FEATURES OF ATMOSPHERIC PRESSURE DISCHARGES WITH A TRANSVERSE COMPONENT OF THE VELOCITY OF GAS FLOW TO THE CURRENT CHANNEL

V.Ya. Chernyak, V.V. Iukhymenko, K.V. Iukhymenko, N.V. Klochok, O.V. Kolomiiets, D.K. Hamazin, D.L. Chernolutsky

Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

E-mail: yvitaliy@ukr.net, chernyak_v@ukr.net

The atmospheric pressure rotating gliding discharge was studied in work. A comparison of a rotating gliding discharge with a discharge in a transverse airflow were made. The clear analogies between rotating gliding discharge and discharge in the transverse airflow, were found during research.

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INTRODUCTION

Low-temperature plasma is used in various fields of science and technology. There are many designs of plasma generators with different types of discharges. Physicochemical activity of plasma has been known for over 100 years, however, a systematic study of plasma chemistry began only in the mid 60s of last century [1]. Today there are many scientific works devoted to these studies [2-9]. However, unsolved problem of creating powerful industrial atmospheric pressure plasma-chemical systems with long-term time of work that could generate wide-aperture flow of plasma still exists. Duration of work of the plasma generators is usually limited by electrodes erosion. The rotating gliding discharge (RGD) may be a promising source of atmospheric pressure plasma that satisfies above requirements. The interest to such system appeared because it allows obtaining non-equilibrium atmospheric pressure plasma with large cross section (tens of square centimeter).

1. EXPERIMENTAL SETUP

The scheme of the system for the study of a rotating gliding discharge is shown on Fig. 1. The system is an axisymmetric system of electrodes: the central electrode (1) and the peripheral electrode (2) are separated by a fluoroplastic insulator (3). The central electrode is an anode (+) and has a truncated cone shape. Its base is a ledge 2 mm high and 30 mm in diameter. The diameter of the cut surface of the cone is 8 mm, the height of the whole part is 8 mm. The peripheral electrode is an earthed cathode (-), a flange with a central aperture of 25 mm in diameter. The fluoroplastic insulator has a cavity and channels (4) are directed to the cavity with a tangent to form a vortex stream of plasma-forming gas. The discharge was ignited between the central and peripheral electrodes when supplied with voltage from the power supply. The airflow (G) supplied through the lower tangentially directed channels, carrying the discharge externally, causing it to slide along the electrodes of the system. The photos of the combustion of discharge at different airflows are shown on Fig. 2.

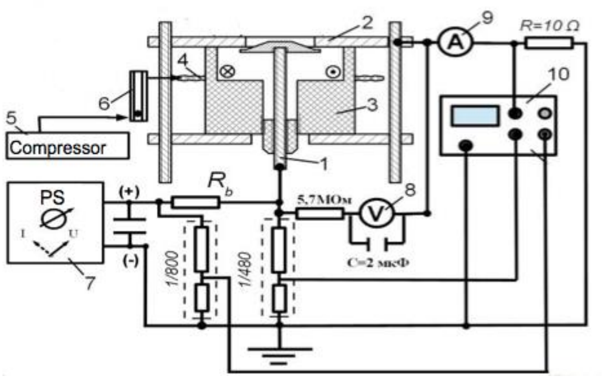

Fig. 1. Scheme of an experimental system for the study of a rotating gliding discharge

Photography and video of the discharge was carried out using the NIKON D7100 camera, with a fixed frame exposition of 1/8000 to 1/30 s and a frame rate of 60 frames per second. Video of the discharge made it possible to see that at the same time there is only one current channel rotating on the surface of the electrodes. At low airflow rotation is slow, and at high flow - very fast. Also from the photos and videos it was evident that this discharge is very similar in shape and behavior for transverse discharge (TD). It was decided to compare a rotating gliding discharge with a transverse discharge.

