# THE INFLUENCE OF CORONA-LIKE DISCHARGES ON PROCESSES OF STABILIZATION OF ELECTROHYDRODYNAMIC AUTOOSCILLATIONS IN WATER ELECTROLYTES

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The kinetic features of electrohydrodynamic processes for multiple, line and circular current concentrators were investigated experimentally with breakdowns in water electrolytes (0.3%–5% NaCl). For the first time, the regimes of electrohydrodynamic autooscillations in circular current concentrators made from metal and in the form of circular hole in dielectric film were obtained. It is shown that the phase self-synchronization of autooscillations is provided by coalescence of growing local bubbles in single torus-like bubble during explosive boiling of liquid and discharges inside the bubbles. The corona-like discharges in bubbles play a role of stabilizing factor of collapsing bubbles formation. The domain of corona-like discharges is in the range from 100 to 700 V.

## Introduction

Nowadays, the studies of interaction between plasma generating discharges breakdowns with liquid become of growing interest [1]. It is connected with problems of water purification for social sphere and industry.

Earlier, electrohydrodynamic autooscillations in connected in parallel $N$ round current concentrators with diameter $d$ placed at a distance $r > 6d$ from each other were studied in [2, 3]. In the present work, solid circular electrodes and diaphragms of width $h$ corresponding to

$N$ round current concentrators with $d = h$ placed in line or in ring at distance $r = 0$ from each other were studied experimentally. The objective was to reveal the stable modes of autooscillatory processes for similar devices.

## Experimental Setup

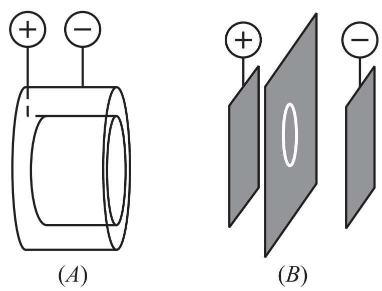


**Figure 1** Experimental setups

The experiments were performed at setups $A$ and $B$ presented in Fig. 1.

Setup $A$ consisted of circular metal current concentrators with outer diameters $D$ = 3–10 mm with a ring width $h = 0.17$–$0.9$ mm. The concentrators were connected to "+" polarity of voltage supplier. The opposite electrode was a plate from stainless steel placed at a distance $H \geq 6D$ or a coaxial cylinder. In the case of cylinder, the region between the electrodes was filled with epoxy resin.

Setup $B$ consisted of slot-like and circular current concentrators in the form of diaphragm carving in lavsan film with $D$ = 6–8 mm, $h$ = 0.35 mm, and thickness $\delta = 100$ $\mu$m. The deviation of slot width along perimeter was $\pm 0.1$ mm.

As electrolyte, water solutions of natrium chloride with concentration $k$ = 0.3%–5% were used. The electrical scheme of the setup consisted of capacitor $C = 200$ $\mu$F charged to voltage $U_C$ = 50–800 V through a controlled electromagnetic switch. The additional inductance was connected to the discharge circuit, which could be varied in the range $L$ = 0–18 mH. In all experiments, the active resistance of electrolytic cell was in the range $R_h > 2\sqrt{L/C}$. For current and voltage measurements, Tektronix TDS-210 oscilloscope was used. Hydrodynamic processes were visualized by high-speed camera MotionXtra HG-LE. Additionally, light emission from breakdowns was registered by PMT-35.

## Results of Experiments

Figure 2 shows typical current $I$ and electrode voltage $U$ oscillograms for regimes of autooscillations in circuits with slot-like and circular current concentrators without (Fig. 2$a$) and with additional inductance $L = 7.7$ mH (Fig. 2$b$).

The oscillograms show that current autooscillations can be realized both with and without additional inductance.

Figure 3 shows the example of high-speed filming (half section) of electrodynamic processes on a stainless-steel circular concentrator of diameter $D = 6$ mm and ring width $h = 0.25$ mm ($L = 7.7$ mH). The presented film frames and oscillograms show that the process of torus-like bubble growing begins at the moment of maximal current. The breakdowns between metal electrode and electrolyte occur at the stage of current fall and voltage rise due to the coil self-inductance $L$.

