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The features of high-current gas discharge in a narrow gap between the liquid electrolyte and solid electrode

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Abstract. Gas-dynamic phenomena on the boundary "plasma – liquid electrolyte" currents in the range (10 – 21) A were studied. The regularities of the influence of deformation of the surface of the electrolyte on the characteristics of the gas discharge were revealed.

1. Introduction

Gas discharges with liquid electrodes allows producing chemically active non-equilibrium plasma at atmospheric pressure directly to a relatively simple manner. Therefore, in recent years, a growing interest in the study of such discharges, and the possibilities of their practical application [1-7]. On the boundary "plasma-electrolyte" there are complex processes of interaction of the gas discharge with a liquid medium. Many aspects of these processes currently remain poorly understood.

In paper [8] it pointed out that under the influence of the high voltage applied to the discharge gap, the surface of the electrolyte rises. When the discharge is ignited, there is a reverse phenomenon - the surface of the electrolyte is pressed inward. Some regularities of this phenomenon at currents not exceeding 11 A, were studied in paper [9]. The aim of this work is an experimental study of gas-dynamic phenomena at the "plasma - the electrolyte" at higher discharge current.

2. Experiment

The gas-discharge unit of the experimental device is shown schematically in figure 1. The discharge burned between *1* flowing electrolyte *2* and a water-cooled metal anode *3*. The direction of flow of the electrolyte is indicated by an arrow. Electrolyte was served as a weakly concentrated solution of Glauber's salt in distilled water. The electrical conductivity σ of electrolyte at room temperature were in the range (1.0 – 2.5) mS/cm. Mass flow rate m of the electrolyte through the zone of the discharge was varied from 8 to 40 g/s.

The anode was located at the height H = 15 mm. The thickness of the layer of electrolyte over the current lead was 13.5±0.2 mm. Thus, prior to ignition of the discharge between the electrolyte and the anode there was remained an air gap equal to 1.5±0.2 mm. The discharge was ignited by high-voltage breakdown of the gap. Under the influence of the discharge in the electrolyte was formed a "pit". The depth of "pit" Δh was determined from measurements of the potential distribution inside the electrolyte φ by using a single electric probe. Same probe as in paper [9] was used in experiments. He moved in a vertical direction of the coordinate device. The mechanical movement was transformed

into an electrical signal, and the signal was fed to the "*X*"-entrance tablet two-coordinate potentiometer brand PDP4-02. Signal from the probe via a high resistor «*Y*»-entrance was received.

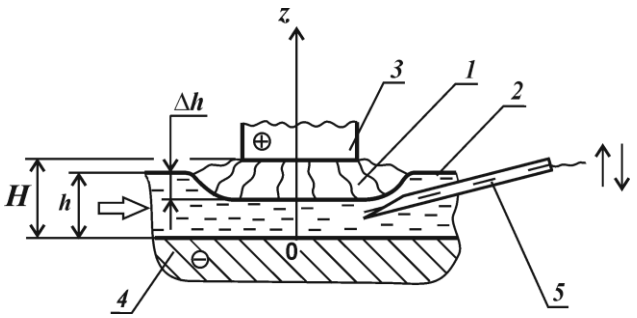

Figure 1. Gas discharge unit: *1* − discharge area; *2* − liquid cathode (electrolyte); *3* − anode; *4* − current lead; *5* − probe.

The research was carried out in the range of currents (10 – 21) A. The source of electrical power was served as a three-phase full-wave rectifier. The power circuit of the ballast resistor was missing. The power supply was grounded. To measure the discharge current and voltage on discharge unit were used pointer devices M1042 type of accuracy class 0.2. The temperature of the electrolyte was measured by a chromel-alumel thermocouple placed over the discharge area along the flow of the electrolyte.

3. The results of experiments, their processing and discussion

The graphs recorded on the tablet device PDP4-02 at different values of discharge current *I* and the mass flow rate *m* of the electrolyte are shown on figure 2. In this figure the vertical dotted line indicates the thickness *h* of the layer of electrolyte.

