CONNECTION BETWEEN ELECTRODES SHAPE AND PLASMA FLOW OF THE GLIDING DISCHARGE

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Contribution deals with form of electrodes and corresponding shape of plasma flow in the gliding discharge reactor. Gliding discharge sustained in air at atmospheric pressure and room temperature. There were studied three elemental electrodes configuration. Plasma was investigated by means of its visible spectral lines for identification of the most reactive plasma region in the flow. Results can be helpful in shaping of the gliding discharge reactor ionized gas region.

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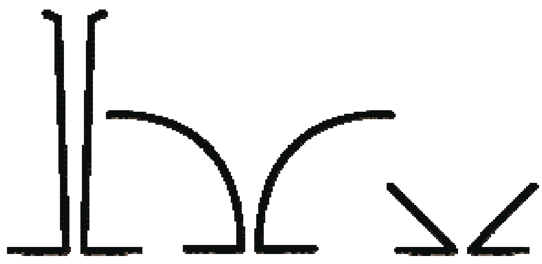
1. APPARATUS

Gliding discharge as "an auto-oscillating phenomenon developing between at least two electrodes that are immersed in a laminar or turbulent gas flow" [1] is subject of intensive studies and many technological applications. Simplicity of this technology stimulates efforts to find new areas of use. These may be connected with requirements on specific shape of plasma flow. To be able to estimate the flow shape, we constructed simple gliding discharge plasma reactor with removable electrodes and studied flow shapes for three types of electrodes (Fig. 1) – "low-divergent" (a), "circular" (b) and "high-divergent" (c) representing limit shapes of electrodes.



a b c

Fig. 1. Electrode shapes:
a – low-divergent, b – circular, c – high-divergent

The electrodes were created from copper wire of 1 mm diameter. Low-divergent configuration remained from two straight 130 mm long electrodes, circular configuration consisted of two ring-shaped (radius 22 mm) electrodes and high-divergent configuration was formed from two triangle-shaped electrodes.

Reactor contained pair of electrodes and was connected to the gas distribution system (compressor, reduction valve and flowmeter) (Fig. 2).

Working gas was injected through the nozzle into the discharge region of the reactor. Experiments were realized in air at atmospheric pressure 763 Torr, temperature about 21°C and humidity about 30 %. The air volume flow was about 20 slm in all experiments. Reactor was supplied by high voltage power source 8 kV/50 Hz. Initial discharge breakdown gap was held at 3 mm for all types of electrodes.

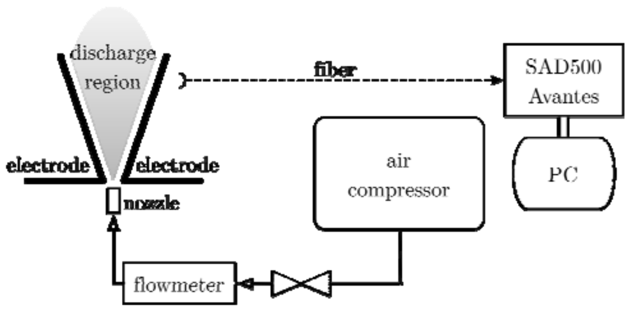


Fig. 2. Reactor with gas distribution system

During all experiments air was injected upwards into the reactor. and initial discharge breakdown gap was at its bottom (Fig. 3).

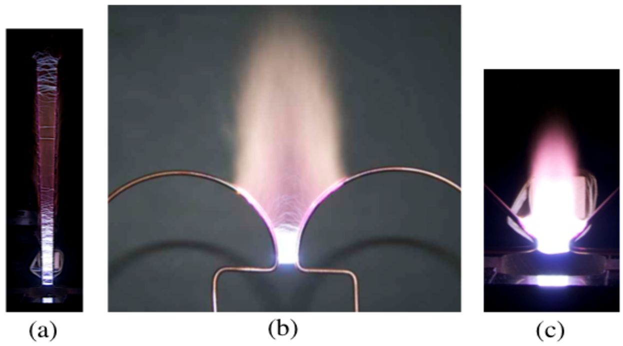


Fig. 3. Plasma flows:
a – low-divergent, b – circular, c – high-divergent

2. EXPERIMENTS

Plasma was investigated by means of its visible spectral lines for identification of the most reactive plasma region in the flow.

