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Experimental study of voltage fluctuations in a glow discharge

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Abstract The article is devoted to the experimental study of voltage pulsations in a glow discharge. The longitudinal discharge was ignited in a stream of air moving in a cylindrical discharge chamber (DC). Copper hollow electrodes were located at a distance of a = (2-8) cm from each other along the axis of the DC. The gas pressure P = (4.7 - 26) kPa and its flow rate G = (0-0.06) g /s were monitored. The discharge current and voltage varied accordingly in the ranges: I = (20-100) mA, U = (1, 5 - 4, 2) kV. The current-voltage characteristics of the discharge were measured. The voltage decreased with increasing current, which is typical for a given type of discharge. The oscillations of the discharge voltage were registered by an oscilloscope; the current-voltage characteristic of the discharge was recorded by a two-coordinate recorder. Three regions of the current-voltage characteristic were detected. The luminous positive discharge column (PC) occupied the entire interelectrode space in the current region I = (100-70) mA. In the current range I = (70-40) mA there is a smooth transition to the discharge without visible glow of the PC with a significant increase in the discharge voltage. With further reduction of the current intensity (the third region), the discharge exists almost at a constant voltage until its quenching. Low-frequency and high-frequency oscillations of the discharge voltage were observed at the boundary of the second and third regions of the current-voltage characteristic.

1. Introduction

A plasma glow discharge is widely used in gas-discharge light sources, as the active medium of gas lasers [1-10], modern technologies for production of various coatings, nanotechnology methods for obtaining unconventional materials [11-14]. Therefore, the study and research of glow discharge plasma parameters is of great scientific and practical interest. Glow discharge in longitudinal and transverse gas flows is actively investigated in modern conditions [15 – 18]. This is due to the needs of practice, since for specific technological tasks various DC and ways of organizing the flow of matter in them are required. Obtaining a stable discharge with the parameters necessary for practice is one of the problems in this area. The glow discharges, as well as the arc discharge, are generally no stationary [19-20]. The purpose of this article is an experimental study of voltage fluctuations in a longitudinal glow discharge.

2. Experiment

The scheme of the experimental setup is shown in Fig. 1. The air through the needle cone **1** and the flow meter **3** (rheometer RDS-10) was supplied to the discharge chamber DC **4**. The DC is a quartz tube with an internal diameter of 10 mm (Fig.1.b). The discharge was ignited in the longitudinal flow between the copper hollow cylindrical electrodes: the cathode and the anode.

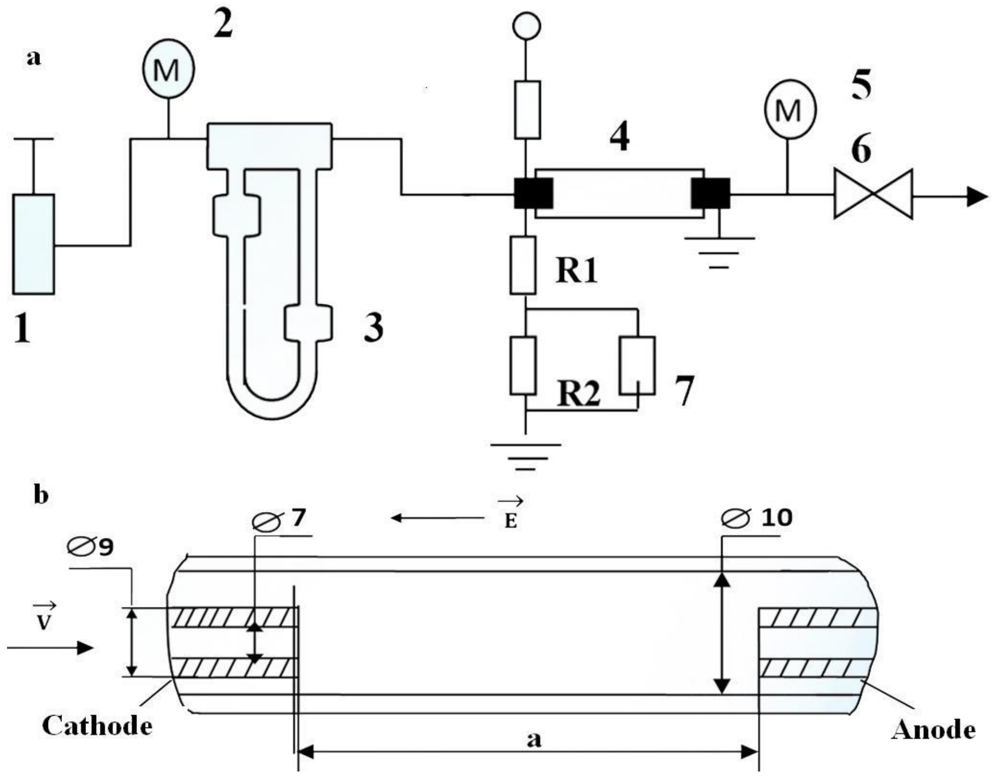


Figure 1. The scheme of the experimental setup: a - gas-dynamic path; b-discharge chamber.

The gas moved in a direction from the cathode to the anode. The distance between the electrodes could be changed in the range from 2cm to 8cm. The spent medium from the DC entered the capacity and was removed into the atmosphere by a vacuum pump. The static pressure in the RC was measured by U-shaped mercury manometers **2** and **5**. The flow rate and the pressure value were controlled by the valve **6**. The oscillations of the discharge voltage were registered by an oscilloscope **7**. The current-voltage characteristic of the discharge was recorded by a two-coordinate recorder of the type H-306.

3. Results

Figure 2 shows the current-voltage characteristics of an electrical discharge in an air stream. The experiment showed three characteristic regions of current-voltage characteristics. After the ignition of the discharge, the starting point falls on the first region I of the current-voltage characteristics. Therefore, for the full description, the inverse branch of the U-I characteristic is considered. Figure 2 shows two volt-ampere characteristics: 1- for a discharge with an air flow, 2 - for a discharge in still air. For the first curve, with a decrease in current strength from 100 to 70 mA (curve 1, region I), the value of the discharge voltage slowly increases. The positive discharge column reaches almost to the cathode. In the current range I = 70 ... 40 mA there is a smooth transition (region II) of the luminous discharge to the discharge without visible glow. With a further decrease in the current intensity (region

III), the discharge exists almost at a constant voltage up to quenching. The glow in this case is observed only from the ends of the hollow electrodes. In the quiescent gas (curve 2), there are also all three regions of the current-voltage characteristic. However, region I shifts towards lower currents, and regions II and III are respectively narrowed.

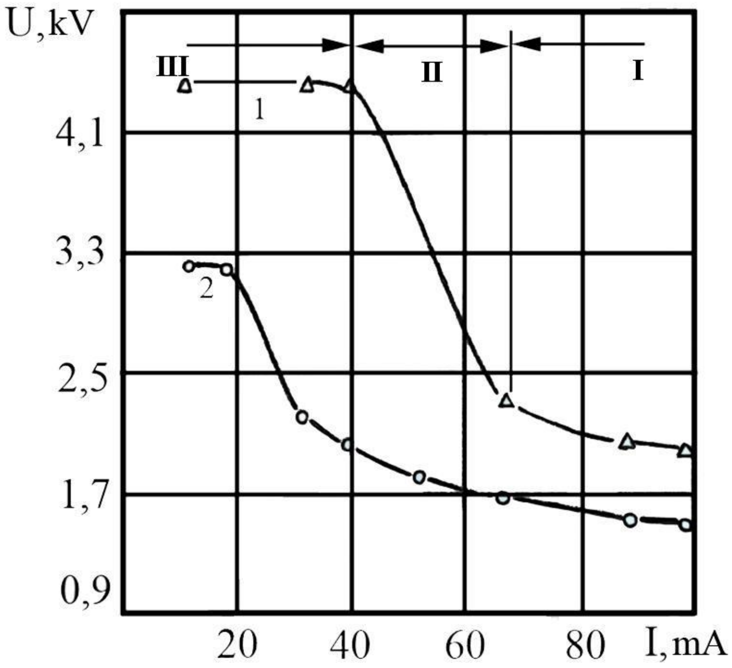
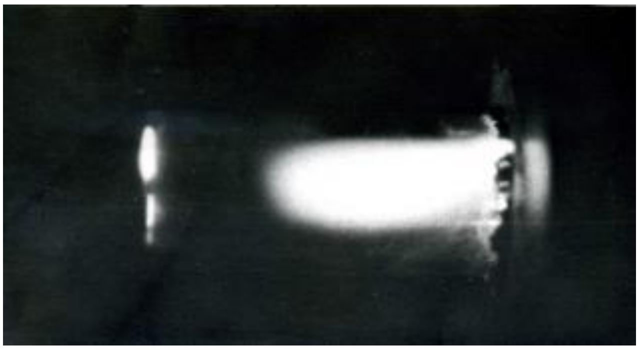


Figure 2. Current-voltage characteristic of an electric discharge in the longitudinal air flow: a = 0.04 m, P = 26 kPa; 1 – G = 0.04 g/s; 2 – G =0.

The current-voltage characteristics practically did not change when the polarity of the electrodes changed.

Photos of the discharge are shown in Figure 3. As can be seen from the photographs (Fig. 3a), the discharge consists of a brightly shining region extending up to the anode and a dark space near the cathode. Directly at the cathode there is the luminous layer. It was found that as the current increases, the length of the dark space decreases, and the surface of the cathode, covered with a luminous layer, increases. In a discharge with a gas flow (Fig. 3b), the positive column of the discharge contracts and loses its axial symmetry.



a

b

Figure 3. Photos of the discharge without a gas flow (a) and with a gas flow (b), P= 3, 6 kPa, a = 0, 03 m, I = 10 mA: a – G=0, b – G = 0, 02 g/s.

With increasing air flow, the discharge voltage first rises, reaches a maximum, then decreases and remains constant (Fig. 4).

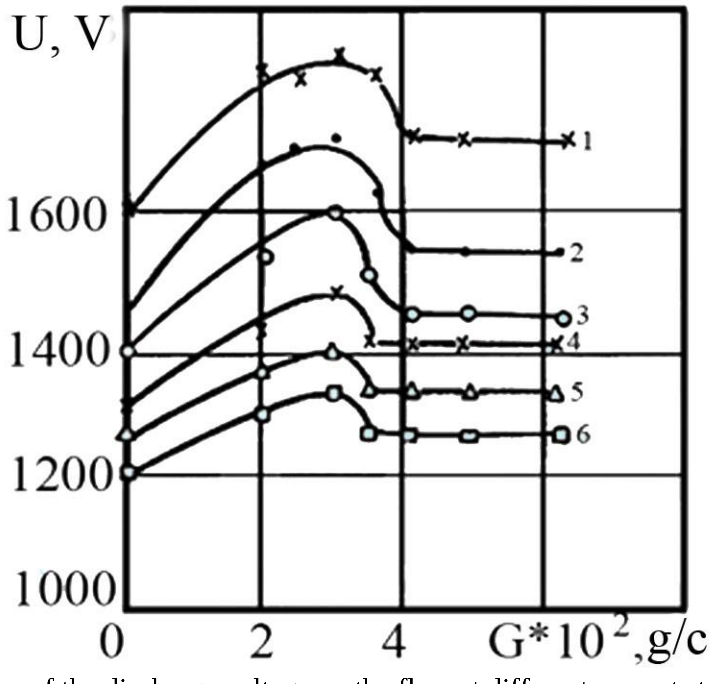


Figure 4. Dependence of the discharge voltage on the flow at different current strengths: 1- I=30 mA; 2- I= 40 mA; 3- I= 50 mA; 4- I= 60 mA; 5- I=70 mA; 6- I= 80 mA; P = 4 kPa.

With increasing pressure and decreasing current strength, discharge stability deteriorates, and voltage pulsations appear (Fig. 5). Low-frequency periodic and aperiodic damped voltage fluctuations occur in a discharge without an air flow. These voltage pulsations occur due to low frequency oscillations of the power supply voltage. The frequency of the variable component is 300 Hz. These low-frequency ripple voltages correspond to the discharge without visible glow of the PC. With further reduction of the current intensity, the discharge is extinguished. In the air flow, the nature of the oscillations varies. High-frequency voltage oscillations (Fig. 5) with a frequency f = (5 – 100) kHz appear in a discharge with an air flow. This feature is observed throughout the investigated range of currents. High-frequency voltage pulsations have the shape of a sinusoid, and their frequency decreases with increasing airflow. The region in which high-frequency voltage oscillations occurred was determined by analyzing the oscillograms. High-frequency voltages oscillations are absent at currents greater than 20 mA.

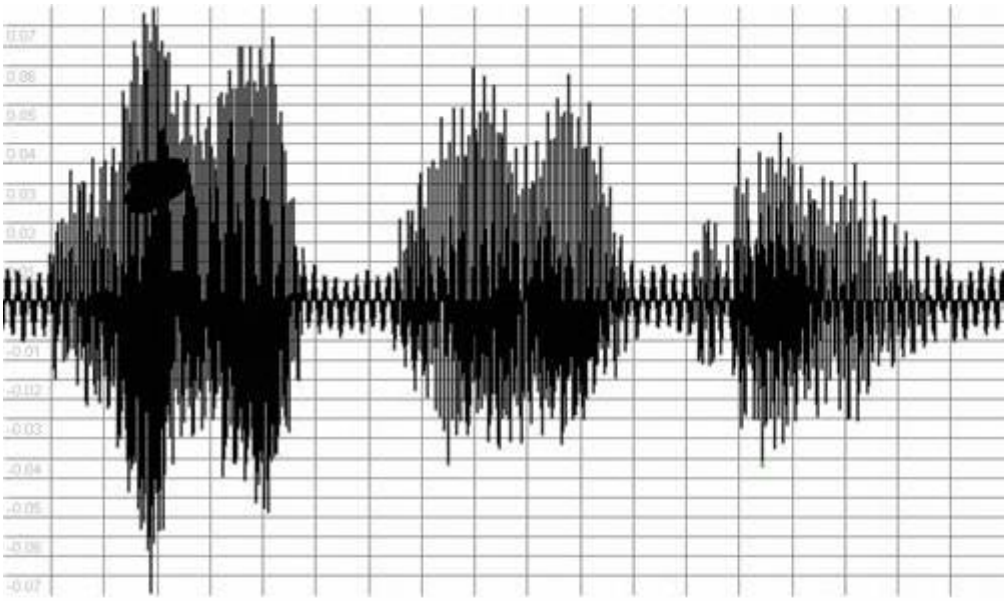


Figure 5. The typical oscillogram of discharge voltage pulsations: G = 0.03 g / s, I=8 mA, U=1380 B

4. Conclusions

A longitudinal glow discharge in the air flow was studied in this paper. The effect of air flow on the current-voltage characteristics of the discharge was obtained. An increase in the air flow in the interval G = (0-0.03) g / s causes an increase in the discharge voltage. With a further increase in the flow rate to the value G = 0.06 g / s, the discharge voltage practically does not change. Simultaneously with this increase in the discharge voltage, its structure changed: the discharge lost its axial symmetry and contracted. With a decrease in the discharge current in the interval I = (70-40) mA, the luminous region of the discharge disappears, and its voltage increases sharply. In this region of transition to the dark form of the discharge, high-frequency and low-frequency oscillations of the discharge voltage are observed. An increase in the air flow rate leads to an increase in the discharge current, at which high-frequency voltage pulsations occur.

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