The Rotating Gliding Discharge in Quartz Tube and Open Half-Space at Atmospheric Pressure

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Rotating sliding discharge (RGD) was investigated into limited volume and open half-space. The current-voltage characteristics of the discharge and its specifications are described. The results of optical research: photos and emission spectra of the discharge are presented.

Keywords: RGD, plasma, plasma chemistry, erosion.

1 INTRODUCTION

Active introduction of plasma technologies into industry has a number of limiting factors. The plasma device electrodes short life, which is connected with their erosion is one of them.

It is known from fundamental electric discharge machining (EDM) that most electrode degradation originated from high-energy particles bombardment. They are forming by high electric field intensity, when it existed at the electrode vicinity. So anode has degradation when energy input has short duration, but cathode has such process while the energy input duration is increased [1-2].

The first case relates to spark erosion, which is characterized by the streamer breakdown mechanism, and increased the value of the electric field near the anode. The second case relates to a so-called electric pulse mode [3], which is closer to the Townsend breakdown model.

In addition to these criteria, the erosion of the electrodes still largely determined by the electrode material, its temperature, native carrier gas pressure at which the electrical discharge current value and fed to the discharge capacity [4].

Thus, erosion is a rather complicated and complex phenomenon which is an integral part of DC discharges. A reduction of erosion is one from keys to the increasing reliability and service life of plasma devices.

In this work the rotating gliding atmospheric pressure discharge (RGD) in the curled air flow was investigated. It is assumed that this type of discharge is a promising atmospheric pressure plasma source for plasma-chemical hybrid wide-aperture systems [5].

2 THE EXPERIMENTAL SETUPS

The experimental setup for the investigation of RGD in the confined space, which is bordered by dielectric wall, is shown at figure 1. The same setup was used for investigation of RGD in the open half-space, but without elements (6), (7), (8) and (9), which are shown at figure 1.

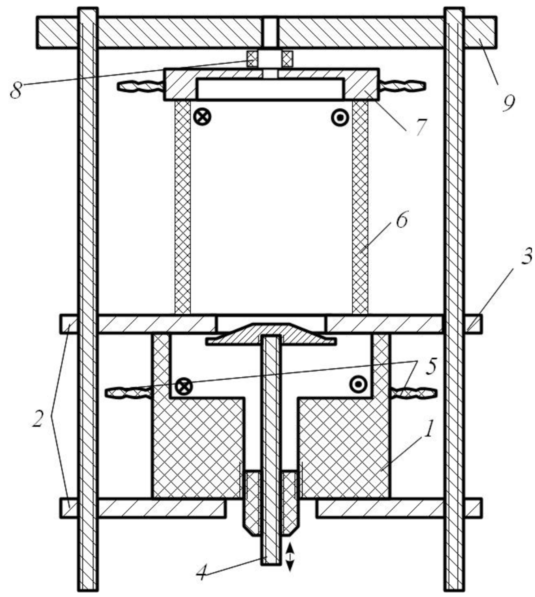

Fig.1: The scheme of experimental setup for research of RGD in reactor zone

The system schematic drawing (see figure 1.) shows fluoroplastic chamber (1) which is pinched between two metal flanges (2). Flange (3) is the system peripheral electrode, which has 10 mm height and contains the center hole with 25 mm diameter. The pin (4) is the system central electrode, which can moves vertically along the fluoroplastic chamber axis and there are various metal caps that can be wrapped on it. The central electrode has the shape of a truncated cone shape and base bump with 30 mm diameter. The air flow coming into the system through channel (5) and has direction tangentially to the wall of the chamber, mentioned above.

Quartz tube (6) is modeling of plasma-chemical system reaction volume (reactor) and attached over the electrode system. The top of quartz tube (6) is closed with flange, which has channels (7) that directed tangentially to the reactor wall. There are ceramic insulator (8) and clamp flange (9) in this system, also.

The central electrode (Figure 1, position 4) was positive (anode) and the peripheral electrode (Figure 1, position 3) was connected to the negative potential (cathode). The flow of air injected by FIAC Cosmos compressor and controlled with two rotameters. They were connected in parallel. The airflow is bleeding through channel (5), or through both channels (5) and (7) concurrently. It is depending on the airflow organization in the system (Figure 1).

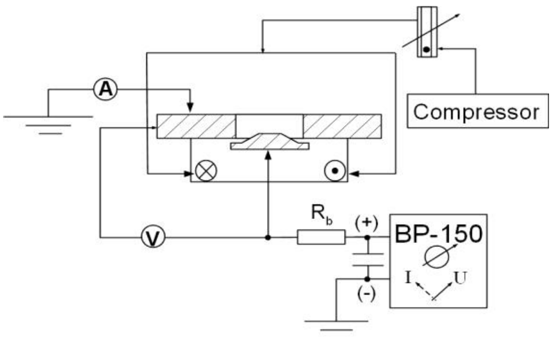

Fig.2: The electrical circuit including measuring lines

The power supply BP-150 served as RGD energy source. Electrical parameters were measured by standard analogue devices. The discharge current and voltage duration and waveform were measured by analogue universal two-channel S1-74 oscilloscope. Emission spectrum of RGD plasma radiation was registered by portable spectrometer Solar TII S150-2-3648USB. Photography and video surveillance were made by Nikon COOLPIX L100 photographic camera and NIKON D7100 camera-recorder. The last has the exposure time in the range from 1/8000 to 30 s.

