X International conference

Plasma Physics and Plasma Technology

Contributed papers

Minsk, Belarus
September 12 – 16, 2022

B.I. Stepanov Institute of Physics
National Academy of Sciences of Belarus

The National Academy of Sciences of Belarus
B.I. Stepanov Institute of Physics of the National Academy of Sciences of Belarus
Joint Institute for High Temperatures of the Russian Academy of Sciences

X International Conference

PLASMA PHYSICS AND PLASMA TECHNOLOGY

(PPPT-10)

Minsk, Belarus
September 12 – 16, 2022

CONTRIBUTED PAPERS

Minsk
«Kovcheg»
2022

UDC 533.3(082)

EDITORS:
N.V. Tarasenko, A.A. Nevar, N.N. Tarasenka, M.S. Usachonak

Proceedings of the X International Conference «PLASMA PHYSICS AND PLASMA TECHNOLOGY» (PPPT-10): September 12-16, 2022, Minsk, Belarus / Edited by N.V. Tarasenko, A.A. Nevar, N.N. Tarasenka, M.S. Usachonak - Minsk : Kovcheg, 2022. – 520p.

ISBN 978-985-884-193-5

THE POSSIBILITY OF USING A GAS DISCHARGE WITH A LIQUID ELECTROLYTE CATHODE TO CREATE A STEAM-WATER PLASMA FLOW

G. Tazmeev[1], B. Timerkaev[2], Kh. Tazmeev[1]

[1]Kazan Federal University, Naberezhnye Chelny Institute, 68/19, prospekt Mira, Naberezhnye Chelny, 423812, Russia. gktazmeev@kpfu.ru
[2]Kazan National Research Technical University named after A. N. Tupolev. 10, K. Marx Street, Kazan, 420111, Russia.

Gas discharges with liquid electrolyte electrodes have great potential for practical applications. They are promising for use in water disinfection technologies, synthesis of various functional materials, plasma activation of liquid reagents, and other areas of industrial activity. In high-current regimes, a significant amount of matter enters the plasma column from the liquid cathode. The discharge burns in a vapor-gas medium. It becomes possible to create a plasma flow that is acceptable for energy-intensive technologies. For example, the work [1] shows the acceptability of a gas discharge with a liquid electrolyte cathode for processing waste polymer materials. However, methods for generating powerful plasma flows in gas discharges with liquid electrolyte electrodes are still far from perfect. There are questions related to the choice of electrolyte, the design of the plasma generator, the introduction of reagents into the plasma, etc.

To the choice of electrolyte.

With prolonged discharge burning, the aqueous solution used as a liquid electrolyte cathode decreases. The aqueous solution is partially spent on the formation of the plasma flow. An additional amount of aqueous solution is required. In this case, it is desirable to keep the electrophysical parameters of the solution unchanged. If they remain unchanged, then there is no need to adjust the discharge current, and the electric power of the discharge device will not change.

In the simplest version, distilled water can be added instead of a solution. This option has been tested experimentally. The essence of the experiments was as follows. In the hydraulic system, the volume of the aqueous solution was kept constant (V_s = const). Distilled water was added continuously. After adding a certain amount of water, a sample was taken and the specific electrical conductivity of the aqueous solution σ was measured.

Figure 1 shows the results obtained for various aqueous solutions. They are prepared with the same concentrations. Relative values are plotted along the axes. Horizontally - the ratio of the amount of distilled water to the total volume of the aqueous solution. On the vertical - the ratio of electrical conductivity to its initial value. This ratio varies for different electrolytes in different ways. For some it decreases, and for others it increases. In the case of an aqueous solution of sodium chloride, it changes insignificantly. On the basis of this, an aqueous solution of sodium chloride was chosen as the electrolyte.

