

## Research of plasma-electrolytic processes in various ratio of the area anode to the cathode

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**Abstract.** The object of research is the plasma-electrolytic processing, namely the influence of area ratio of the anode and the cathode to the parameters of the process. Defined area ratio anode to cathode, at which the discharge burning occurs on the cathode, on the anode or on the both electrodes simultaneously. Determine the required ratio of the electrodes ( $S_1 \geq 2 S_2$ ) for discharge burning of the electrode  $S_2$

### 1. Introduction

Recently, most research efforts aimed at the study and application of low-temperature plasma produced when using liquid electrodes. Gas discharge is initiated on the surface of one of the electrodes immersed in an electrolyte, wherein burning takes place between solid and liquid. Given combination of electrodes allows the polishing, cleaning, formation of micro-relief surface [1,2], the application of functional coatings [3], diagnosis and cleaning fluid [4]. Despite the numerous practical applications of this variety of gas discharge at the moment there is no consensus about its nature and its main parameters. It is considered that the discharge occurs subject to inequality of surface areas of solid electrodes  $S_1 > 5 S_2$  [5,6], immersed in an electrolyte. It is assumed that the discharge burns in the steam shell, which was formed by the heating liquid around the electrode. But it is also possibility to ignition of the discharge in gas bubbles formed on the surface of the electrode [7]. At present there is no information on which of the electrodes – on the anode or on the cathode will be the initiation of a gas discharge when they have the same areas, and depending on the type of electrolyte used. Therefore, the aim of this work is to determine the influence of ratio of the areas electrodes on the course of plasma-electrolytic processing.

### 2. Experimental

The study was performed on the installation, the functional diagram is shown in Figure 1. It consists of a current source 1, electrode system 2, the oscilloscope 3, series resistor 4, of the plating bath 5, voltmeter 6, thermocouple 7, ammeter 8.

The electrode system is formed so that the electrodes are vertically fixed by horizontal metal bolts, through which current flows. To prevent changes in the size of the area on the electrodes were putted on the dielectric protective covers that are left open just a well-defined part of the electrode. Maximum surface area of electrode in contact with the surface of the electrolyte was 339.5 mm<sup>2</sup>. For ignition discharge on any of electrodes its contacting surface decreased relative to initially a predetermined maximum value.



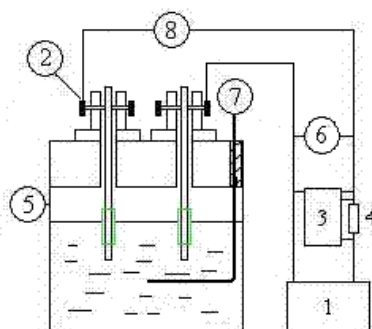


Figure 1. Functional diagram of the experimental setup.

Investigations were carried out on specimens made of steel grades 12X18H9T, Art. 3, copper, graphite. Before the experiment the samples were subjected to a thorough grinding and subsequent polishing. The electrolytic bath is filled with the studied electrolytes the required concentration and composition. As studied electrolytic cathode, an aqueous solution of  $\text{NaHCO}_3$  5% of concentration by weight,  $\text{pH} = 7$ .

The main operating parameters of the electrode system: the voltage on the electrodes, the magnitude of the discharge current, the current density on the electrodes. Voltage increased stepwise at an interval of 5 - 10 V. Measuring the voltage on the anode was carried out by a digital multimeter device APPA 105 relative measurement error of 0.1%. With a digital multimeter APPA 305 we measured current. Changing the shape of current and voltage at the time of discharge ignition was determined by the oscilloscope FLUKE 105 time base varied from 5 ns to 60 s.

### 3. Results

Let's consider initiation of a gas discharge in a solution of  $\text{NaHCO}_3$  with different electrodes. For convenience of description, plasma-electrolytic process, introduce the parameter  $a/k$ , indicating the ratio of the area of the anode to the cathode area. When using electrodes made from steel 3, a ratio  $a/k = 1$  discharge burned at the anode surface, the ignition voltage of 110 V. In the case of the other electrodes at voltages of 110 - 120 V short bursts were observed on the cathode, but with increasing voltage at the cathode chuffing disappeared and sustained discharge burning is initiated at the anode. In case of using steel electrodes 12X18H9T (0,12% - C, 18% - Cr, 9% - Ni and Ti < 1%) with  $a/k = 2,26$  discharge began to burn on the cathode at a voltage of 110 V, while burning electrode is red-hot and began to melt. The current-voltage characteristics (CVC) plasma-electrolytic processing using steel electrodes 12X18H9T shown in Figure 2.

The working solution during the plasma-electrolytic processing with steel electrodes did not change. When using copper electrodes solution turns blue, preserving transparency.

