Study of a DC electric discharge with a cathode loaded in the water flow

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Abstract. A gas discharge in the air between two solid-state electrodes, one of which is in a stream of water and serves as a cathode, has been studied. Two variants are considered. In the first version, the working end of the cathode protruded from the water, and in the second version it was completely immersed in water. Electric and spectral characteristics of discharges obtained under the same conditions of electric power are presented. As the cathode, aluminum, copper, titanium and graphite rods were used. The discharge current was in the range of 13-15 A.

1. Introduction

Electric discharges excited in the presence of a liquid medium are of interest as a tool that allows one to obtain a plasma with extensive possibilities of practical applications. They find application in the processes of water purification, the synthesis of metal nanoparticles, the preparation of finely dispersed oxide powders and many other technological processes [1-9].

In experiments, the metal electrode is either mounted deep inside the liquid, or above it. In this work, an intermediate variant is considered when a solid-state cathode is located near the surface of a liquid medium – water.

2. Experiment

The experiments were carried out on an experimental setup, a detailed description of which is given in [10].

Figure 1. The cathode assembly. 1 – rod cathode; 2 – dielectric tube. Arrows indicate the direction of the water flow.
In the figure 1 schematically shows the cathode assembly. It consists of a rod cathode 1 inserted into the dielectric tube 2. The figure shows two options: (a) - above the water; (b) - under water. The working end of the cathode in version (a) comes out of the water and is not wetted by water, in version (b) it is under a thin layer of water. Depth of immersion $h$ with allowance for water rise is within 2-3 mm.
Figure 2. Instant photos and waveforms. Exposure 0.2 ms. Location of the cathode: (a) - above water; (b) - under water.

Cathodes from various materials were used in the experiments. The anode was made of copper. The mass flow rate of water was 10 g/s. The specific electrical conductivity was within 150 ± 10 μSm/cm.

The interelectrode distance (from the end of the cathode to the anode) was set to 4 cm in version (a) and 5 cm in version (b). The discharge radiation was recorded with a high-speed AvaSpec-3648 optical fiber spectrometer in the wavelength range of 484-708 nm with a resolution of 0.15 nm (diffraction grating – 1200 slits/mm, input optical gap – 10 μm). The radiation was projected onto the input of the spectrometer by a short-focus (28 mm) collecting lens.

3. The experimental results and their analysis

Figure 2 shows instant photographs of the electric discharge, as well as current and voltage oscillograms for the two cathode locations.

Aluminum cathode (figure 2, row 1).

In both variants ((a) and (b)), the cathode intensively erodes. Erosion products are solid fine particles of white color. The working surface is covered with a solid non-metallic crust, which has strong adhesion to the metal base. The plasma column is dominated by blue-blue radiation. In variant (b), a thin channel of red color is formed on the side of the cathode, characterizing the presence of radiating hydrogen atoms. Both in variant (a) and in variant (b), oscillations of current and voltage are recorded in the oscillograms, and in variant (b) the amplitude of pulsations is much larger.

Copper cathode (figure 2, row 2).

In variant (b), the emission of hydrogen atoms in the near-cathode zone becomes brighter. In this embodiment, current ripples and voltages are greatly enhanced compared to the aluminum cathode. The end of the cathode under the water is purified to a metallic state. The cathode eroded and smoothed. Fine particles of copper are found in the products of erosion. The electric discharge characteristics are described in more detail in work [9].

Titanium cathode (figure 2, row 3).

Radiation of a discharge is extremely bright in both variants. There are no specific shades. In variant a, current ripples and voltages occur rarely, in variant b they become intense and large-scale. In this case, some asymmetry is observed in the oscillograms of the current, and the voltage. At the end of the cathode a nonmetallic crust of black color is formed, which is destroyed intensely during the burning of the discharge.

Graphite cathode (figure 2, row 4).

With prolonged operation, unlike metallic cathodes, graphite lights up to form a flame. In variant (b), in the near-cathode zone, the emission of hydrogen atoms predominates, as is the case with aluminum and copper cathodes. Graphite eroded evenly along the end of the cathode.

Figure 3 shows spectra of discharges recorded at the time of the maximum radiation in the options of cathodes location under water. All spectra were obtained in the same operating mode of the spectrometer. Therefore, from the spectra it is possible to estimate the radiation intensities of discharges with different cathodes. From a comparison of the spectra it follows that the most intense is the emission of a discharge with a titanium cathode. Moreover, the discharge produces intense radiation in the entire wavelength range in the visible region. The discharge with the aluminum cathode emits intensively in the region of small wavelengths. In the radiation of a discharge with a copper cathode, only the spectral lines of copper atoms are the most intense. The radiatio of a discharge with a graphite cathode turned out to be the least intense. In the same modes of operation of the spectrometer, the radiation was not fixed.
4. Conclusions
When the cathode is under a thin layer of water, its erosion increases. A large number of products of erosion come in the plasma column. Particles heated in a plasma column intensify its radiation. The most intense radiation occurs in the case of a titanium cathode.

An electric discharge with a cathode immersed in an aqueous stream can be used to produce a heterogeneous plasma and to study its properties.

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