# The Properties of Colliding Surface Discharges in Air

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It is known that discharges excited at the boundary between two dielectrics may be used in in medicine, plasma chemistry and aerodynamics applications [1-3]. One of the possible applications of surface discharge is the generation of micro-plasma formations in the gas at atmospheric pressure [4]. According to [5], the optimal values of E/p are implemented in micro-plasma providing realization of strongly-nonequilibrium medium. This feature may be used for the new materials synthesis or for properties modification of nano-scale objects. The micro-plasma formation is possible, when the oppositely-directed discharges are propagated by the dielectric layer surface from the two single-charged electrodes [6]. Early [7] it was shown that inter-electrode gap reduction up to L <5 mm limit the length of the streamer channels and influence on the natural discharge processes. The possibility of adjustment of the discharge at the micro and macro levels determines the interest in this phenomenon and need in a comprehensive study of the properties of such a discharge in dense gases.

This paper presents results study properties of the colliding surface discharges on fiber-glass plastic with different inter-electrode gap length (L=0.5-20 mm) and the thickness of dielectric substrate (d=0.8, 1.5 mm). The discharge was excited in a quasi-continuous mode with dU/dt ~ $10^9$ Volts per second (*f*=8 kHz) in the atmospheric air. Investigations were performed on an experimental setup which is shown in Fig 1 and completely described in [6,8]. Additionally discharges were registered in visual ($\lambda$=0.3-1$\mu$) and IR regions ($\lambda$=3-5$\mu$) of spectra by camera Panasonic-DMC-LC20EN and IR-camera IRTIS-2000.

Thus, our studies include simultaneous photo-registration of plasma emission, oscillographic measurements of voltage and current and spectral diagnostics in UV, visible and IR ranges.

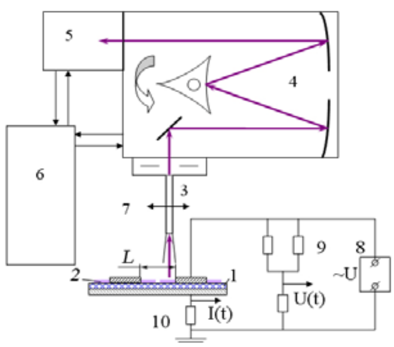



Fig.1. Experimental setup: 1-electrode system; 2-surface discharge; 3-waveguide; 4-6-spectrometer Shamrock sr-303i; 7- traverse; 8-hight-voltage source; 9-hight-voltage divider 10-shunt

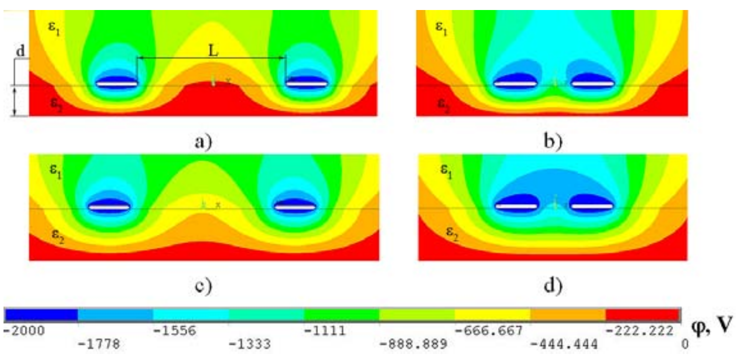
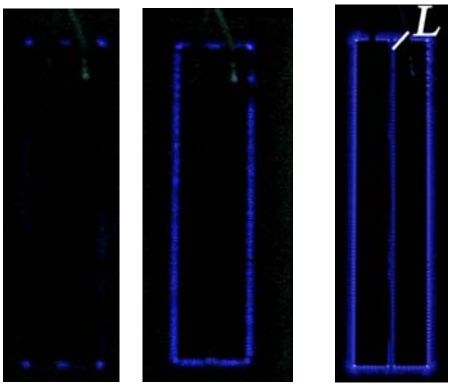



