On the effect of large-scale perturbations of surface of a liquid electrolyte cathode on the properties of gas

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Abstract. A gas discharge between a liquid electrolyte cathode and a copper anode was experimentally investigated in the current range of 1-15 A in the presence of disturbances on electrolyte surface. Two options were considered. In the first variant, disturbances were created by supplying gas to the inside of surface layer of electrolyte. And in the second version, a two-level cathode zone was organised on the electrolyte surface.

1. Introduction

In recent years, due to unique possibilities of practical application, gas discharges with liquid electrolyte cathode have become the object of close study [1]. In most studies, discharge was obtained above the free smooth surface of electrolyte [2-9]. Under the influence of discharge, the state of surface can change, in particular, ripples can form on surface [10]. There is very little information in literature about discharges that burn when smooth electrolyte surface is disturbed. In this work, the problem was posed to study the properties of discharge in the presence of disturbances in the form of large-scale irregularities on surface of liquid electrolyte cathode.

2. Experiment – first option

In figure 1 schematically shows the cathode assembly of gas discharge device. It is equipped with a ring current lead and a porous insert. Air was supplied inside the porous insert.

![Figure 1](image1.png)

The discharge was ignited at sufficiently large interelectrode distances. The metal anode was located above cathode assembly at a height of 6-8 cm. Electrical power was supplied from a three-phase two-half-period rectifier. Voltage ripples were smoothed by an induction-capacitive filter. Aqueous solutions of sodium chloride with different concentrations were used as the electrolyte. The specific electrical conductivity of solutions $\sigma$ was in the range of 8-16 mS/cm.

Instant photos of discharge were obtained using a high-speed video camera VIDEOSKAN-401, which allows shooting frames with an exposure of 1 $\mu$s. The current and voltage were recorded with an AKIP-15/1 double-beam storage oscilloscope with a bandwidth of 25 MHz.

The electrolyte flowed out of cathode assembly, forming a smooth horizontal surface (figure 2a). The air flow foamed the electrolyte (figure 2b).
Figure 2. Photographs of electrolyte surface in the absence of gas flow (a) and when gas is supplied to the cathode assembly (b).

In figure 3 shows snapshots of electrolyte surface taken during discharge burning.

Figure 3. Instant photographs of surface of electrolyte cathode in the absence of gas flow (a) and with gas supply (b). Exposure 0.2 ms. Current 6 A.

As can be seen, the gas supply leads to significant changes in surface of electrolyte cathode. The distribution of "cathode spots" becomes uneven. Significant current ripple can be expected. However, oscillograms of currents and voltages turned out to be practically the same in both versions (figure 4). Small-scale high-frequency pulsations are present here. They are a characteristic feature of gas discharge with liquid electrolyte cathode [11, 12]. Some smoothness of oscillograms in figure 4b, apparently, was obtained due to the stabilization of plasma column by a weak gas flow.

Figure 4. Oscillograms of current and voltage in the absence of gas flow (a) and with gas supply (b). The interelectrode distance 7 cm.

3. Experiment – second option
In figure 5 shows a diagram of cathode assembly. A dielectric tube with an upward projection is mounted inside the outlet channel. It is supplied electrolyte. In this way, the surface of electrolyte cathode becomes two-level. The metal anode was located at an altitude 4 cm above of the top end of the dielectric tube.
Figure 5. Cathode assembly. 1 – output channel, 2 – current lead, 3 – dielectric tube, 4, 5 – flows of electrolyte.

The upper level of electrolyte has a spherical shape (figure 6a). At currents of less than 2 A, the binding of discharge to electrolyte occurred at this level. Cathode "spots" were distributed over a spherical surface (figure 6b). When current increases, discharge goes to the lower level (figure 6c).

Figure 6. External view of cathode assembly (a) and instant photographs of discharge in current modes 1 A (b) and 9 A (c). Electrolyte is an aqueous solution of sodium chloride. $\sigma = 11$ mS/cm.

Some video frames contain images of upper electrolyte level. Such patterns arise when plasma column deviates from central position. It can be pay attention to following situation. A dark space is recorded above the upper electrolyte level.

Figure 7. Current and voltage. Electrolyte is an aqueous solution of sodium chloride. $\sigma = 11$ mS/cm. Distance between the lower electrolyte level and anode is 8 cm.

There is no radiation from electrolyte surface at this level. No cathode spots are observed. Consequently, discharge is not always closed from anode to the nearest electrolyte surface. Thus, the presence of tube does not significantly change current flow in these modes. This fact is indirectly confirmed by oscillograms (figure 7). There are no sudden surges in current and voltage.

4. Conclusion
A gas discharge with a liquid electrolyte cathode in the presence of large-scale disturbances of its surface has been obtained and investigated. The studies were carried out at relatively high currents (1-15 A) and interelectrode distances (4-8 cm). Disturbances were created by supplying gas to the inside of surface layer of electrolyte, as well as by creating a two-level cathode zone on surface of
electrolyte. It was found that such perturbations practically do not affect the processes of current flow in gas discharge. The results obtained can be useful in the development of high-current plasma devices with a liquid electrolyte cathode.

References
1. Bruggeman P and Leys C 2016 Plasma Sources Science and Technology 25 053002
2. Petov A E et al. 2011 Gorenje i plasmohimija 9(3) 160
3. Gaisin F M, Gizatullina F A and Kamalov R R 1985 Fizika i himija obrabotki materialov No. 3 58
4. Gaisin A F and Tazmeev Kh K 2005 High Temperature 43(6) 810
5. Tazmeev G K et al. 2016 Applied Physics No. 1 72
6. Tazmeev Kh K, Arslanov I M and Tazmeev G Kh 2016 J. Phys.: Conf. Ser. 669 012058
7. Tazmeev G K et al. 2017 J. Phys.: Conf. Ser. 789 012060
8. Tazmeev G K, Timerkaev B A and Tazmeev K K 2019 J. Phys.: Conf. Ser. 1328 012075
9. Tazmeev G K et al. 2018 High Energy Chemistry 52(1) 99
10. Vasilykh D V et al. 2005 Khimicheskaya Fizika 24(8) 96
11. Tazmeev K K et al. 2015 Applied Physics No. 2 58
12. Tazmeev G K, Timerkaev B A and Tazmeev K K 2016 J. Phys.: Conf. Ser. 669 012057