Spectra were scanned by "OceanOptics SAD 500, Avantes" fiber optic spectrometer in direction perpendicular to the plasma flow longitudinal axis. Spectra were taken along this axis in the whole discharge region. The spectrometer's wavelength range was adjusted to interval from λ_{down} = 190.35 nm to

λ_{up} = 861.41 nm, hence measured spectra's resolution λ_Δ equaled to

$$\lambda_\Delta = \frac{(\lambda_{up} - \lambda_{down})}{(\delta_\lambda - 1)} = \frac{(861.41 - 190.35)}{(2^{11} - 1)} \cong 0.328\,[\mathrm{nm}]\,,$$

δ_λ = 2048 was the number of samples corresponding to the bit range of A/D converter.

Air plasma spectra involve significant oxygen and nitrogen lines and we used them in evaluation of our experiments. Reactivity of air plasma is i.a. based on existence of exited oxygen and nitrogen atoms. For identification of the most reactive part of the plasma flow we measured intensities of plasma radiation in visible spectra range (Fig. 4), then used the NIST database [2] and found corresponding oxygen and nitrogen lines:

$$\text{for } \lambda_A = 463.061\,\text{nm : NIII; } 2s2p(^3P^\circ)4p\text{—}2s2p(^3P^\circ)5s$$

$$\text{for } \lambda_B = 463.885\,\text{nm : OII; } 2s^2 2p^2(^3P)3s\text{—}2s^2 2p^2(^3P)3p$$

$$\text{for } \lambda_C = 500.113\,\text{nm : NII; } 2s^2 2p(^2P^\circ)3p\text{—}2s^2 2p(^2P^\circ)3d$$

$$\text{for } \lambda_D = 567.602\,\text{nm : NII; } 2s^2 2p(^2P^\circ)3s\text{—}2s^2 2p(^2P^\circ)3p$$

Furthermore both the first negative system of N_2^+ and the second positive system of N_2 lines were identified near the wavelength 390 nm (see Fig. 4).

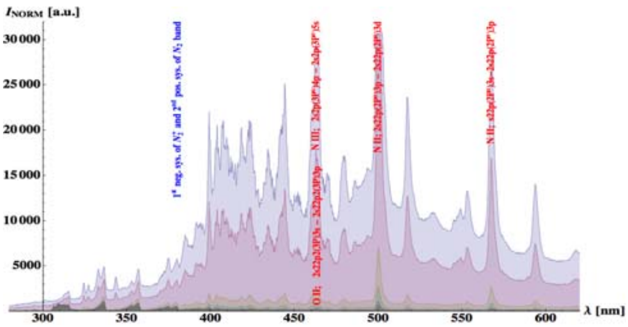


Fig. 4. Spectrum for circular configuration of electrodes

There is close relationship of observed spectral intensity peaks and plasma particles excitation. The most excited part of the plasma flow – marked with highest intensity values – seemed to be in vicinity of the ignition region in all tested configurations.

Individual spectral lines intensity distributions are on Fig. 5-7.

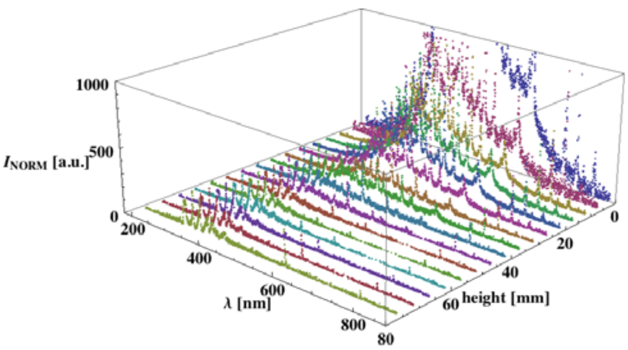


Fig. 5. Intensity distribution along longitudinal axis (low-divergent configuration of electrodes)

Position of the most reactive part of the plasma flow identified with spectral measurements seem to be in agreement with snaps of plasma flow (Fig. 3).