Fig.2. Electric potential distribution in colliding surface discharge electrode systems at pre-breakdown stage : a) L=4mm, d=0.8 mm; b) L=1mm, d=0.8 mm; c) L=4mm, d=1.5 mm; d) L=1mm, d=1.5 mm. Dielectric permeability: $\varepsilon_1$=1 (air), $\varepsilon_2$=5-6 (fiber-glass plastic)




a) b) c)

Fig.3. Discharge irradiation on dielectric surface around high-voltage electrodes at different voltage levels (L=2mm, d=1.5mm): $|U_a|<|U_b|<|U_c|$

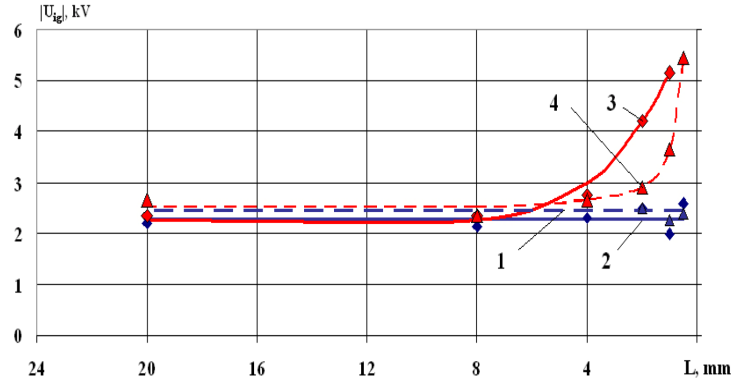
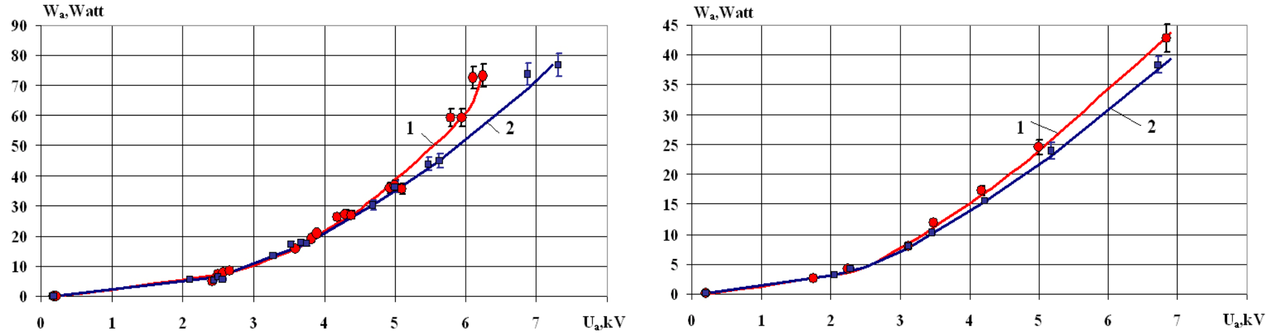



Fig.4. The ignition discharge voltage $U_{ig}$ vs inter-electrode gap length L for outer (1-d=0.8 mm, 2-d=1.5 mm) and inner (3-d=0.8 mm, 4-d=1.5 mm) electrods edges