3 RESULTS AND DISCUSSION

3.1 THE RGD IN OPEN HALF-SPACE AT ATMOSPHERIC PRESSURE

One of the main variables under investigation of RGD in the open half-space system was airflow through it. The comparison of current-voltage characteristics (CVC) obtained at different airflows (G=30-80 *l*/min) and constant electrode configuration, showed that CVC shape has weak dependence from airflow within the limits of experimental error (Figure 3).

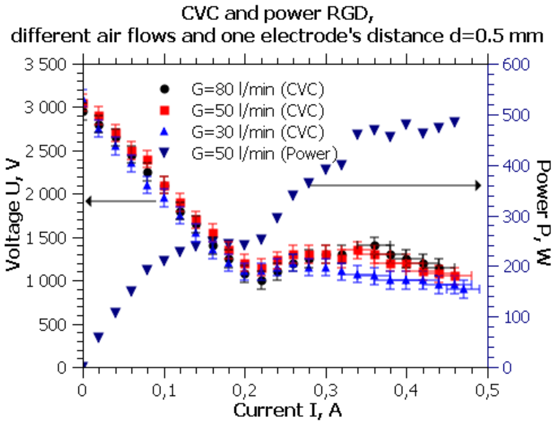

Fig.3: Rotating gliding discharge CVC

Researches of instantaneous values of voltage and current using oscillograms showed that current and voltage signals are unipolar and have fluctuating and constant components. The absolute values of the signals don't go down to zero in the quasi-stationary RGD mode. The fronts of current and voltage are reversed. The fluctuating components of current and voltage are connected, probably, with the changing of absolute discharge length. Increasing the length of the discharge channel leads to its bigger resistance, so current in it drops and the voltage increases. Oscillated current and voltage photos are shown at Figure 4. Here we use the following notations: CH1 - current, I (X: 2 ms/div, Y: 0.2 A/div); CH2 - voltage, U (X: 2 ms/div, Y: 480 V/div). White line is position of current and voltage zero, respectively. Oscillograms were received when average measured values of current and voltage were following: <I>=320 mA, <U>=1.300 kV.

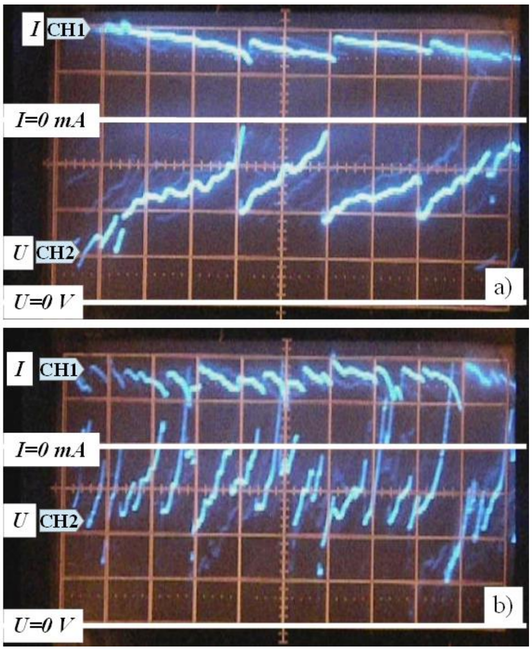

Fig.4: Photos of current and voltage oscillations. Airflows are 40 l/min (a), 80 l/min (b). Interelectrode gap d = 0,5 mm

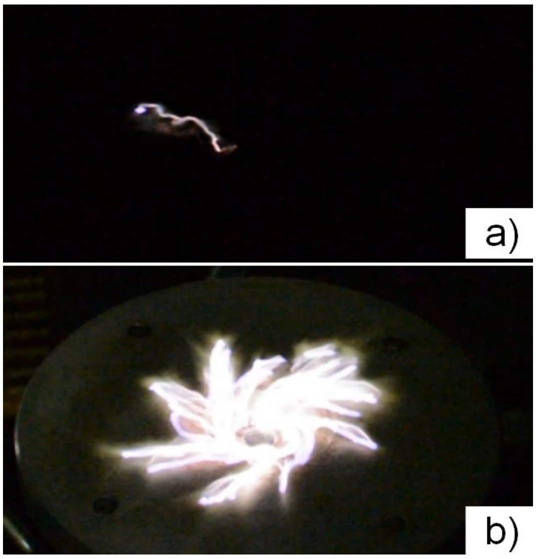

Fig.5: Air flow G=80 l/min, current <I>=320 mA, voltage <U>=1300 V, d=0.5 mm, exposure time 1/8000 sec (a) and 1/60 sec (b)

The pulsations of RGD current and voltage have average frequency which was estimated using oscillograms and they showed that it is increased, when airflow through the discharge gap has enhancement. This frequency belongs to the range from a few hertz to one kilohertz, for airflows 20 *l*/min and 80 *l*/min, respectively.

