Cluster issue ‘Spots and patterns on electrodes of gas discharges’

Concentration of electrical current onto the surface of electrodes of gas discharges in well-defined regions, or current spots, is often the rule rather than the exception. These spots occur on otherwise uniform electrode surfaces, a regime where one might expect a uniform distribution of current over the surface. In many cases, multiple spots may appear, forming beautiful patterns and surprising the observer.

Important advances have been attained in the last 15 years in experimental investigation, understanding, and modelling of spots and patterns in discharges of different types; in particular, high-pressure arc discharges, dc glow discharges and barrier discharges. It became clear that in many, if not most, cases there is no need to look for special physical mechanisms responsible for spots or patterns on uniform electrode surfaces: the spots or patterns originate in self-organization caused by (nonlinear) interaction of well-known mechanisms. In particular, it was shown that standard mechanisms of the near-cathode space-charge sheath are sufficient to produce self-organization, and it is this kind of self-organization that gives rise to cathode spots in low-current high-pressure arcs and normal spots and patterns on cathodes of dc glow discharges. It became clear that spots and patterns on electrodes of gas discharges, being self-organization phenomena, are inherently related to multiple solutions, which must exist even in the most basic self-consistent models of these discharges, with one of the solutions describing a mode with a uniform distribution of current over the electrode surface and the others describing regimes with different spot patterns. It is in this way that self-consistent numerical simulations of many spots and patterns have been performed.

Papers in this cluster build on the aforementioned advances. Multiple solutions in the theory of dc glow discharges and the cathodic part of arc discharges are reviewed in [1]. Results from the observations of patterns in high-pressure dc glow discharges are reported in [2, 3] (patterns on cathodes of microdischarges) and [4] (patterns on liquid anodes). Self-consistent numerical modelling of patterns on cathodes of glow microdischarges is reported in [3]. Normal spots in a glow discharge in axial magnetic field are simulated in [5]. Experimental results on spots on electrodes of high-pressure discharges operating at currents up to fractions of ampere, which are rather high compared to those typical for glow discharges and insufficient for electrodes to be heated up to temperatures typical for arc discharges, are reported and interpreted on the basis of the concept of normal current density in [6, 7]. Results of self-consistent numerical modelling of spots on cathodes and anodes of high-pressure arc discharges are reported in [8] and [9], respectively, and stability of spots on cathodes of high-pressure and vacuum arc discharges is studied numerically in [10]. The paper [11] contains new experimental data on spots (‘tufts’) on a negative corona electrode.
Stationary and rotating spot patterns in a pulsed rf discharge and rotating ‘spoke’ patterns in an impulse magnetron discharge are studied experimentally in [12] and [13], respectively. Experimental results on electrode spots in pulsed discharges in tube-plate and needle-plate configurations are reported in [14].

Barrier discharges using resistive, semiconducting or dielectric barriers have certain additional characteristics. Through the properties of the used barriers they possess inherent current limitation that makes them immune to arc transition. Barrier discharges are also known to exhibit a wealth of discharge structures ranging from diffuse, laterally homogeneous, appearance over apparently randomly distributed current filaments to well-ordered stable patterns, sometimes even different sub-patterns interlaced in time. The article [15] describes laterally patterned barrier discharges using a semiconductor electrode. A number of contributions [16–19] are devoted to different aspects of pattern formation in dielectric barrier discharges (DBDs). The physical mechanisms and the dynamics of pattern formation in DBDs are analyzed in detail in [20] on the basis of self-consistent numerical simulations and experimental results.

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