Enhancing of the glow discharge stability in chamber with cathode sections coated by a discontinuous dielectric coating

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Abstract. A method of increasing stability of the glow discharge in a gas flow is implemented by reducing the effective current density at the cathode. In this method the current redistributes at the partitioned cathode using the change in the area of the working surface of each section by applying a discontinuous dielectric coating so that it reaches the distribution of the maximum sustainable current discharge across the working surface of each cathode section.

It is known low-temperature plasma of glow discharge is widely used as active media of gas lasers [1]. Flow of gas is effectively used to increase the volumetric energy deposition in a glow discharge both in subsonic and supersonic flow regimes [2,3]. However there is a significant heterogeneity of the distribution of characteristics in the transverse gas flow both along and across the direction of the electric field. It is necessary underline that the electric field in cathode area is much higher than in the main area of the discharge. There is also a significant energy release in the cathode region due to the high cathode potential drop. The discharge current tends to concentrate in the cathode spot with normal current density. Due to the increased electric field strength at the cathode the possibility of development of instability in this discharge region is greater than in the remaining region of the discharge.

This work presents a method of increasing the stability of the glow discharge in the gas flow by reducing the effective current density at the cathode region. According this method the current is redistributed at partitioned cathode by way of changing areas of the working surface each cathode section by applying a discontinuous dielectric coating to achieve the distribution of the maximum sustainable discharge current across the working surface of each cathode section.

Each cathode section is covered by the dielectric discontinuous coating with the ratio of the areas $S_M/S_C < 0,5$, where S_M - the area of the uncovered metal surface, for example in the form of a grid, and S_C – is the total surface area of the cathode section.

As it is known the discharge at the cathode region is compressed in the cathode spot whose dimensions are much smaller than ones of the positive column. Consequently substantial non-uniformity of the discharge is observed in the direction from the cathode to the positive column. In the proposed method the surface area of each cathode section can considerably exceed the working surface area. In this case the effective area through which the current flows on each section of the cathode is much larger than the area through which the current flows to the uncovered metal surface. So the average effective current density on the cathode section is smaller, respectively the dissipation

is stretched along the surface of cathode section and the average value it is also much less. The heat flow is distributed on a larger surface section of the cathode to be more efficiently withdraw due to external cooling. As a result the terms of discharge instability worsen, its homogeneity is increased. The range of the ratio of the surface areas $S_M/S_C < 0,5$ is defined because when $S_M/S_C > 0,5$ experiments have shown insignificant effect.

The method of organization of discharge in the gas flow has been implemented using the chamber depicted in Fig. 1. The anode of the discharge chamber 1 is made solid and flushed with the dielectric wall 2. The partitioned cathode is located between the dielectric plates 3. Cathode sections 4 is separated by a dielectric 5 and connected to the negative pole of the power source through the ballast resistances R. The discharge chamber is connected to gas pumping and cooling of the cathode sections, it is marked by arrows in Fig.1 a). A view of the cathode section from the discharge area is shown in Fig.1 b).
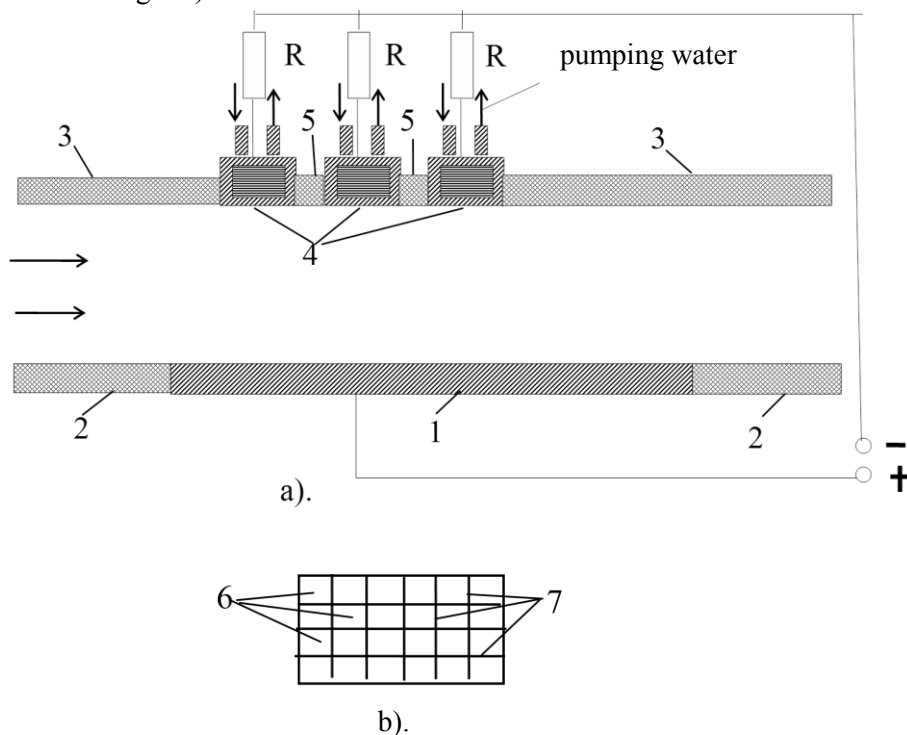

Fig. 1 a). A principal scheme of the discharge chamber. b). View of the cathode section from the discharge area.

The discontinuous dielectric coating is performed on a metal substrate, for instance in the form of squares 6. The remaining open metal surface forms mesh 7 on condition $S_M/S_C < 0,5$.

 This method is performed in following sequence:

1. to start pumping the gas through discharge chamber, to turn on pumping the cooling water throw the cathode sections 4, to apply voltage to the electrodes 1, 4, to measure the maximum sustainable discharge currents in each cathode section;

2. to register cathode section, which grid 7 is not completely covered by the discharge and to turn off the facility;

3. to recover again above-mentioned cathode section by discontinuous dielectric coating so that the working area of the mesh to reduce;

4. to repeat further the cycle 1-3 to achieve the result that the discharge will completely cover working surfaces of all cathode sections.

Discharge is eventually quasi-distributed along the entire surface of the cathode unit. In this case the average current density and the dissipation along the surface can be reduced more than an order of magnitude.

Experiments on the discharge chamber with the following parameters: the input cross-section of the discharge chamber 5x5 cm^2, gas flow rate of 3.4 g/s, the gas pressure is 38 Torr, pumped gas - air, bare metal surface on each cathode section forming a grid with a cell size of 5x5 mm^2, the area ratio of S_M /S_C was 0.09 (max current per section 0.1 A). Homogeneity and stability of the discharge significantly increased. Volumetric specific energy deposition reached 6.8 W/cm^3. Limit energy deposition is increased more than 2.5 times as compared to the case discharge chamber with uncoated dielectric cathode sections.

References
[1]   Raizer Yu P 2009 *Physics of gas discharge* (Moscow: Intellect)
[2]   Timerkaev B A 2014 Glow discharge in a transverse supersonic gas flow at low pressures *Therm. Phys. of high temp.* **52** 489 - 93
[3]   Saifutdinov A I and Timerkaev B A Drift model of glow discharge with account of nonlocal value of the electric field in the ionization source 2012 *J. Eng. phys.* **85** 1104‑09