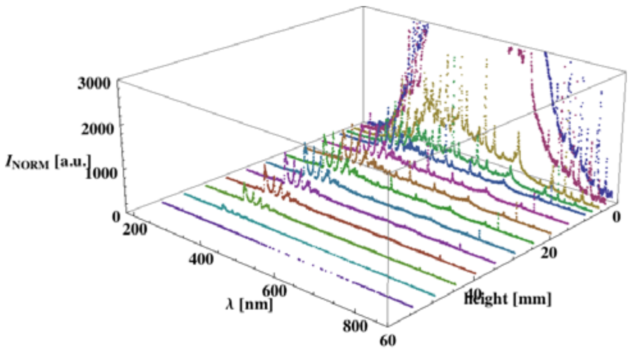


Fig. 6. Intensity distribution along longitudinal axis (circular configuration of electrodes)

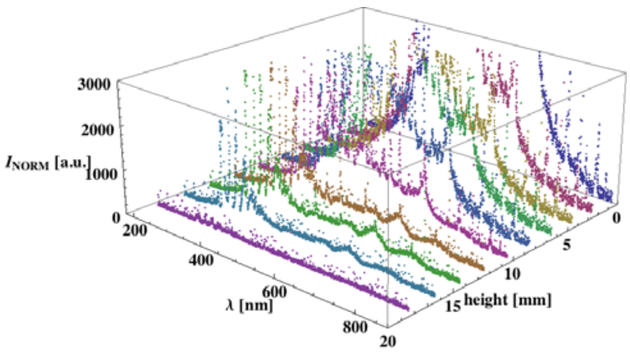


Fig. 7. Intensity distribution along longitudinal axis (high-divergent configuration of electrodes)

We can see that plasma flow existence was fully limited to the inter-electrode space in case of low-divergent configuration, when the ionized column rupture began in the first half of the inter-electrode space (see Fig. 3, a). On the contrary plasma flew out of the inter-electrode region in both circular and high-divergent configurations (see Fig. 3, b, c). It seems that the most ionized gas region probably exist at the outflow of high-divergent configuration.

Combination of these three electrode configurations might allow shaping of more complicated forms of the ionized gas region for every specific gliding discharge reactor application.

3. SUMMARY

- We studied connection between some elementary electrodes contours and corresponding plasma flow shapes in the gliding discharge reactor. Three basic electrode configurations were used.
- Experiments were realized in air at atmospheric pressure and room temperature.
- For identification of the most reactive part of the plasma flow we measured intensities of important oxygen and nitrogen lines in visible plasma radiation spectra.
- Results can be helpful in shaping of the gliding discharge reactor ionized gas region.

ACKNOWLEDGEMENTS

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ВЗАИМОСВЯЗЬ МЕЖДУ ФОРМОЙ ЭЛЕКТРОДОВ И ПОТОКА ПЛАЗМЫ СКОЛЬЗЯЩЕГО РАЗРЯДА

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Исследуется вопрос соответствия формы электродов и потока плазмы в реакторе со скользящим разрядом. Скользящий разряд поддерживался в воздухе при атмосферном давлении и комнатной температуре. Были исследованы три основные конфигурации электродов. Плазма исследовалась с помощью видимых спектральных линий для выявления наиболее активных областей в потоке плазмы. Результаты могут быть полезны для создания реактора со скользящим разрядом в ионизованной газовой области.

ВЗАЄМОЗВ'ЯЗОК МІЖ ФОРМОЮ ЕЛЕКТРОДІВ І ПОТОКА ПЛАЗМИ КОВЗАЮЧОГО РОЗРЯДУ

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Досліджується питання відповідності форми електродів і потока плазми в реакторі з ковзаючим розрядом. Ковзаючий розряд підтримувався в повітрі при атмосферному тиску і кімнатній температурі. Було досліджено три основні конфігурації електродів. Плазма досліджувалася за допомогою видимих спектральних ліній для виявлення найбільш активних областей у потоці плазми. Результати можуть бути корисні для створення реактора з ковзаючим розрядом у іонізованій газовій області.