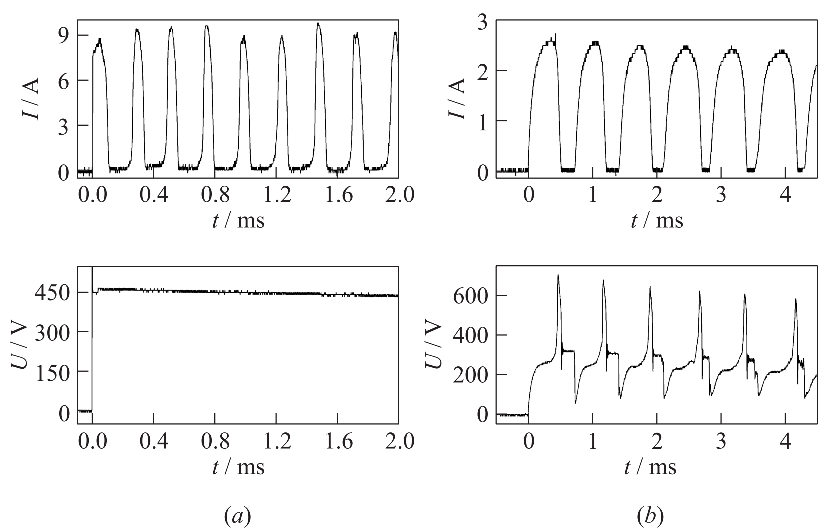


**Figure 2** Typical current $I$ and electrode voltage $U$ oscillograms for regimes of autooscillations in circuits with slot-like and circular current concentrators without ($a$) and with ($b$) additional inductance $L = 7.7$ mH

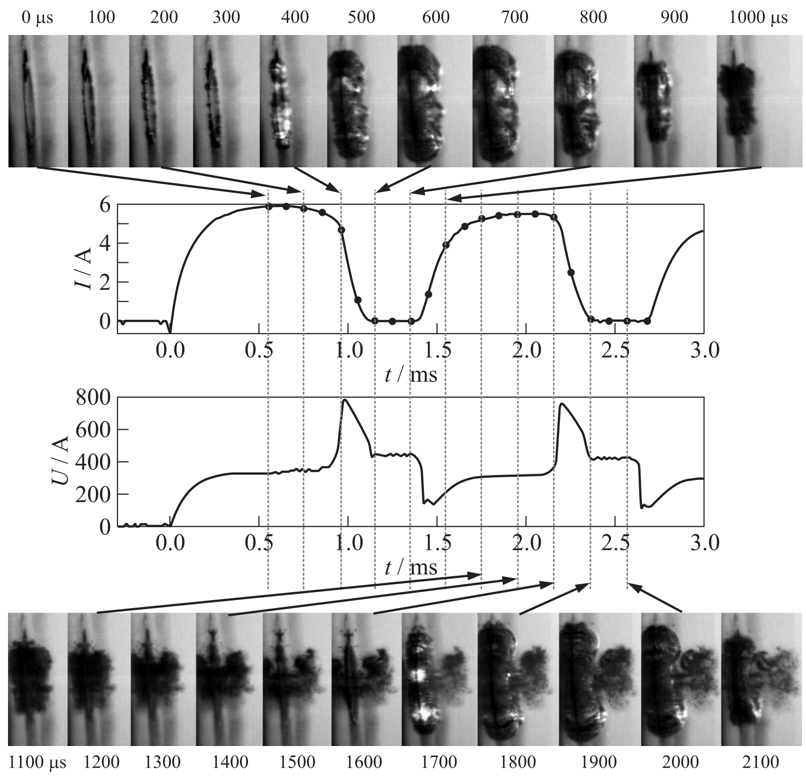


**Figure 3** Example of high-speed filming (half section) of electrodynamic processes on a stainless-steel circular concentrator of diameter $D = 6$ mm and ring width $h = 0.25$ mm

Figure 4 shows the example of high-speed filming (setup $B$) of electrohydrodynamic process development on a diaphragm circular current concentrator with $D = 8$ mm, $L = 0$, and $U_C = 700$ V.