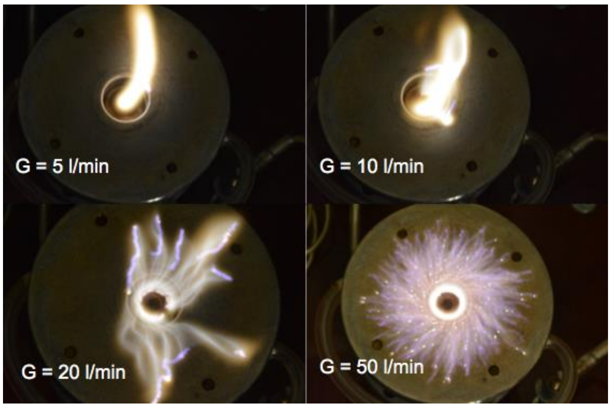

Fig. 2. Photo of the RGD at different air flows

A system based on a transverse discharge, unlike a rotating gliding discharge, has no axial symmetry, but has a symmetry relative to the plane. This fact makes studying the discharge more convenient, since the discharge moves in the frontal plane of the discharge system. The schematic drawing of the system for the study of the transverse discharge is shown on Fig. 3.

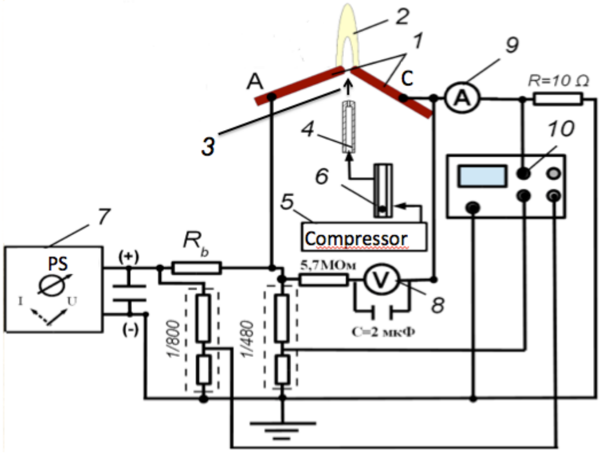

Fig. 3. Scheme of an experimental system for the study of a transverse discharge

The system consists of two electrodes (1) the left one – anode, the right one – cathode. Electrodes of cylindrical shape with a diameter of 6 mm. Material of electrodes – copper. The ends of the electrodes were rounded. The electrodes were inclined towards one another at an angle of approximately 120°. The inter-electrode distance was 1.5…2 mm. The airflow (3) supplied perpendicular to the discharge (2) through a tube with a nozzle (4) having a cylindrical aperture of 1.5 mm in diameter. The distance from the nozzle to the electrode is 15 mm.

In both experiments only the discharge part (plasma generator) was changed. All other devices remained the same. The airflow was inflated by the FIAC Cosmos compressor (5) and controlled by float rotameters (6). Depending on the type of system, the rotameters have the following grades: RS-3A (total airflow of 5 l / min) and Dwyer (RMA-22-SSV or RMA-23-SSV, 25 l / min and 50 l/min respectively). The voltage source served by the power supply unit BP-150 (7). Electrical parameters were measured with the help of standard analogue voltmeter (8) and ampermeter (9). The duration and shape of the discharge current and voltage signals were measured by the ATTEN ADS2202CA oscilloscope. Video of voltage and current oscillograms at discharge were provided with the camera Nikon COOLPIX L100.

2. RESULTS AND DISCUSSION

Current-voltage characteristics of the discharge are presented on Fig. 4. For both types of discharges current-voltage characteristics have descending character. This is typical for arc discharge. Photos of a rotating gliding discharge and a transverse discharge during the supply of air are shown on Fig. 5.