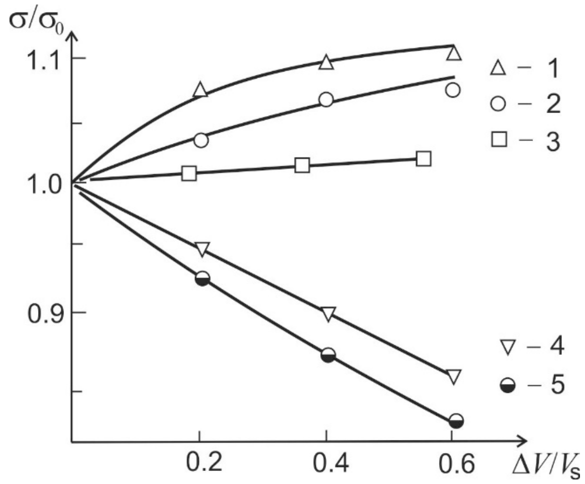

Fig. 1. Changes in electrical conductivity of aqueous solutions. 1 – 0.1M Na_2SO_4; 2 – 0.1M KCl; 3 – 0.1M NaCl; 4 – 0.1M NaOH; 5 – 0.1M KOH.

The choice of concentration of the aqueous solution.

The current-voltage characteristics of the discharge (I–V curve) turned out to be increasing (fig. 2). Moreover, the steepness varied depending on the electrolyte concentration. The lower the concentration, the steeper the I–V curve. From a practical point of view, this I-V curve is a very good discharge property, as the combustion stability increases and there is no need for a ballast resistor in the power supply circuit. Accordingly, energy losses are reduced.

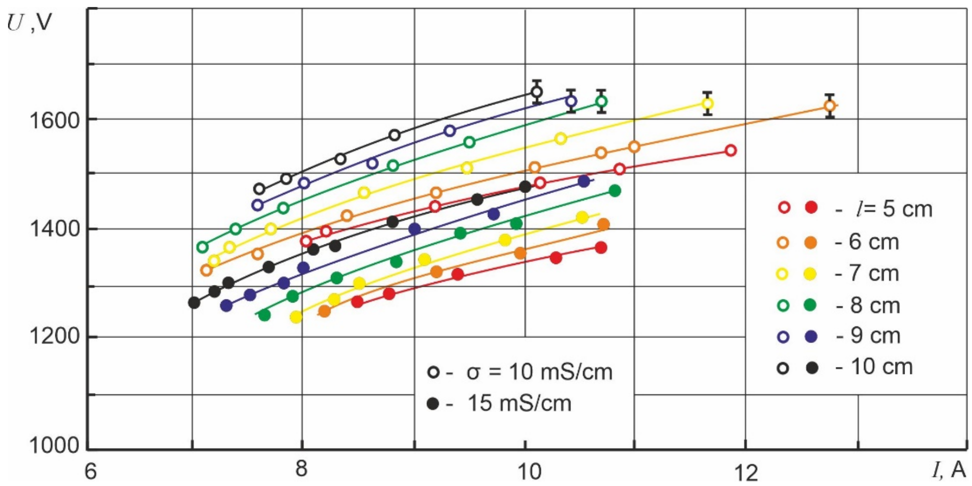

Fig. 2. Current-voltage characteristics.

Experiments have shown that the discharge burns steadily at concentrations at which $\sigma < 20$ mS/cm.

In the case of using aqueous solutions with low concentrations, the discharge switched to the combustion mode with contracted channels. When such channels appeared, the current increased sharply. Again there was a need for a ballast resistor. It was experimentally found that for operation without resistor, the concentration of an aqueous solution of sodium chloride should be in the range of 0.05 to 0.2 mol/l.

To the orientation of the plasma flow in space.

In the classical version, the liquid cathode is located at the bottom and the solid anode is installed above the cathode. The discharge between the cathode and the anode burns in the vertical direction. The plasma flow goes up from the liquid cathode. This configuration of the discharge makes it difficult to form a plasma flow in other directions. Technical solutions are required that allow the formation of a different discharge geometry. In this work, the problem is solved by using a porous insert on the cathode. On fig. 3 shows instantaneous photographs of plasma streams going in different directions from the cathode.

The photos were taken using a high-speed video camera VIDEOSCAN-401. Exposure 0.2 ms. The discharge current is 8 A. The distance between electrodes is 6 cm.

