# Electrode erosion in DBD plasma actuators

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Electrodes erosion in plasma actuators can play a key role in aerodynamic applications, limiting durability of discharge systems and influencing discharge structure and characteristics. The paper is devoted to the detailed study of the morfological modification of the foil Cu and Al electrodes in surface DBD and its effect on the discharge parameters.

Plasma actuators based on dielectric barrier discharge are studied as a perspective tool for boundary layer control in various aerodynamic applications. Novel methods of the transition control, utilizing the strategy of boundary layer forcing from the leading edge by plasma actuators, strongly increase the requirements to the discharge parameters control. Among the key parameters influencing the discharge structure and its effect on the flow are the condition of the dielectric barrier and the exposed electrode edge. The degradation of the polymer barrier was studied in numerous works [1], [2], showing that local decrease of the barrier thickness near the electrode leads to progressive power consumption increase leading finally to the burnout of the actuator. This problem can be solved by using the ceramic barriers, resistant to the heating and etching in the discharge region. Still, the electrode degradation remains the issue for all known systems with the electrode exposed to gas, thus potentially limiting the durability of the actuator [3]. Besides, material and condition of the electrode edge strongly affect the dynamics of the microdischarges (MDs) that can possibly be the main reason of the turbulence generation by actuator.

Erosion processes in sDBD are not studied very well, still, some analogy can be taken from the corona discharges. In the latter case, electrode erosion takes place mainly in the negative polarity of the electrode [4], [5]. The mechanisms of the erosion can be different, from cathode sputtering to the elecro-exposive mechanisms. Both discharge dynamics and parameters was shown to be strongly affected by the oxide film formed at the surface of the electrode: formation of the stable oxide layer on the electrode leads to the chaotization of the discharge position on the tip and the special structure of the erosion pits on the electrode.

This work is devoted to the detailed study of the evolution of electric characteristics of the surface DBD during the tens of hours run in quiescent conditions, simultaneously with the study of the morphological changes of the electrode edge. Study was performed in a room air at discharge frequencies 25-100kHz and voltages up to 4kV. Actuator was manufactured using alumina ceramics as a dielectric. 20 μm thick copper and alumina foils were used for electrode manufacturing. Discharge power and the shape of volt-coulomb cycles were recorded simultaneously with the microscopic images of the discharge. Study of the electrode edge was performed both by SEM and laser scanning microscopy.

The structure of the discharge on the Al and Cu electrodes after an hour of operation is shown in fig.1a. Discharge structure is stationary for Cu electrodes, while for Al electrodes stochastic movement of the MD position occurs. Study of the electrode edge after the discharge operation shown that for Cu electode (fig.1b) at the position of the discharge the bare electrode material is observed, surrounded with a oxide redeposition regions. The edge of Al electrode (fig.1d) is covered by a thick oxide layer, with the redepositited oxides forming a hump at a distance 50-200 μm from the electrode edge. This layer has to be electrically swithed each time when the MD is formed in negative half-period, that leads to its pit-wise erosion with typical crater diameter of 300 nm.

Change of the electrode morphology leads to the change of the discharge electric properties (fig.1c). For Cu electrode, discharge power increases after the discharge onset by ~10-30% during half an hour, for Al discharge power decreases. Formation and removing of the oxide layer at the position of the electrode spot strongly affects the shape of the voltage-coulomb cycle, that means that statistics of the MDs is different in these two cases. Cu electrode treatment leads to synchronization of microdischarges along the electrode span and periods. For Al, no structure is obtained on the active part of VQ cycle, once more indicating that stochastic discharge mode is realized.

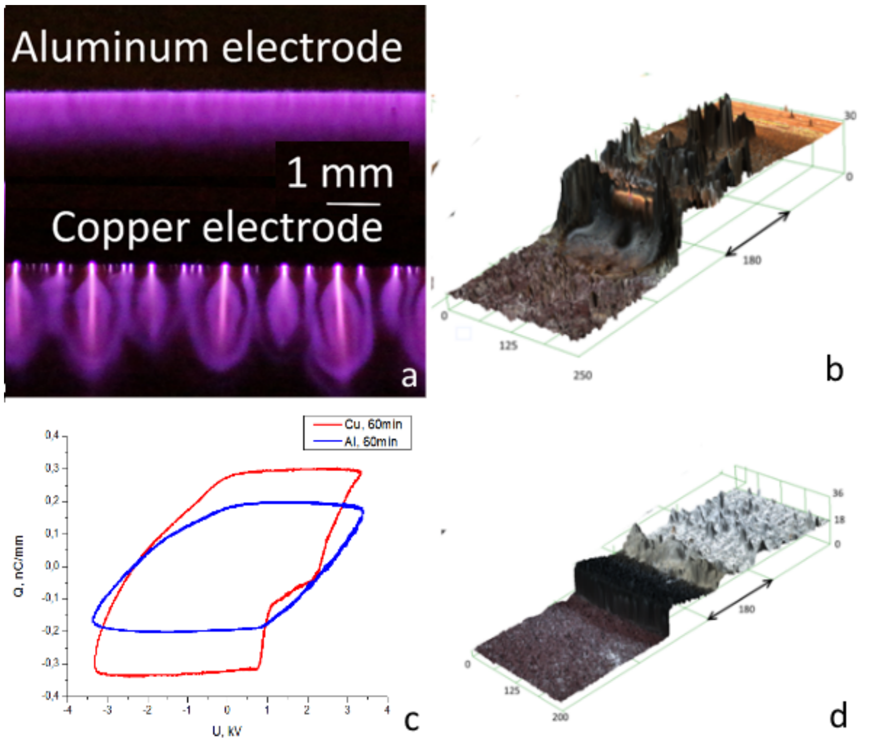


Fig.1. a) Long-exposure image of the discharge on Al and Cu electrodes. b),d) structure of the electrode edge after 28hours of operation, c) volt-coulomb cycles for Cu and Al electrodes 1h after voltage onset. *f*=110kHz, U=3.2kV


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