Photography of RGD (Fig. 5) at the different exposure time showed that discharge is a single subtle current channel that quickly rotates around the symmetry axis of the system.

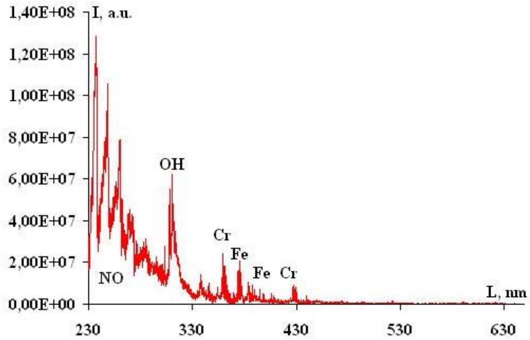

Fig.6: RGD emission spectrum. Airflow G=25 l/min., current <I>=310 mA, voltage <U>=1000 B

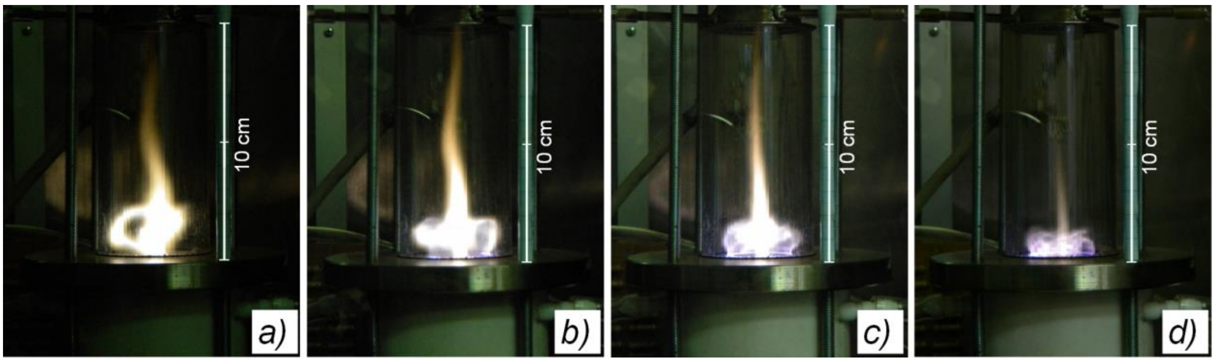

Fig.7: RGD in a confined space. The airflow is blown through the channels (5) and (7) (Fig. 1) with flow ratio 1/1. Interelectrode gap d = 0,75 mm. Exposure time: (a) 1/140 sec; (b) 1/48 sec; (c) 1/36 sec; (d) 1/22 sec

The RGD emission spectrum was obtained when optical fiber view axis had orientation on the axis of discharge rotation at 5 mm height above the flange (3) (see Figure 1).

This spectrum signal has accumulation time = 10 000 ms and presented at Fig. 6. Interelectrode gap = 1 mm.

The population temperatures of rotational [T_r(OH)] and vibrational [T_v(OH)] levels were calculated from the OH radical spectrum band (Fig.6.), which was processed with Specair 2.0 program. They are: T_r(OH)=3000 K (ΔT_r=1000 K) and T_v(OH)=4500 K (ΔT_v=500 K), respectively. The population temperature of electron levels [T_e(Cr)] was calculated from chromium atom lines. It is T_e(Cr)=6000 K (ΔT_e=500 K).

It should be noted, remembering the life of a plasma system, this discharge constantly moves on the system electrodes, so its discharge bindings cover quite large effective area of the system electrodes (~16 cm^2 at the cathode and ~2.5 cm^2 at the anode). Therefore, it is expected that systems based on RGD will have a longer service life.

3.2 THE RGD IN QUARTZ TUBE AT ATMOSPHERIC PRESSURE

Researches of RGD in a confined space showed that the glow region, which is formed at the system axis, has a torch shape. Figure 7 shows typical photographs torch glow. The photos were obtained when the total airflow, current and voltage were following: (a) G_Σ=30 *l*/min, I=300-310 mA, U=1300-1400 V; (b) G_Σ=40 *l*/min, I=280-300 mA, U=1400-1500 V; (c) G_Σ=50 *l*/min, I=300-310 mA, U=1200-1300 V; (d) G_Σ=60 *l*/min, I=320 mA, U=1000-1050 V. The presence of glow region at the system axis gives base for assuming that the use of such plasma generator will be effective for plasma chemistry needs. This torch, perhaps, will be a good injector for particles, which are activated by plasma, to the reaction zone of chemical reactor in plasma-chemical hybrid systems.

4 CONCLUSIONS

Researches of RGD into swirling airflow demonstrated:

1. RGD is a single current channel that rapidly rotating around the system symmetry axis.
2. Discharge current and voltage oscillograms point to the existence of fluctuating and constant components. The fluctuating component shape is closed to sawtooth.
3. When RGD is burning in the confined space the torch glow appears on the system axis.

Acknowledgements

This work was partially supported by Ministry of Education and Science of Ukraine, National Academy of Sciences of Ukraine, Taras Shevchenko National University of Kyiv.

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