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SHORT COMMUNICATIONS
PLASMA CHEMISTRY

Features of Mass and Charge Transport to Gas Discharge Plasma from Aqueous Sodium Chloride Solution Serving as a Cathode

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Interest in gas discharges with an aqueous salt, base, or acid solution as a cathode is due to the fact that they make it possible to obtain nonequilibrium plasma at atmospheric pressure by relatively simple methods. The plasma itself has a great potential for practical application [1–5]. It is mainly formed from the components of the aqueous solution. This fact is confirmed by the presence in the emission spectrum of a gas discharge of intense lines and bands due to atoms, molecules, and other solvent and solute fragments [6–8]. The emission spectrum also manifests the presence of impurities, the content of which in the aqueous solution is as low as ppb level [9].

As is known, free electrons do not exist in liquids, including water. Therefore, in the case of a cathode in the form of an aqueous solution, there is no thermionic emission and there is no ejection of electrons by ion bombardment. The mechanisms of electron escape to plasma that are characteristic of arc and glow discharges with metal cathodes are inoperative. To explain the mechanisms of charge transport from solution to plasma and vice versa, various models are proposed. Thus, Polyakov et al. [10, 11] substantiated a model of the two-step emission of electrons from a liquid cathode. In the first step, the particles accelerated in the discharge generate valently unbound electrons in the aqueous solution and the electrons are subsequently hydrated. In the second step, layer-by-layer evaporation of the near-discharge volume of the aqueous solution containing hydrated electrons is assumed.

In [12–14], the cathode sputtering of an aqueous solution was taken as a basis. It is believed that the substance is transferred mainly in a droplet phase from the cathode to the plasma. Anions and cations in the droplets enter the discharge region, and charge carriers are generated from them in the discharge gap.

Sirotkin and Titov [15] considered the ratio in which the evaporation and atomization mechanisms contribute to mass transport from the liquid to the gaseous phase. It was found that cathode sputtering prevails in the current range of 10–50 mA. The experiments were carried out using an aqueous solution of sodium chloride with a concentration of 0.5 mol/L.

Processes on the liquid/plasma interface are mainly studied at low currents, which are tens of milliamperes. There is no reason to believe that the picture of phenomena will remain unchanged when the current load is increased.

The purpose of this work was to study the processes of mass and charge transport to gas discharge plasma from an aqueous electrolyte cathode at increased currents.

The experiments were carried out on an setup described in [16]. The current used was $I = 11.00 \pm 0.05$ A. The length of the discharge gap was 7.0 cm. As a liquid cathode, a sodium chloride solution in distilled water with a concentration of $C_0 = 0.1$ mol/L was used. Its volume in the hydraulic system of the experimental setup was unchanged, $V_s = 15.0 \pm 0.1$ L. In the experiments, the constancy of the volume was ensured by adding distilled water to compensate for the consumption of the solution. This operation was performed in a continuous mode with observing the condition of equality of the consumption and addition rates. In the chosen current regime of the discharge, the aqueous solution was consumed at a rate of $m = 0.71 \pm 0.02$ g/s.

In the experiments, it was found that after gas discharge treatment, the pH of the aqueous solution increased (up to 11.0 or more). This change is explained by the fact that during the discharge, some of the Cl^- anions are removed from the solution and replaced by hydroxyl (OH^-) ions. Since the solution contains Na^+ cations, the gas discharge results in the formation of sodium hydroxide in the dissociated state. It can be neutralized by adding hydrochloric acid to the solution. In this case, the reaction yielding sodium chloride will occur: