The influence of a supersonic flow of gas at glow discharge

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Abstract. Experiments have been carried out to study the effect of a supersonic gas flow on a transverse glow discharge in the case when the supersonic gas outflow enters the region of Faraday dark space, i.e. the positive column ends before reaching the supersonic jet. And also in the case when the supersonic outflow of gas falls into the region of the positive column. It is established that the organization of the supersonic flow changes the glow pattern of the glow discharge, creating a spatial inhomogeneity in the interelectrode space.

1. Introduction

Supersonic gas pumping can significantly change both gas-dynamic parameters and electrical characteristics, such as the concentration of charged particles, the electric field strength, in the interelectrode gap of a glow discharge [1-5]. In [1-3], the authors studied the mutual influence of the electrical characteristics of the discharge and the gas-dynamic parameters of the flow in supersonic nozzles with a Central body. They showed that supersonic gas pumping can significantly increase the stability of the discharge and increase the energy deposits in the discharge. In [4-5], it was shown how the distribution of internal characteristics of a glow discharge can be controlled using supersonic gas pumping. However, the range of pressures at which the effect of supersonic gas pumping is most clearly manifested in the parameters of the glow discharge was not so wide. Basically, this effect depends on the discharge volumes, the location of the supersonic flow core, the current value, and, of course, the pressure itself. Therefore, this paper continues to study the processes that occur when a glow discharge interacts with a transverse gas flow passing at supersonic speed through the discharge core.

2. Experimental setup

The experimental setup for studying a glow discharge in a supersonic flow consisted of vacuum systems, gas supply, electric power, measuring devices, and a vacuum flask, inside which the supersonic nozzle, confuser, and electrode system were placed axysymmetrically (figure 1.). The Electrodes are located along a straight line perpendicular to the axis of symmetry of the nozzle and confuser, at a distance of l=35 mm from each other. The pressure was measured at three sites: at the nozzle inlet, in the space under the dome, and the restored pressure after the confusor. The gas flow rate was determined using a rotameter of the RS-5 type. The power source was a direct current source, which allows you to smoothly adjust the voltage in the range from 0 to 5 kV. The source has a built-in ballast resistance, an ignition device, as well as an ammeter and voltmeter. The vacuum system consisted of a vacuum pump, a receiver and a vacuum flask.
The nozzle and the confuser is made of PTFE. The confuser is used for organizing compaction surges and pressure recovery. The nozzle is a special gas channel for changing the gas velocity, consisting of a confusor and a diffuser parts. The geometric dimensions of the supersonic nozzle are as follows: the diameter of the nozzle in the critical section $d_1 = 0.5 \text{ mm}$, at the outlet and $D_1 = 5 \text{ mm}$, the area of the critical section $S_1 = \pi \cdot d_1^2/4 = 0.196 \text{ mm}^2$, the area of the output section of the nozzle $S_2 = \pi \cdot D_1^2/4 = 19.625 \text{ mm}^2$. The length of the supercritical part of the nozzle is $l_1 \text{ mm}$. The geometrical sizes of nozzles: diameter at the critical section of $d_2 = 4 \text{ mm}$ and at the entrance of $D_2 = 10 \text{ mm}$, respectively. The area of the critical cross sections $S_3 = \pi (d_2 - d_3)^2/4 = 0.785 \text{ mm}^2$, the area of the inlet section of the nozzle $S_4 = \pi D_2^2/4 = 78.5 \text{ mm}^2$. Length of the subcritical part of the confuser is $20 \text{ mm}$.

3. Experiment

Initially, a pressure of 5 Torr was created under the flask and in the receiver. Next, a glow discharge was carried out and a rotameter was used to organize the supply of a supersonic air flow to the discharge area. The pressure in the discharge area was raised to 17 Torr. Figure 2 and figure 3 show photographic images of the discharge for different currents and gas flow rates.

4. Discussion of experimental results

In Figure 2, the gas pressure and discharge current correspond to the case when the supersonic outflow of gas enters the region of Faraday dark space, i.e., the positive column ends before reaching the supersonic jet. In the photo, the area of the supersonic jet does not glow at all and is visible as a black column with a diameter of 5 mm. The edges of this pillar glow, clearly highlighting its borders. Moreover, the glow near the supersonic jet has a reddish color, while the positive column glows white. This fact is explained by the fact that the supersonic jet works as an injection pump, removing gas particles near the flow boundary. This creates a thin region of gas rarefaction near the supersonic jet. Despite the small values of the electric field strength in the region of Faraday dark space, the greater rarefaction of the gas provides a reduced electric field strength $E/N$ sufficient for the excitation of oxygen atoms. This condition is met on both sides of the supersonic jet.
Figure 2. Image of the discharge glow. The supersonic gas flow is located in Faraday dark space

Figure 3. Image of the discharge glow. Supersonic gas flow is in the positive column

In figure 3, the gas pressure and current strength correspond to the case when the supersonic outflow of gas falls in the region of the positive column. In this case, the positive pole is broken. Just as in the previous case, the positive pole does not light up. But the glow is observed on both sides of the supersonic jet.

5. Conclusions
Thus, the organization of the supersonic flow makes it possible to influence the glow pattern of the glow discharge, creating a spatial inhomogeneity in the interelectrode space. This, in turn, makes it possible to artificially create not only different brightness of the radiation of different sections of the positive column, but also to choose different colors of radiation.

References
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