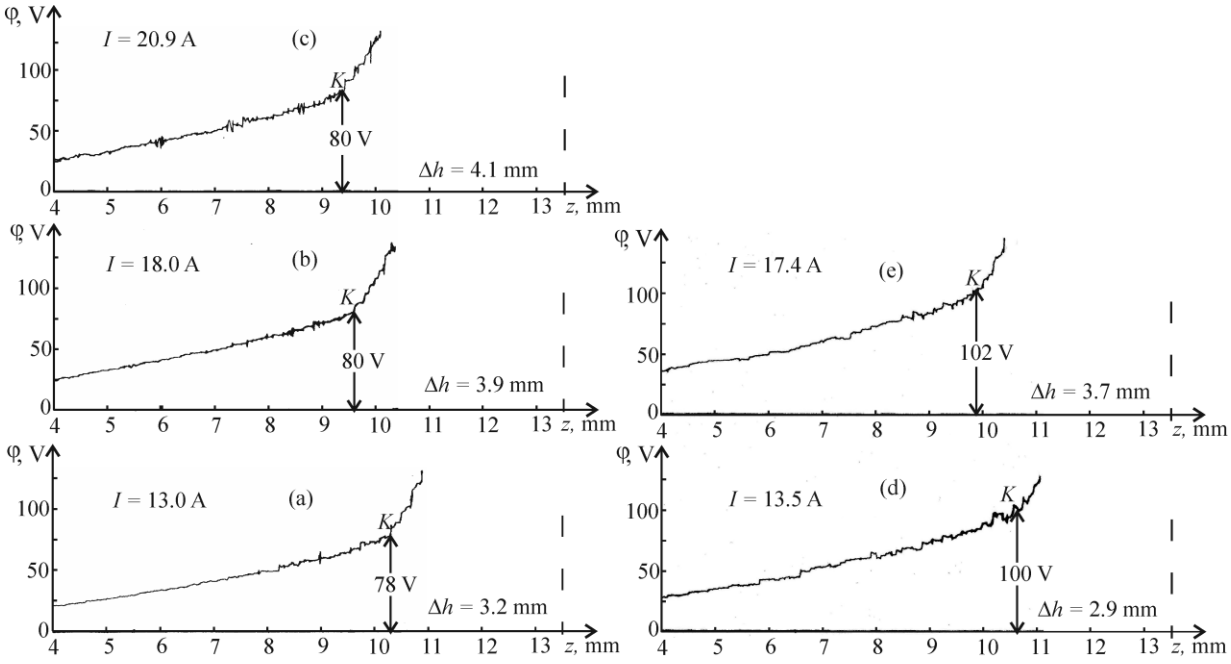

Figure 2. Potential distribution within the electrolyte of the cathode at low intensity of cooling. σ = (2.50±0.05) mS/cm. (a), (b), (c) – m = 10 g/s; (d), (e) – 40. Temperature of the electrolyte: (a) – *t* = 73 °C; (b) – 76; (c) – 79.5; (d) – 53; (e) – 61.

As can be seen, in all cases, inside the electrolyte the potential of φ grows linearly along a vertical coordinate *z* measured from the surface of the current lead (to point *K*). The values of φ, recorded by a probe at its exit from the electrolyte, are much higher (after a point *K*). Coordinate of a point *K* determines the position of the boundary "plasma – electrolyte". The depth of "pit" Δh is equal to the difference of the values of *h* and *z* coordinates of the point *K*. With increasing current, the depth of "pit" is growing. Such regularity is observed in all the investigated range of variation of the parameters *m* and σ.

Some of the results which obtained using an electrolyte with lower specific electrical conductivity equal to (1.35±0.05) mS/cm, are given in table 1. As follows from comparison of graphical and tabular data, the depth of "pit" is almost independent of the electrical conductivity of the electrolyte. The main parameter affecting the depth of "pit" Δh, is the discharge current *I*.

Table 1. The results of experiments

m, g/c	*I*, A	Δh, mm
10	13.4	2.7
	17.0	3.3
	19.7	4.1
40	12.9	2.9
	15.0	3.2
	20.2	3.9

The dynamic impact of the gas discharge with liquid electrolyte cathode with the formation on its surface "pits", results in the following remarkable phenomenon. It is as follows. At constant values of *m* and σ the value of potential φ corresponding to the point *K* practically remains constant. In other words this means that the voltage drop ΔU_k on the liquid electrolyte cathode is practically independent of current because the value of ΔU_k numerically equal to the potential corresponding point *K* on the graphs to the dependence of φ from *z* (figure 2). When current is increased, graphics is located above as noted earlier. However, the point *K* is shifted to the left, resulting in a value of φ, corresponding to this point does not change. From a physical point of view the constancy of ΔU_k is due to the following reasons. On the one hand, according to Ohm's law, with the increase in current increases the voltage drop in the electrolyte, which should lead to an increase in ΔU_k. On the other hand, reducing the thickness of the electrolyte layer by increasing the current is reduces electrolyte ohmic resistance of the cathode, and therefore the ΔU_k, is numerically equal to the product of the ohmic resistance at the current is decreases. Due to these mutually exclusive two factors ΔU_k remains almost unchanged.