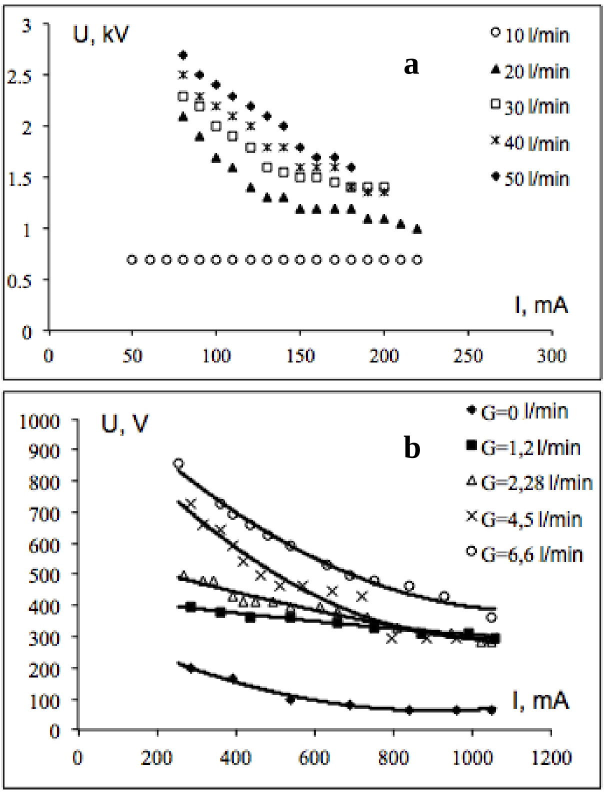

Fig. 4. Current-voltage characteristics of the rotating gliding (a) and transverse (b) discharges for different airflows

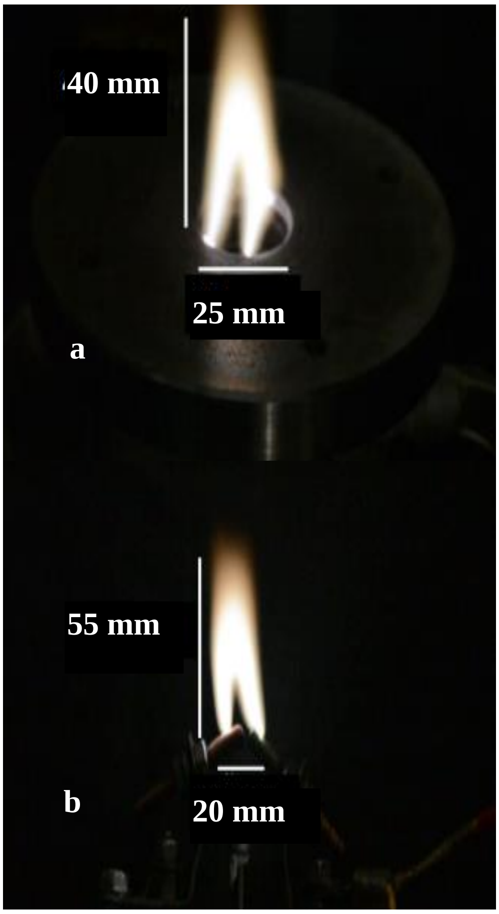

Fig. 5. Photo of discharges. Frame exposition 1/60 s, I = 300 mA. a – RGD, G = 6 l/min; b – TD, G = 0.5 l/min

Results obtained from video observations showed that the shape and size of the discharges are almost identical. The difference in the flows of the plasma-forming gas is due to the geometry of the arresters.

The length of the discharge changes, it increases with time and under the influence of airflow. When the maximum length is reached, the discharge breaks and re-ignites in the intercolectrode space (switched).

Discharge current channel appears as a thin filament diameter of about one millimeter (Fig. 6). The length of the discharge channel increases with time and under the influence of airflow. At break time, the length of the discharge is minimal.

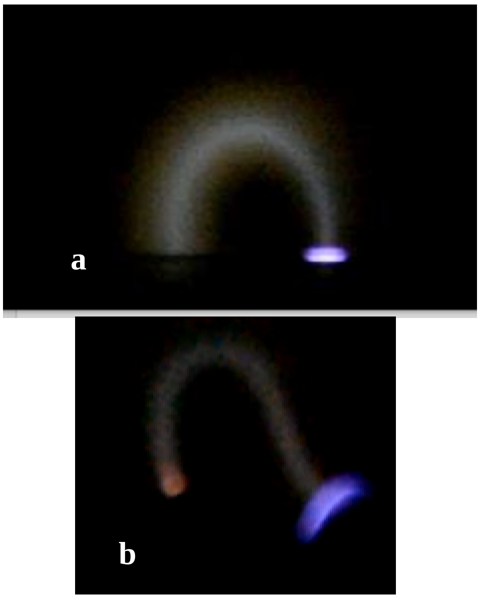

Fig. 6. Photo of the current channels. Frame exposition 1/8000 s, I = 300 mA. a – RGD, G = 6 l/min; b – TD, G = 0.5 l/min

