Self-organization of the anode spots and fluctuations of dc glow discharge parameters in atmospheric pressure helium

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Stable anode spots patterns are studied in a glow discharge at atmospheric pressure helium. The presence of two or more anode spots is accompanied by fluctuations of discharge parameters: discharge current, interelectrode voltage, light intensity, etc. The spots disappear at anode region contraction at a current of several amps.The frequency of fluctuations is on the order of 1 MHz. Correlation functions of fluctuations of spots luminosity, discharge current and voltage were obtained. At certain discharge parameters a synchronization of spots oscillations occurs, and voltage and current fluctuations become almost regular.

Self-organization of the current spots on electrodes in patterns with pronounced symmetry was manifold described in the last century [1]. They considerably impact homogeneity and stability of discharges. However, multiple observations of formation and self-organization of current spots on electrodes were found complicated for theoretical description. Recently, there has been an increasing interest to these phenomena connected with atmospheric pressure glow discharges (APGD) [2, 3]. In the given report, anode spots formation in dc helium APGD is under investigation and the correlation of spots intensity behavior with discharge parameters fluctuations is established. In the experiments, two- and three-electrode configurations of APGD were used [4, 5].

In the two-electrode configuration [4], the APGD is ignited between flat copper electrodes in a hermetic discharge chamber. Helium flow of about 1 l/min at atmospheric pressure is provided

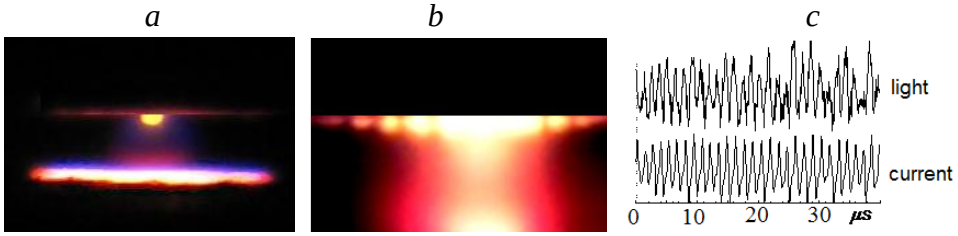

Fig. 1. Images of the anode spots at different interelectrode gaps and discharge currents: *a* – less than 1 mm and 10 mA, *b* – 8 mm and 200 mA. Waveforms of the current and light oscillation (c).

through the chamber. Integral light in visible region was detected from the outside of the discharge chamber by two photomultipliers. To obtain a spatial resolution the image of glow discharge was focused onto a slit-diaphragm located in front of a photomultiplier. Discharge current fluctuations were registered using a measuring shunt of 50 Ohm. Oscillating components of photomultiplier signals, voltage and discharge current were registered by two storage digital oscilloscopes C8-40 (Belvar).

Using varied combinations of discharge current or/and interelectrode gap it is possible to obtain one (Fig. 1 *a*, top electrode is anode), two, etc. anode spots. At the currents of tens and more milliamps stable anode patterns form (Fig. 1 *b*). They disappear at anode region contraction occurring at a current of a few Amperes. In the presence of two or more spots on anode the fluctuations of the discharge parameters (light intensity, discharge current, interelectrode voltage) are observed (Fig. 1*c*). The frequency of these oscillations lies in the MHz region. Their amplitude constitutes a few tens per cent of the total discharge current at low currents (tens of milliamps) and slightly changes with the current increase.

For small interelectrode gaps (less than 1 mm) and currents of about 10mA it is possible to obtain one stable spot. In case the power supply voltage U_{ps} is less than the breakdown U_{br} for this gap, the fluctuations of the spot emission and discharge current (or voltage) are absent. However, if $U_{ps} > U_{br}$,

the relaxation oscillations of the current and voltage [6] take place. Naturally, the frequency of these oscillations depends on the parameters (capacitance, inductance) of the external circuit.