As is known, the ohmic resistance of the electrolyte is significantly reduced with increasing temperature. In our experiments, with increase of current, temperature of electrolyte was increased, therefore the ohmic resistance decreased. And this, in turn, should lead to a decrease in ΔU_k. Thus, there is another, probably more important reason affecting to ΔU_k. It consists in heating the electrolyte. At high mass flow rates, the electrolyte heats little, and therefore with the growth of *m* is formed on the cathode a higher voltage drop ΔU_k, in particular it can be seen from comparison of the data presented in figure 2. If $m = 10$ g/s the voltage drop at the cathode is in the range of (78 – 80) V (figure 2(a), 2(b), 2(c)), and if $m = 40$ g/s it is (100 – 102) V (figure 2(d), 2(e)).

Deepening the "pit" with increasing current lengthens the discharge gap, which in turn leads to an increase in the discharge voltage U_d and with it the voltage at the terminals of a gas discharge device: $U = \Delta U_k + U_d$. For this reason, current voltage characteristics (CVC) are increased (figure 3).

The increasing character of the dependence of U and I is due to only one cause, namely, the increase of the discharge gap due to the formation of "pit" in the cathode electrolyte, as the voltage drop at the cathode is almost constant for all values of current. The same reason as the main considered in work [9] for the formation of increasing CVC in the current range (4 – 10) A. Thus, increasing CVC – is an inherent property of a gas discharge with a liquid electrolyte cathode with short distance between the electrodes.

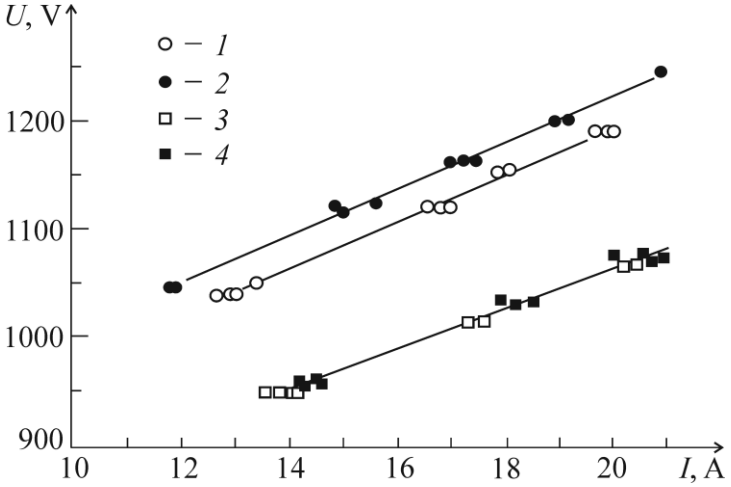

Figure 3. Current-voltage characteristics of the gas discharge device. *1*, *2* − σ = (1.35±0.05) mS/cm; *3*, *4* − (2.50±0.05) mS/cm. *1*, *3* – *m* = 10 g/s; *2*, *4* – 40.

4. Conclusions

The formation of "pits" in the electrolyte is a characteristic feature of a gas discharge with liquid electrolyte cathode at small distance between the electrodes, and the depth of "pit" grows with increasing current.

The voltage drop on the liquid electrolyte cathode is practically independent of current, due to the decrease of the ohmic resistance of the cathode at current increases due to the change in the thickness of the layer of the electrolyte and increasing its temperature.

References

[1] Maksimov A I and Khlyustova A V 2009 *High Energy Chemistry* **43** No. 3 149
[2] Rybkin V V, Smirnov S A, Titov V A and Arzhakov D A 2010 *High Temperature* **48** 476
[3] Levko D S, Shchedrin A I, Chernyak V Y, Olshvskii S V and Nedybalyuk O A 2010 *Technical Physics Letters* **36** 998
[4] Samukawa S, Hori M, Rauf S et el. 2012 *Phys. D: Appl. Phys.* **45** 253001
[5] Tazmeev Kh K, Arslanov I M and Tazmeev G Kh 2014 *J. Phys.: Conf. Ser.* **567** 012001
[6] Kashapov L N, Kashapov N F and Kashapov R N 2015 *IOP Conf. Ser.: Materials Science and Engineering* **86** 012019
[7] Valiev R A, Shakirov Yu I and Iliuchin A N 2014 *J. Phys.: Conf. Ser.* **567** 012040
[8] Lazarenko B R, Faktorovich A A, Duradzhi V N and Bryantsev I V 1970 *Eelektronnya Obrabotka Materialov* No. 4 18
[9] Miftachov M N, Tazmeev A Kh, Tazmeev Kh K and Fridland S V 2006 *Journal of Physics and Thermophysics* **79** 532