In the rotating gliding discharge, the vortex stream of air swirling into a whirlpool by means of channels directed at the tangent to the wall of the fluoroplastic chamber, it stretched the discharge and forced to slide along the electrodes around the symmetry axis of the system. The discharge motion led to the movement of the points of attachment to the electrodes in the direction of motion and increases the length of the discharge channel. The phenomenon of changing the binding places depends on the velocity of the discharge along the symmetry axis of the system. It was also observed that the distance between the points of the binding of the discharge was always greater than the inter-electrode gap. At small streams, the discharge was drawn into a high and long arc, while the speed of its movement around the axis of the system falls. With the increase of the flow rate, the current channel was blown out on the surface of the electrodes, due to which its height decreased, but the length remained almost unchanged.

In the transverse discharge, there was also a change in the length of the current channel over time. There were observed pulsations of the current channel (the channel first increased, and then again became a small size). Also, the binding place on the electrodes changed.

On Figs. 7, 8 represent oscillograms of currents and voltages of rotating gliding and transverse discharges in the presence of airflow. The voltage was measured

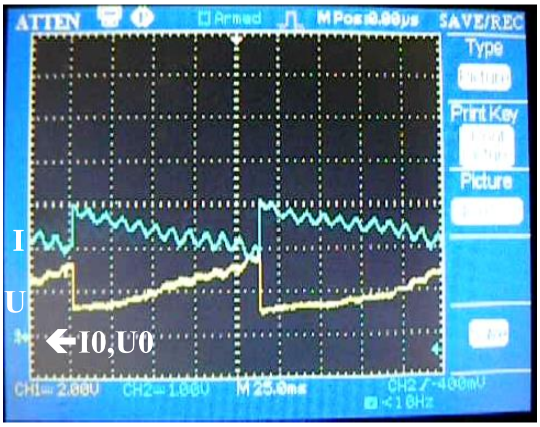

Fig. 7. Oscillograms of discharge current and voltage for RGD: I = 0.1 A/div, U = 960 V/div, t = 25 ms/div (G=6 l/min)

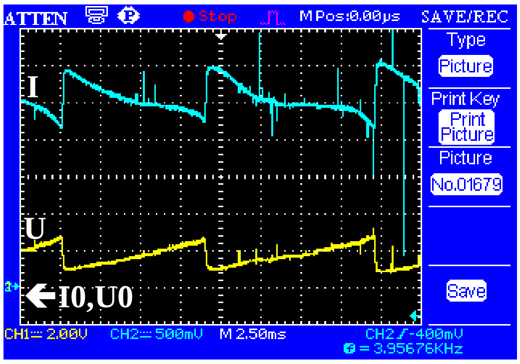

Fig. 8. Oscillograms of discharge current and voltage for TD: I = 0.05 A/div, U = 960 V/div, t = 2.5 ms/div (G=0.5 l/min)

using a voltage divider with a 1/480 ratio. The current was measured using a measuring resistor at a nominal 10 Ω. In the absence of airflow, oscillations of current with frequency of 100 Hz are observed. In the presence of airflow there is a fluctuation of discharge (the length of the current channel is changing) and the modulation of voltage and current at the discharge occurs pollen signal. From these results it can be concluded that transverse discharges of atmospheric pressure do not have a direct current mode when powered by a direct current source and the modulation of current and voltage is a saw tooth signal.

The main mechanism of current modulation is the periodic change in the length of the current channel with a constant electric field brought on, which is accompanied by a change in the binding sites to the electrodes. Increasing the length of the discharge current channel, and consequently increasing its resistance, leads to a gradual increase in voltage and, accordingly, a decrease in the values of current. It is worth noting that the voltage and current in the discharge never fail to zero.