Figure 3 shows current-voltage characteristics of a plasma-electrolytic processing using 5% solution of  $\text{NaHCO}_3$ , for various area ratios electrodes 3 made of steel, copper. Current-voltage characteristics of the discharge on the anode are different from the CVC discharge on the cathode by having a maximum. For CVC of the anodic process is characterized by a high near 130 V for nearly all electrodes, except for copper. In case of using copper electrodes at low voltages is a maximum due to the formation of the oxide layer and its subsequent destruction. The presence of this process leads to a shift of the main peak in the region of 150 V, and discharge initiation occurs at 120 V. In the case of the cathode of the process current-voltage characteristic increases linearly, then reaching a certain value and remains constant. Can distinguish that the discharge burning on the cathode occurs at a high current density than anode. Let us consider in more detail the current-voltage characteristics of

plasma- electrolytic processing with electrodes made of steel 3. In an applied voltage of 170 V for the ratio  $a/k = 1$  current density was  $26 \text{ mA/mm}^2$ , and for  $a/k = 1,76$  -  $52 \text{ mA/mm}^2$ . Investigation of the ignition discharge at various  $a / k$  showed that it is possible to achieve the ratio at which the discharge will occur at both electrodes. For electrodes made from steel 3 in a ratio  $a/k = 1,45$  alternately the discharge burning observed at both electrodes. But it is also burned in the cathode first, and then further increasing the voltage on the anode ignited. For the ratio  $a/k = 1,76$  and above the discharge burning occurred only at the cathode. A similar pattern was observed for the copper electrodes. The figure clearly shows if you do not take into account the values of the currents that shape the curve for  $a/k = 1,45$  is from itself an intermediate state between the curves for  $a/k = 1,76$  and  $a/k = 1$ . And it is precisely this curve traced two maxima at 130 V and 170 V. When comparing the CVC for  $a/k = 1$  and  $a/k = 1,76$  with CVC for  $a/k = 1,45$  shows that the peaks at 130 V are the same, difference is that the second peak, which arises from the dominance of the cathode discharge at high voltage. This behavior of the CVC is due to, that at different times the discharge burning prevails at any one of the electrodes.

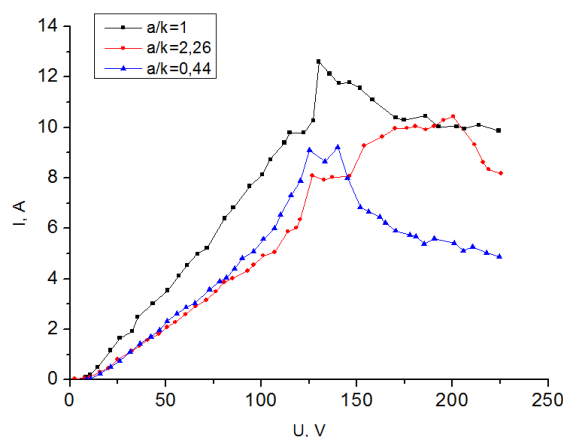


Figure 2. Current-voltage characteristics of a plasma-electrolytic processing using a 5% solution  $\text{NaHCO}_3$

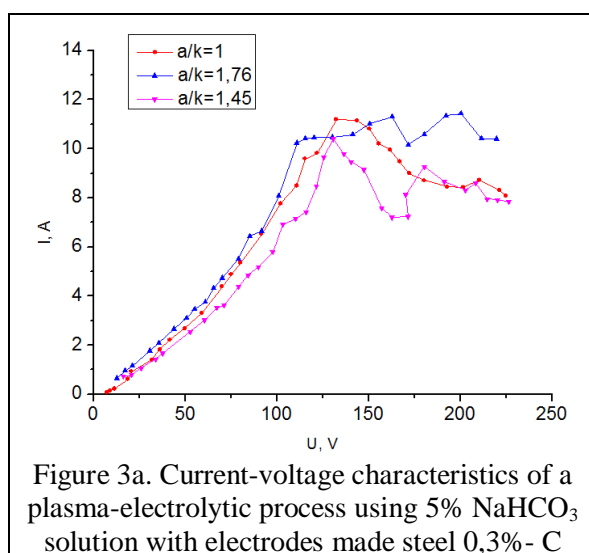


Figure 3a. Current-voltage characteristics of a plasma-electrolytic process using 5%  $\text{NaHCO}_3$  solution with electrodes made steel 0,3%- C

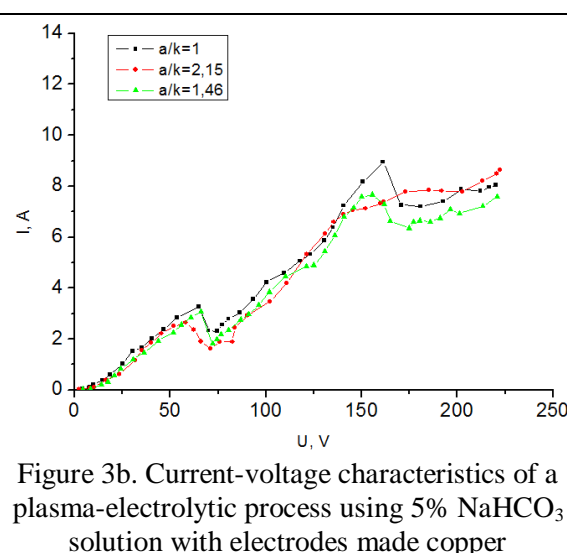


Figure 3b. Current-voltage characteristics of a plasma-electrolytic process using 5%  $\text{NaHCO}_3$  solution with electrodes made copper

Using the ripple voltage allowed simultaneously initiates discharges both the anode and cathode. The applied voltage obtained after full wave rectification affects each new period. Analysis of the oscillograms confirms this statement. By selecting a certain area ratio anode to cathode ( $a / k = 1.46$ ) allowed a variable discharge burning on the anode and cathode. Thus, a prerequisite for discharge

burning of the electrode  $S_2$  is the following relationship:  $S_1 \geq 2 S_2$ . This will optimize the technological process of plasma-electrolytic processing and make it more energetically favorable.

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