Time evolution of emission profiles and spatial structure of a plasma jet streamer discharge in contact with liquid

O Jovanović[(*)1], F Krčma[2], L Dostál[2], N Puač[1], N Škoro[1]

[1] *Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*

[2] *Faculty of Chemistry, Brno University of Technology, 612 00 Brno, Czech Republic*

[3] *Faculty of Electrical Engineering and Communication, Brno University of Technology, 612 00 Brno, Czech Republic*

[(*)] olivera@ipb.ac.rs

Atmospheric pressure plasma jets have been intensively studied for the last two decades due to their wide field of application [1-2]. One of the most common targets exposed to cold plasma is liquid. Numerous investigations have demonstrated that the electrical properties of the plasma and its reactivity impact the water target by modifying physicochemical features such as pH, electrical conductivity, and the transfer of reactive species into the liquid [3]. In order to fully comprehend the complex interaction between discharge characteristics and treated liquid properties, an in-depth diagnostic of the plasma jet is required. Analysis of emission profiles from the discharge can provide various infomration. Ultrafast cameras can capture clear discharge images on a timescale ranging from ns to µs, which allows insight of development of discharge profiles and interactions with the water surface [4].

In this research we used two ultrafast framing cameras to record temporal evolution of the streamer emission generated by using a specially designed pin-type atmospheric pressure plasma jet operating in contact with a liquid sample. The experimental setup of the atmospheric pressure pin-electrode jet operating in contact with liquid sample is presented schematically in Figure 1. The powered electrode was connected to the high-voltage (HV) and the second electrode was the target – a water sample placed in a grounded quartz vessel.

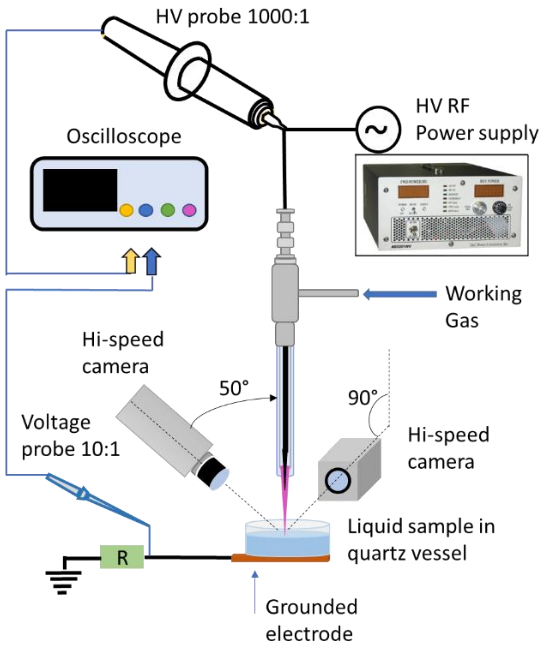

Fig. 1: Schematic representation of the experimental setup.

Distilled water, tap water, and saline solutions were used as targets in order to test targets with different conductivities. Pure He or Ar were used as working gases with gas flows of 1 slm and 2 slm, respectively, adjusted by a mass flow controller.The plasma in the experiments was generated and controlled by using a commercial HV high-frequency power supply providing continuous sinusoidal signal with the frequency of 350 kHz. To monitor voltage and current waveforms we used an oscilloscope, and corresponding probes. The discharge current flowing through the ground line was obtained by measuring voltage drop across a 1 kΩ resistor.

Ultrafast frame imaging of the streamer discharge was performed by useing of two Hi-speed cameras (I-Speed 726, IX Cameras, and FASTCAM SA-X2, Photron). The development and propagation route of streamers formed between powered pin electrode of the jet and the liquid surface were observed from side-on positions. The first camera was positioned perpendicular to plasma jet axis in order to observe the development and expansion of the streamer between the powered electrode and the liquid. To capture formation and propagation of smaller filaments on the liquid's surface, the second camera was installed above the sample, at an angle of 50° from plasma jet axis. Fast-framing cameras allowed observation of the transient behaviour of the streamer by recording of the emission profiles in a time frame short enough to see the effect. The spatial distribution of the emission generated by the streamer discharge and branching of the filaments at the water surface were recorded for different jet operating parameters and the liquid target conductivity.

Figure 2 shows discharge profiles in argon (a) and helium (b) in the case when the target was 4 ml of distilled water (conductivity 2.1 µS/cm). The images were taken with a camera placed at an angle of 90° with respect to the vertical axis of the plasma jet. The results showed that the contact surface of the Ar streamer and water was much larger than in the case of helium. Branching at the interface level was more pronounced in Ar streamers. The streamer was more intense, less distorted and with more homogeneous emission along its axis in the case of He plasma.

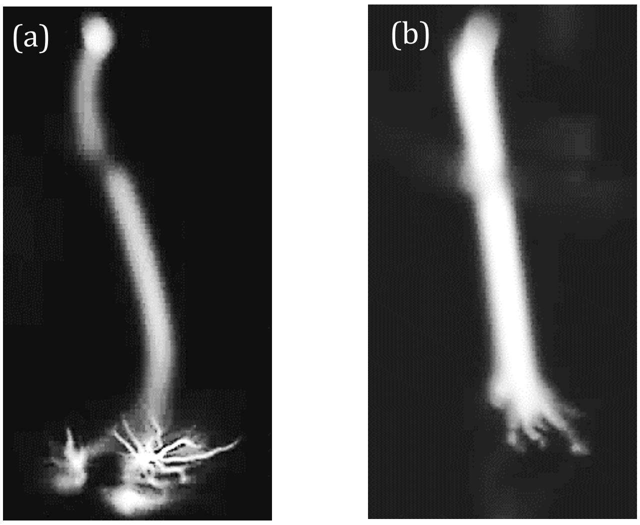

Fig. 2: Streamer spatial profiles in argon (a) and helium (b) in the case when the target was 4 ml of distilled water.

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