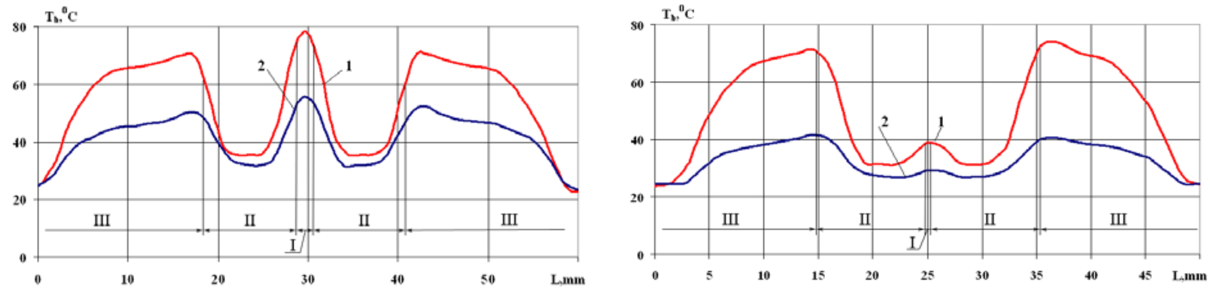
As the initialization of the processes is determined by the pre-breakdown stage of the discharge, we analyze the electric fields generated by designed electrodes configuration. The simulation was carried out in an electrostatic approximation in ANSYS program environment. The potential distributions are presented on Fig.2 and demonstrate the changes in the electric field structure when the distance between same sign charged electrodes is decreases. It is observed the potential equalization for gaps with L < 1 mm, which should complicate the process of ignition of the discharge. This fact is confirmed by experimental observations (Fig.3). As the voltage increases the glow of the discharge occurred on the outer edges of the electrode (Fig.3. a, b) and only after that the plasma is excited into inter-electrode gap (Fig.3.c). As it follows from Fig.4 the ignition discharge voltage in the inter-electrode gap starts to differ from ignition discharge voltage on the outer electrodes at L <4 mm. The magnitude of $U_{ig}$ is also affected by the thickness of the dielectric barrier, which is caused by the increase of the impedance.

The peculiarity of the discharge in a narrow gap is reflected by the alteration of active discharge power $W_a$ dependence on the voltage level [9]. For colliding surface discharges the transition to small gaps (L <1mm) leads to a decrease in $W_a$ (see fig.4). However, the observed changes are insignificant. It indicates a continuing of ionization process in the inter-electrode gap




a) b)

Fig.5. Active power $W_a$ vs voltage $U_a$ for different parameters of the electrode system: a)-d=0.8 mm, b) d=1.5 mm. 1-L=20 mm 2-L=0.5 mm



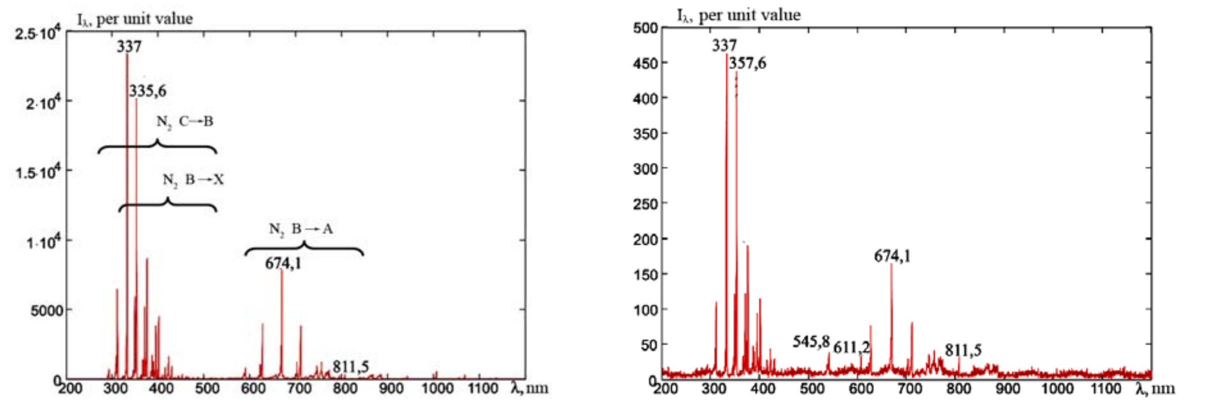

a) b)

Fig.6. The brightness temperature distribution on the working surface in center of electrodes system: a) - L=4 mm; b)-L=0.5 mm. 1-d=0.8 mm, 2-d=1.5 mm, I-inter-electrode gap; II- zone of discharge electrodes; III-outer zone

L, despite a significant reduction of the radiation intensity in visible spectral range. This is confirmed by the IR-imaging of the electrodes systems surface (Fig.6). It is clear that temperature gradients are present at the working edges of electrodes (zones II, Fig.6). This indicates the presence of continuous heat dissipation from the inter-electrode space L by dielectric substrate.

