Heat Characteristics of Glow Discharge at Low Pressure with Supersonic Gas Flow

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Abstract. Here, the results of experimental investigations on neutral gas temperature distribution over glow discharge plasma under transverse supersonic gas flow through a confined area of the discharge space. It is found that in the flow area the gas temperature decreases sharply. In addition, this leads to further increase of neutral particles concentration in flow area and, as a result, sustain existence of discharge at extremely low pressures.

1. Introduction
An impact of transverse supersonic gas flow on the glow discharge characteristics was observed in recent papers [1 – 4]. The effect opens up real opportunities to manage internal parameters of the discharge [5-8]. Namely, the glow discharge self-organization under proper supersonic gas flow will be determined by the flow area position in the discharge space. Supersonic gas pumping permits to obtain variable values of the neutral gas concentration over the discharge space. This effect is brighter with low pressures in the chamber. Certain advantages of such realization of the discharge are observed also with moderate and elevated vacuum pressures. The physics of processes with transverse supersonic gas flow pumping is determined by values of electric field strength. At very low pressures when the free path length of neutral particles is of the order of inter-electrode distance the self-contained glow discharge cannot operate: at these conditions the electrons on the path from cathode to anode cannot reproduce sufficient number of positive ions. Appearance of neutral particles in the confined flow area of the inter-electrode distance leads to generation of electron-ion pairs there due to collision ionization. Consequently, we have a peculiar distribution of the charged particles' concentration, electrons and ions will move off from the flow area with different velocities. As a result, in the area of higher concentration of neutral particles one has a higher concentration of positive ions. Elementary calculations shows that ions drift speeds are higher than a flow rate [3]. Therefore, ions are removed from this area by electric field, but not by gas flow. Both the internal field of space charges and the superposed external field provide a peculiar distribution of electric potential and field strengths. Electric field is slightly increasing till the boundary of supersonic stream area then it is sharply decreasing. Thus, all nearelectrode areas of a classical glow discharge are moved in a supersonic area [9-12].

2. Experiment
Results of the experimental investigations of axial temperature distribution in discharge chamber are represented in this work. Electrical schematic diagram of the discharge chamber for neutral gas temperature measurements is shown in Fig. 1. The discharge chamber represents the
cylindrical channel of molybdenum glass. The chamber has special branch pipes for installation of supersonic nozzle 5 to provide the supersonic stream and confusor 6 for gas evacuation. Cathode and anode during experiment are water-cooled. The supersonic nozzle and confusor made of epoxy, put on the corresponding branch pipes of a discharge chamber and hermetically sealed. Such nozzles are applied at not really larger velocities of supersonic flow. The chromel-copel thermocouple 4 was used for the temperature measurements. During experiment the thermocouple was moved along an axis of a discharge chamber. Movement of the thermocouple 4 was controlled by means of a vernier scale.

![Diagram of the probe researche discharge chamber axial section](image)

**Fig. 1.** Diagram of the probe researche discharge chamber axial section, 1 – cathode; 2 – anode; 3 – the interelectrode space isolated by molybdenic glass; 4 – thermocouple; 5 – the air evacuation pipe; 6 – the pipe for supply of gas in the chamber through the nozzle.

3. **Discussing**

There are many ways of gas heating in the glow discharge. As the ionic mobility is much less than electron mobility, the electric field energy is generally transferred to electronic gas. Afterwards part of this energy is transferred from electrons to neutral particles by elastic collisions, i.e. it is spent for direct gas heating [9]. The rest part is spent to excite the oscillating freedom degrees of molecules. Due to these processes, rather high vibrational temperatures are achieved in molecular gases. Just, the very small part of supplied energy is spent for electronic gas heating.

Experimental results of gas temperature measurement along the discharge chamber at various current values without supersonic gas flow are given in Fig. 2.
Fig. 2. Temperature distribution in the positive column along the channel for various discharge current values.

As it is seen from the Fig. 2, gas temperature smoothly decreases along a discharge chamber from cathode to anode.

The experimental results of gas temperature measurement along the discharge chamber at various current values with supersonic gas flow are given in Fig. 3.

Fig. 3. Axial temperature distribution in the discharge with supersonic gas flow.
4. Conclusion

Comparison of Fig. 2 and Fig. 3 shows that gas temperature in the field of a supersonic current (area from 23 mm to 28 mm) quite sharply decreases. Flow heat transfer and gas cooling due to the adiabatic expansion after supersonic nozzle can explain this.

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