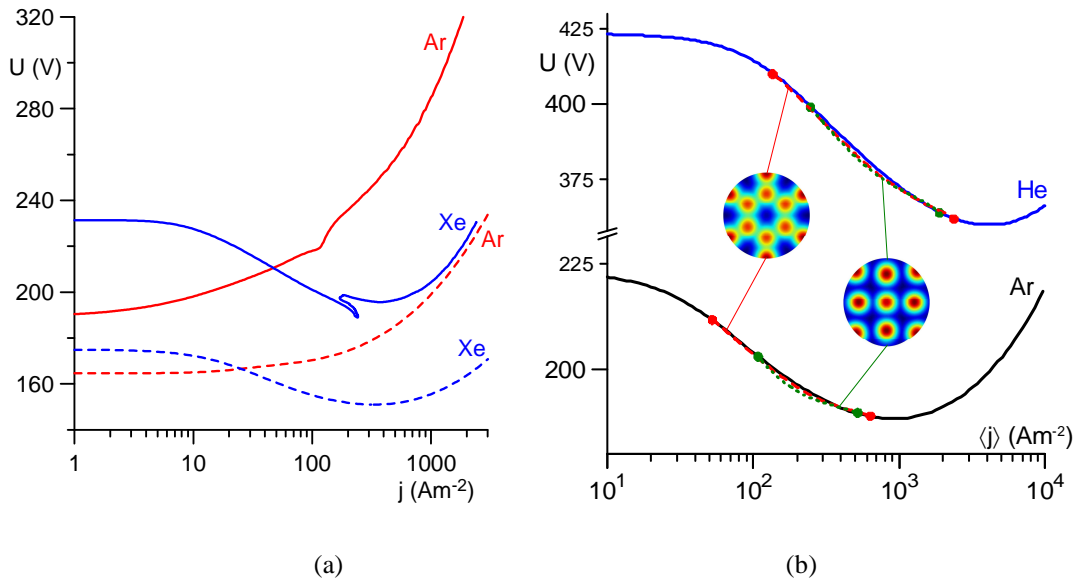


Fig. 1: (a): CDVCs, 30Torr. Solid: detailed model. Dashed: basic model. (b): CVCs, R=0.5mm, 530Torr for He and 75Torr for Ar. Solid: 1D mode. Dashed and dotted: 3D modes. Circles: bifurcation points.

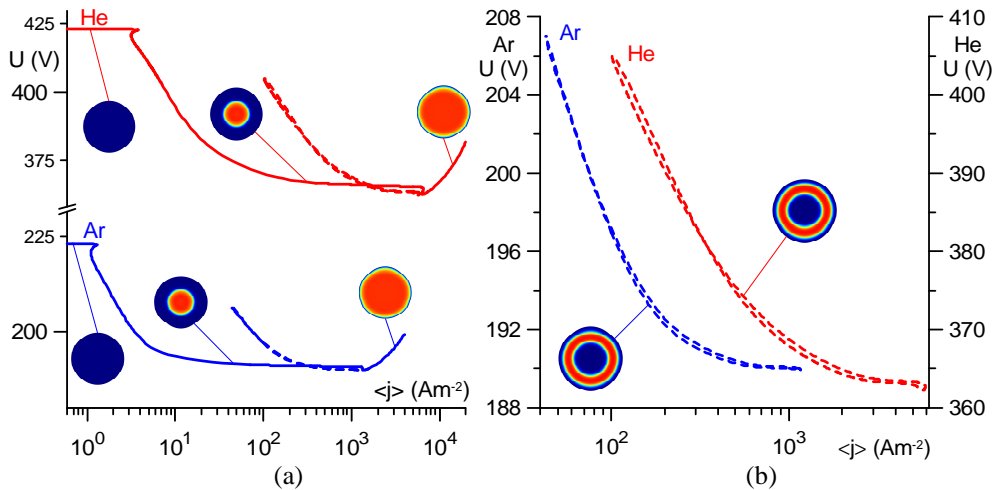


Fig. 1: CVCs, CVCs, R=1.5mm, neutralization of charged particles at the wall of the discharge vessel taken into account, 530Torr for He and 75Torr for Ar. Solid: Fundamental (2D) mode. Dashed: first non-fundamental 2D mode.

In summary, self-organization in microdischarges observed in [1] appears to be a general phenomenon. One should be able to observe it also in gases other than xenon provided that the experimental conditions, such as pressure, are right.

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