Abilizations by the Bockasten method [10] for three sections of current channel of rotating gliding discharge were conducted (Fig. 9,a, lines 1-3). For these sections were built radial distribution of the emission coefficient of a plasma (Fig. 9,b). From these dependences, we see that at the semi-heights for different sections the diameter of the current channel has different values (1 ~ 1.2 mm, 2 ~ 2.6 mm, 3 ~ 3.4 mm).

For rotating gliding discharge the diameter of cathode binding ~ 3 mm and for TD ~ 4 mm.

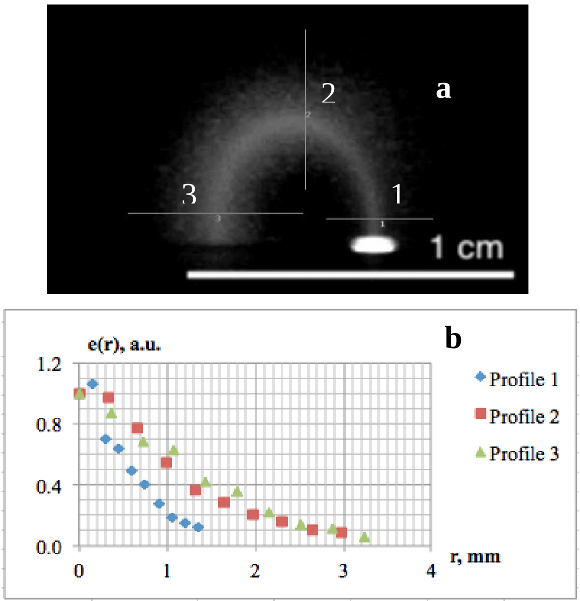

Fig. 9. (a) – photo of the current channel (RGD), (b) – radial distribution of the emission coefficient of a plasma

CONCLUSIONS

1. For atmospheric pressure transverse discharges there is no mode of direct current when direct current source is used. Current and voltage modulation occurs saw tooth signal.

2. The current channel is characterized by jump-like changes in the location of the binding to the electrodes. The jump time is significantly less than the time of the permanent binding location. Constancy of time between jumps is not observed.

3. The main mechanism of the saw tooth modulation is the oscillating nature of the change in the length of the current channel with a practically constant period at intervals of constant binding.

4. Diameter of current channels at atmospheric pressure in both discharges is about 1 mm.

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ОСОБЕННОСТИ РАЗРЯДОВ АТМОСФЕРНОГО ДАВЛЕНИЯ С ПОПЕРЕЧНОЙ СОСТАВЛЯЮЩЕЙ СКОРОСТИ ПОТОКА ГАЗА К ТОКОВОМУ КАНАЛУ

В.Я. Черняк, В.В. Юхименко, К.В. Юхименко, Н.В. Клочок, О.В. Коломиец, Д.К. Гамазин, Д.Л. Чернолуцкий

Исследовался вращающийся скользящий разряд атмосферного давления. Было проведено сравнение вращающегося скользящего разряда с разрядом в поперечном потоке воздуха. В ходе проведенных исследований вращающегося скользящего разряда и разряда в поперечном потоке воздуха были выявлены четкие аналогии между этими разрядами.

ОСОБЛИВОСТІ РОЗРЯДІВ АТМОСФЕРНОГО ТИСКУ З ПОПЕРЕЧНОЮ СКЛАДОВОЮ ШВИДКОСТІ ПОТОКУ ГАЗУ ДО СТРУМОВОГО КАНАЛУ

В.Я. Черняк, В.В. Юхименко, К.В. Юхименко, М.В. Клочок, О.В. Коломієць, Д.К. Гамазін, Д.Л. Чернолуцький

Досліджувався обертовий ковзний розряд атмосферного тиску. Було проведено порівняння обертового ковзного розряду з розрядом у поперечному потоці повітря. У ході проведених досліджень обертового ковзного розряду та розряду в поперечному потоці повітря були виявлені чіткі аналогії між цими розрядами.