The emission spectrum studies were carried out with a help of spectrometer Shamrock sr-303i with a diffraction grating of 600 lines per mm. The recorded spectrums showed a domination of spectral lines associated with the emission of vibrationally-excited nitrogen in the discharge radiation (Fig.7 a). However, further reduction of the inter-electrode gap length (L <1 mm) leads to a decrease in nitrogen emission intensity in 50 times while argon spectral lines does not change significantly. It indicates the increase of the average energy of the plasma electrons.

The analysis of $1^+$ and $1^-$ bands of nitrogen [10] shows that the level $C^3\Pi_u$ is in partial local thermal equilibrium state (Fig.8). As it follows from Fig.9 the reduction of inter-electrode gap length is accompanied by the increase of the energy of vibrationally-excited particles: vibrational temperature of nitrogen increases from 2070 to 3360K for the decrease of L from 1 to 0.5 mm. This allows determining the vibration temperatures value of $N_2$ and its alteration during variation of the




a) b)

Fig.7. Spectral components of discharge radiation for electrodes system with L=0.5mm d=1.5mm: a) on outer electrodes edges; b) into inter-electrode gap

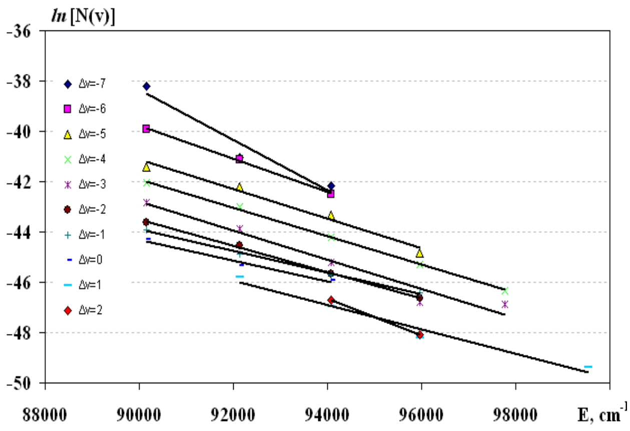



Fig.8. Normalized populations of vibrationally-excited levels for $C^3\Pi_u$-state depending on the energy level (in inter-electrode gap, L = 0.5mm d = 1.5mm)

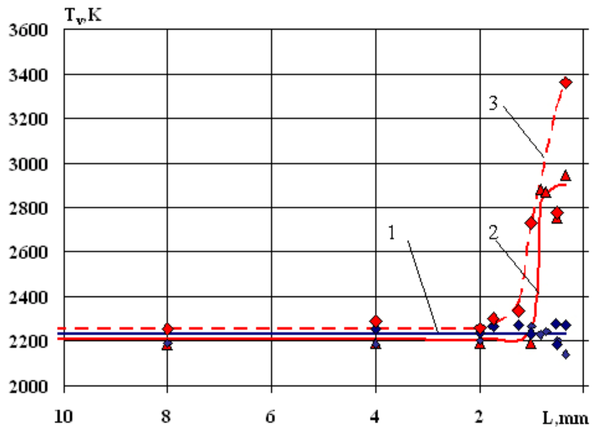



Fig.9. Nitrogen vibration temperature dependency from inter-electrode gap length L: 1-temperature on outside edges of electrodes 2- temperature into inter-electrode gap

electrode system parameters (Fig.9). This dependence has a threshold character and may be explained by the electron distribution function modification.The observed effect indicates the change of the burning mode of the colliding surface discharges when L is less than 1 mm and discharge possibility use for generation a non-equilibrium gas medium.

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