Impact of convective flow on filaments in narrow gap DBD

A Ashirbek (*)[1,2], Y Ussenov[3], M Dosbolayev[4], M Gabdullin[5] and T Ramazanov[4]

[1] *Institute of Applied Sciences and IT, Almaty, Kazakhstan*
[2] *NNLOT, Al-Farabi KazNU, Almaty, Kazakhstan*
[3] *MAE Department, Princeton University, Princeton, United States of America*
[4] *IETP, Al-Farabi KazNU, Almaty, Kazakhstan*
[5] *Kazakh British Technical University, Almaty, Kazakhstan*
(*) *azamat@physics.kz*

Dielectric Barrier Discharges (DBDs) find extensive applications across diverse technological domains such as plasma medicine, agriculture, plasma material deposition, surface modification, additive manufacturing, plasma catalysis, and active flow control [1, 2]. In the case of volume DBD with symmetric-plane discharge electrodes driven by a sinusoidal high voltage (HV) signal, MD channels are randomly distributed. These channels exhibit complex collective phenomena and give rise to diverse self-organized patterns. Understanding the collective interaction and dynamics of MD channels is crucial not only for stationary volumetric DBDs in the air but also for DBDs influenced by external factors. The most popular factor of them is gas flow [3], there is also an unusual approach using convective flow or gas flow convection.

The gas flow convection in the discharge gap plays a role in determining the spatial distribution of charged particles, which in turn contributes to the pre-ionization process in the MD channels in DBD. This pre-ionization in the discharge gap is a crucial element influencing the subsequent development of individual microdischarges and the formation of collective phenomena, such as self-organized patterns. Even in the absence of external gas flow, particle transport occurs due to intense heat transfer and natural convection, since microdischarges in the dielectric gap are a local source of heat. Despite DBD being a transient thermal nonequilibrium discharge, Joule heating coupled with chemical energy dissipation within the discharge volume and the dissipation of a portion of the applied power as heat on dielectrics actively heat the walls of the discharge cell. We concluded in our previous work [4] that the continuous self-heating of the walls of barrier electrodes during the discharge operation generates natural convective flow due to the thermal gradient of the discharge cell electrodes and surrounding air. The velocity of the MD channels rises, following the convective flow velocity due to the elevated thermal gradient. During the self-heating of the barrier electrodes, the number of the MD channels increases, and the distance between the MD channels decreases which leads to more surface density of filaments on the dielectrics. The gas heating in the gap enhances the reduced electric field of the discharge due to a reduction in the density of gas molecules after heat expansion, which in turn results in the growth of the number of currents, amplitude, and reduction in the discharge sustaining voltage.

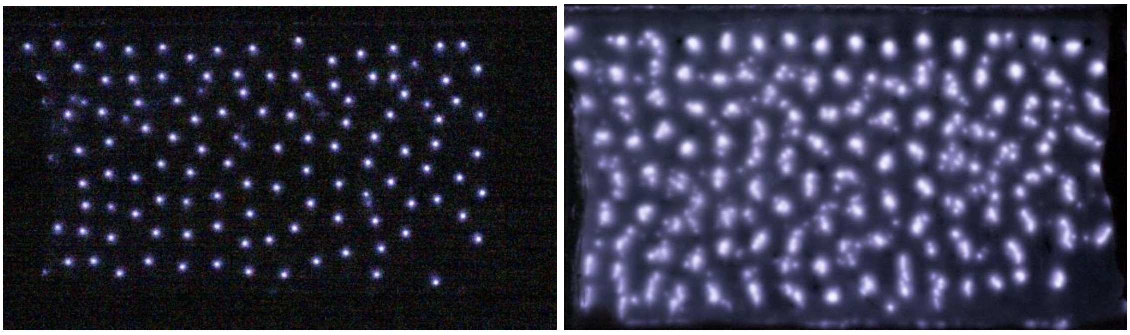

Fig. 1: Photos of the top view of the dynamics of MD behavior at an interelectrode distance of 1 mm at frame rates of 1000 and 24 fps

In this work, we are interested in investigating the effect of the balance between the forces driving the convective flow and the viscous forces at the wall in the boundary region when the discharge gap is significantly narrowed. The dynamics of filaments in the narrowed discharge gap are compared with our previous results on convective air flow [4]. Discharge parameters such as microdischarge and gas flow average velocities, and discharge and dielectric layer temperatures were also measured and compared with previous results. From high-speed imaging of the discharge (fig. 1) and Particle Image Velocimetry (PIV) analysis, the movement of the filaments is obtained, and the average velocity is measured at a certain temperature of the dielectric layer. The convective flow in the interelectrode volume has been modeled using COMSOL Multiphysics.

[1] R. Brandenburg, *Plasma Sources Science and Technology* **26** (2017) 5 053001.
[2] U. Kogelschatz, *Plasma Physics and Controlled Fusion* **46** (2004) 12B B63–B75.
[3] Ye. Ussenov *Plasma Phys. Reports* **46** (2020) 459–64
[4] Ye. Ussenov *Phys. Scr.* **99** (2024) 035608