## Analysis of Results

The experimental results imply that the electrohydrodynamic autooscillations arise both in the case with additional inductance $L$ connected to

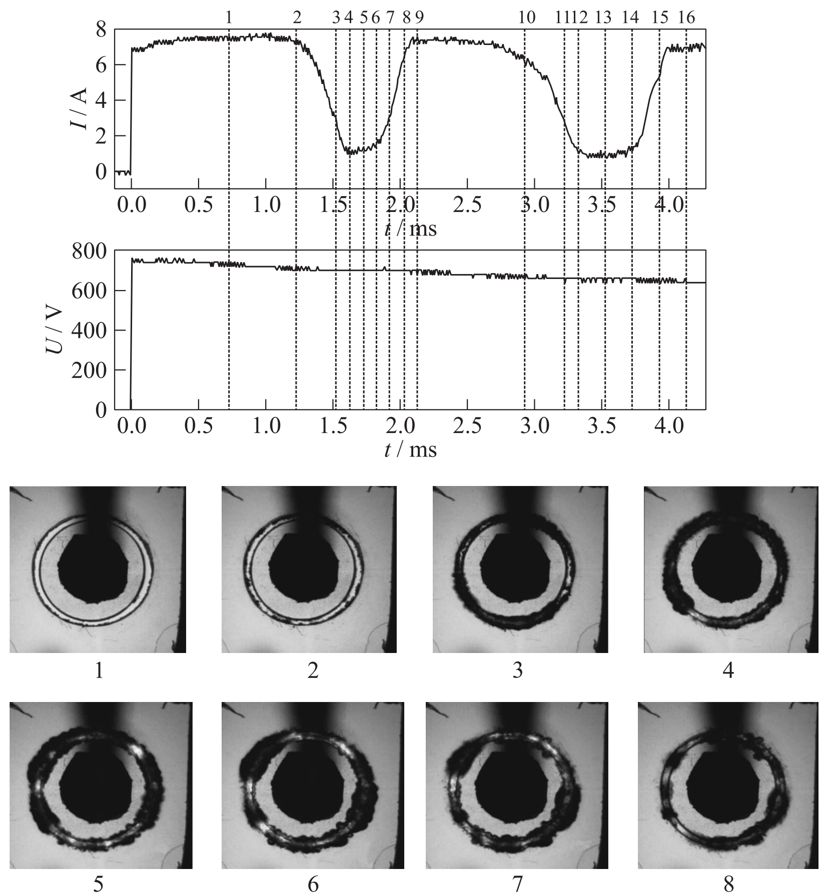


**Figure 4** Example of high-speed filming (setup *B*) of electrohydrodynamic process development

the discharge circuit and for the case without additional inductance. It follows from film frames and oscillograms that the autooscillatory process occurs due to explosive boiling of liquid. The breakdowns observed through light emission are the accompanying phenomena which provide the stability to electrohydrodynamic processes (see the second pulse of tore in Fig. 3). The results of filming and oscillographic measurements of current and electrode voltages imply that:

- in the absence of additional inductance in the discharge circuit, the breakdowns inside bubbles are developed at the stage of bubble collapse at electrode voltage $U = U_C$ ($U_C$ is the voltage on the capacitor $C$); and

- in the presence of additional inductance $L$ in the discharge circuit, the first breakdowns occur at the stage of bubble growth at electrode voltage $U = U_C + U_L = U_C - L \sum_i (dI_i/dt)$. Meanwhile, for developed autooscillations, the breakdowns occur on the necks of torus-like bubbles providing the equalization of the bubble diametral section along perimeter.

Upon connection of the inductance to the discharge circuit, the rise of peak power on current concentrators occurs ($U/U_C \approx 2$–5) due to the generation of voltage pulses in the circuit, and the breakdowns occur at the stage of bubble growth.

The stabilizing factor of collapsing bubble formation is corona-like discharges in bubbles which are developed in necks of line or torus-like bubbles. This points to possible applicability of Paschen's law for gas (vapor) breakdown threshold with minimal product $Pd$ ($P$ is the the pressure inside bubble and $d$ is the bubble diameter). Due to inertial processes, the dynamics of bubble boundaries may be not uniform which can be seen on the video frames. In the experiments, the domain of corona-like discharges was in the range 100–700 V.

## Concluding Remarks

1. The regimes of electrohydrodynamic autooscillations were obtained for the first time for metal and diaphragm circular current concentrators with strip width $h$ and length $l \gg h$ as well as in current concentrations in the shape of rings with diameter $D \gg h$.

2. The mechanism of self-synchronization of electrohydrodynamic processes in linear and circular systems is revealed: advancing breakdowns are developed in the minimal slot gaps and necks of a torus-like bubble.

3. It is shown that phase synchronization of autooscillations is provided mainly by coalescence of growing bubbles whereas corona-like discharges provide the equalization of energy release along bubble perimeter for each subsequent period of bubble generation.

## References

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