Theoretical and experimental study of plasma jet interaction with surface

I. Schweigert[1,2], L. Lin[1], M. Keidar[1]

[1] *George Washington University, Washington D.C. 20052, USA*
[2] *Khristianovich Institute of Theoretical and Applied Mechanics, Novosibirsk 630090, Russia*

Characteristics of streamer propagating over helium jet at atmospheric pressure are studied in 2D simulations and in the experiment. This type of streamer often referred as cold atmospheric plasma jet is widely used for medical applications. We study effect of surface presence and interaction of the streamer with surface with different properties (surface charge, ion-electron emission, biased surface). The enhancement of streamer properties is obtained with biased ring placed some distance from dielectric tube.

Cold atmospheric plasma (CAP) jet becomes attractive research topic due to different applications, in particular for cancer treatments (see for example [1]). The CAP jet forms as a result of ionization along the gas flow passing through high voltage electrodes. Streamer propagates by ionizing neutral particles at front. In Ref. [2], the idea of using a ring with DC voltage was proposed. It was shown that the jet length can be changed by setting up different ring potentials.

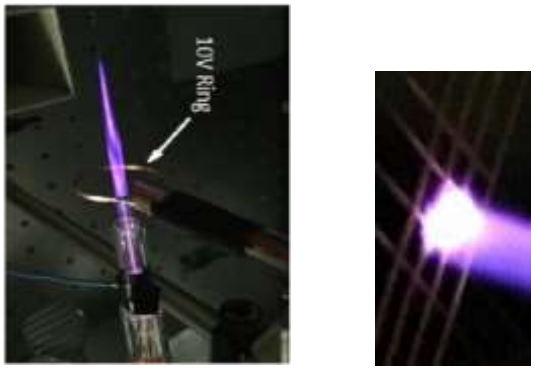

Fig. 1. Experiment: CAP jet with a ring potential and grid.

To study the effect of additional DC voltage from the ring and interaction of jet with a surface we performed experimental and computational analysis of CAP jet shown in Fig.1. The jet is generated by an AC voltage of 4 kV pk-pk at 12.44kHz in a 5LPM helium flow. The ring with applied voltage is place 1 cm apart from the discharge tube. Additionally a grid made from crossed wares covered by dielectric is placed 4 cm apart from discharge tube which models a cell membrane. The photographs of some details of experimental set up is shown in Fig. 1. We have performed 2D simulations of DC discharge in dielectric tube and streamer formation and propagation outside of tube. In our simulation model we use the fluid approach with additional continuity equation for electron energy. The surface charge accumulation and ion-electron emission are taken into account. We assume that streamer propagates over helium at atmospheric gas pressure. In Fig. 2, the ionization rate and electrical field distribution are shown at the time when streamer head is 3 cm apart from the discharge tube exit (at z=2.5 cm) for the case of a 10 V ring potential.

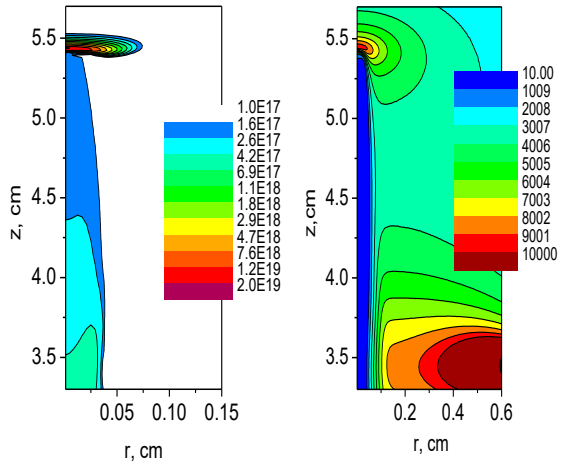

Figure 2. Simulation: Ionization rate, 1/cm^{3}s (left) and electrical field, V/cm (ring) with a ring with 10 V bias.

In simulation the ionization front speed is about 17 km/s. The ionization rate is about 2x10^{19} cm^{-3}s^{-1} and this value is constant during streamer propagation up to 4 cm and then quickly decreases. Note that in simulation the gas flow is assumed to be laminar. Streamer channel radius is 300 microns. The electrical field E in streamer head is about 10 kV/cm. The measured and computed jet characteristics are in good agreement. A variation of ring potential from -1.5 kV to 1.5 kV considerably affect CAP jet properties. The sheath structure and strength of electrical field near grid surface are essentially changed for different surface potentials and emission yield.

[1] M. Keidar at al Br. J. Cancer 105 (2011) 1295.
[2] A. Shashurin, M. N. Shneider, and M. Keidar, Plasma Sources Sci. Technol. 21 (2012) 034006.