At discharge gap of 1 mm or slightly larger two "stable" anode spots can be obtained (Fig. 2 *a*). At the same time, the spots oscillate in opposite phase (Fig. 2 *b*) and their frequencies are two times less

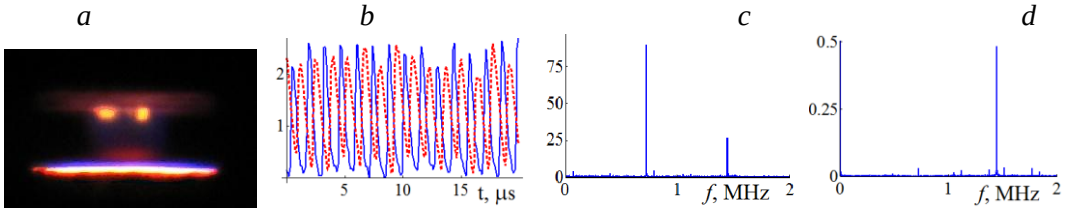

Fig. 2. Image of two anode spots (*a*), their light intensity waveforms (*b*) and Fourier-spectra of the spot intensity (*c*) and discharge current (*d*) oscillations. Vertical scales – arbitrary units.

than the frequency of the discharge current and voltage (Fig. 2 *c, d*). High regularity of these oscillations and their independence from electrical parameters of the supply circuit should also be noted. In case three spots are present the fluctuation frequency of each of them is 4 times smaller than the frequency of discharge current fluctuations.

Fig. 3 *a* shows an image of anode spots structure at a current of 200 mA and a gap of 8 mm. This structure is "stable" over the time, and when discharge current changes from tens of milliamps to amps it modifies from faint to contrast one with the bright spots in the center. The number of these spots grows with discharge current increase. Voltage and current fluctuations are not quite harmonic (Fig. 3 *b*) and their frequency varies in the range of 0.5–0.8 MHz. Fluctuations of light intensity from the region located at a distance of 1.5–2 mm from the anode surface are generally correlated with the fluctuations of discharge current. At the same time the fluctuations of spots light intensity from both the central region of the structure in Fig. 3 *a* and at its edge are almost random (Fig. 3 *c*). Their frequencies are much lower (Fig. 3 *d, e*). In this case the brightness of each spot is proportional to the frequency of its blinking. A synchronization of spot fluctuations takes place for several discharge parameters which leads to regularization of current and voltage fluctuations.

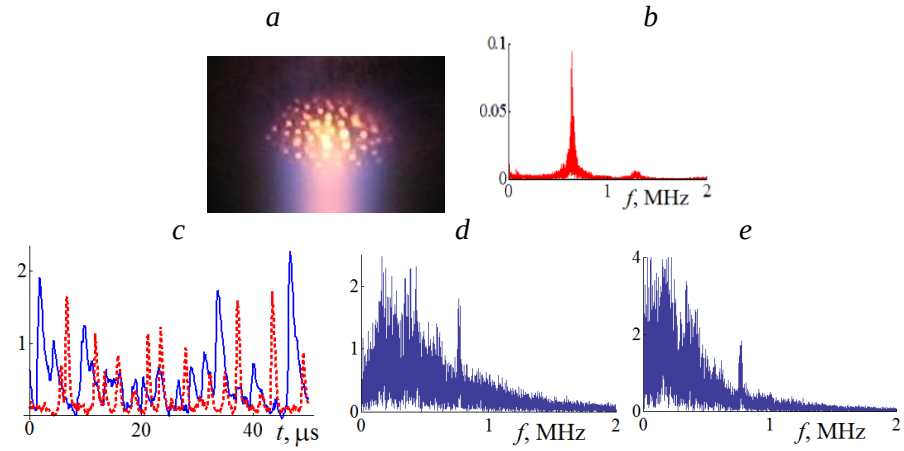

Fig. 3. Image of anode spots pattern (*a*), Fourier-spectrum of current oscillation (*b*), light intensity waveforms (*c*) and their corresponding Fourier-spectra (*d*) and (*e*). Vertical scales – arbitrary units.

In the three-electrode configuration [5], the distance between plasma cathode and the third electrode (second anode) is 2–5 cm. That allows one to observe the patterns on the anode on a broader scale. Diameter of the ring structure, for example, is larger than 2 cm, and the anode spots can be located upon the area larger than 15 cm^2.

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References

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