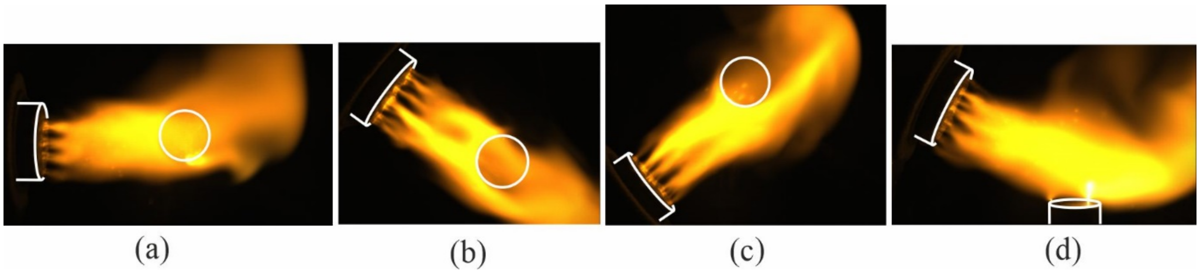

Fig. 3. Plasma flows horizontally (a), at an angle downward (b), at an angle upwards (c) and downward on the anode end (d). White lines indicate the contours of the cathode unit and the metal anode.

The porous insert was made of a refractory material. The anode was a copper rod with a diameter of 25 mm. He was cooled by water.

Electric power was supplied from a rectifier with an output voltage of 1700 V. The current was controlled by a step change in the ballast resistor. The flow of the electrolyte through the porous insert in the current range of 7–12 A was 5–8 ml/s.

To heat losses.

A feature of a gas discharge with a liquid electrolyte cathode is that the heat loss through the cathode unit depends on the flow rate of the electrolyte flowing through it. Regulation of the electrolyte flow allowed the reduction of heat losses through the electrodes to relatively small values (fig. 4). Total heat losses through the electrodes did not exceed 30% of the power consumption.

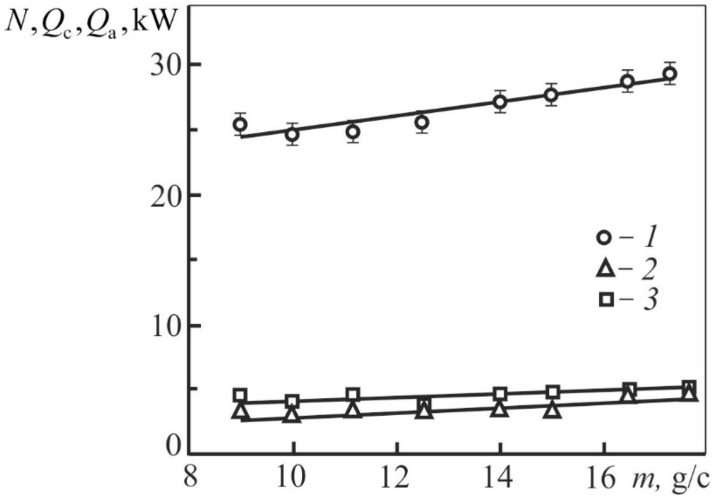

Fig. 4. Powers of the plasma generator (*N*) and heat losses through the electrodes (Q_c and Q_a) as a function of the electrolyte mass flow rate (*m*). σ = 11 mS/cm. *1* – *N*; *2* - Q_k; *3* - Q_a.

Conclusions.

The most suitable electrolyte for long-term combustion of a gas discharge is an aqueous solution of sodium chloride. Its concentration should be in the range of 0.05 to 0.2 mol/l. Using a porous insert on the cathode, one can obtain plasma flows in different directions in space.

Acknowledgments. This work is supported by the Russian Federation President's grant for the state support of young Russian scientists - MK-111.2022.1.2

References

1. **Friedland S.V., Tazmeev A.K., Miftakhov M.N.** Vestnik Kazanskogo tekhnologicheskogo universiteta. 2006. № 6. C. 10-15.