Propagation of Atmospheric Pressure Argon Plasma Jet Impinging on Targets with Different Conductivity

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Atmospheric pressure plasma jets (APPJs) today serve as a tool for treating various surfaces from metals to polymers and biological tissues sensitive to temperature [1]. Adhesion, hydrophilic and bacteriostatic properties of the surface can be changed under plasma treatment [2]. The latest studies showed that not only the plasma affected the object, but also the object could influence the plasma. It was shown in a range of experimental works [3-5] that the target conductivity influenced on the production of reactive species in the cold plasma jets. According to the simulation results from [6,7] the plasma jet dynamics also depends on the presence of the target and its conductivity. To verify this data, the experimental electrophysical setup was created and the plasma jet impinging on conductive targets was studied.

The electrophysical setup consisted of the home-made pulse generator [8] on a base of a high-voltage semiconductor switch [9], the plasma coaxial jet reactor [10] and diagnostic equipment (figure 1). The plasma jet using a DBD configuration was used in the experiment. The high voltage electrode was a copper rod with a diameter of 2 mm placed along the axis of a fused silica tube with a 1 mm-thickness. The ground electrode was a copper ring wrapped around the tube. Thus, the gap distance between the rod and the inner surface of the tube was set to 0.7 mm.

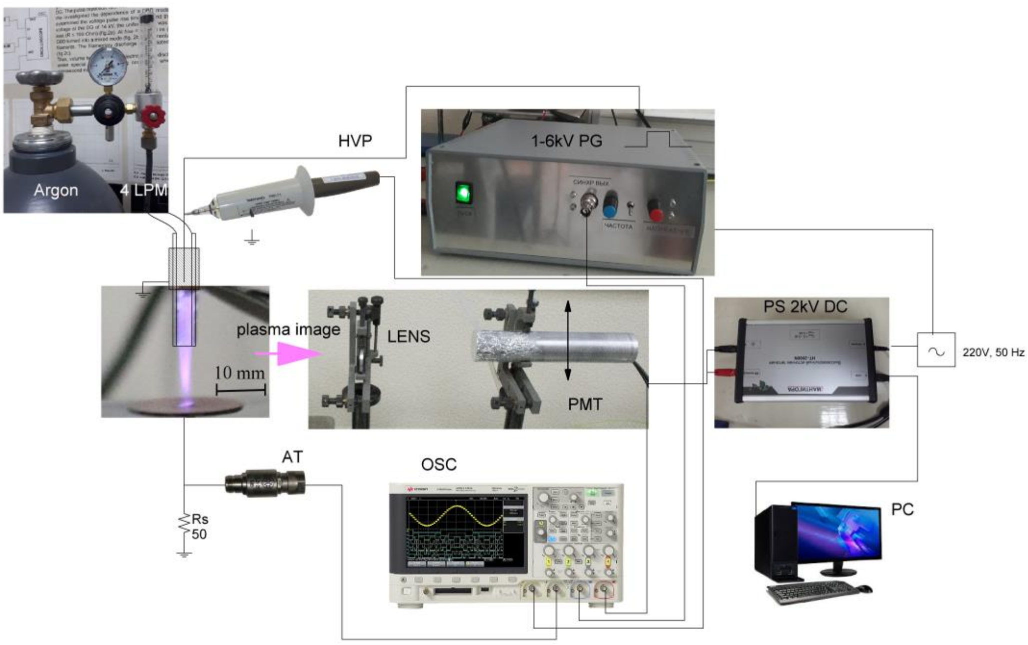

Figure 1. Experimental setup

High voltage (up to 6 kV) unipolar rectangular pulses with 20 ns rise/fall time were formed at the plasma reactor electrodes due to the operation of high-voltage composite switches assembled in a half-bridge circuit. The typical waveform of the current in the DBD reactor without the flow is shown in figure 2. As usual for a pulse supplied DBD [9] two current pulses, primary and secondary ones, are observed at the rising and falling voltage edges, correspondingly. When argon was pumped through the reactor at a rate of 4 liters per minute and 1.5 us-pulses of 6 kV amplitude at 3 kHz frequency were applied to the electrodes from the generator the cold plasma plume was initiated in the surrounded air.

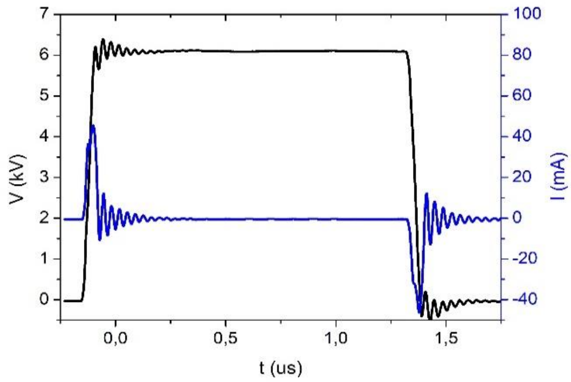

Figure 2. Typical current waveform in the DBD plasma rector without argon flow.

The jet current and the plasma emission intensity were measured to characterize the jet propagation in dependence on the target. The targets with different conductivity were used in the experiments: copper with σ = 6·10^{7} S/m, medical conductive gel Uniagel with σ = 1 S/m and plexiglass with σ = 10^{-13} S/m. The plasma jet impinged on the grounded target, located at a distance of 1.5 cm from the tube outlet. The jet current was estimated as a current through a metal collector with an area of 1 cm^{2}, placed under the target perpendicular to the central tube axis [11]. The jet propagation from the tube nozzle to the target in the air was investigated by using the photomultiplier tube FEU-35 with a maximum sensitivity at a wavelength of 380 nm.

Figure 3 shows that the current waveforms differ when the jet touches the targets of various conductivity. It`s seen that the jet current amplitude (the second peak) is the highest (~40 mA) in the case of the copper object. The smallest one (~8 mA) corresponds to the plexiglass as a target.

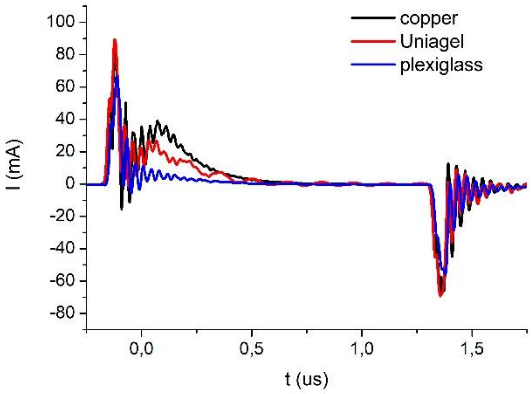

Figure 3. The current waveforms of the plasma jet.

The light emission intensity along the jet propagation axis also varies in dependence on the target (figure 4). The plasma jet light intensity appeared after the primary discharge decreases almost to zero at a distance of 15 mm when the bullet propagates to the copper target and to the gel and at a distance of ~ 8 mm when it impinges on the plexiglass target. After the secondary (reverse) discharge in the tube the plasma jet vanishes faster. Its length in the air is limited to ~ 5 mm in all cases except when the jet propagates to the copper object.

For the target with a high conductivity there are two intensity peaks, one of them is near the outlet of the tube and the other one is near the surface of the target. This is especially well seen when the jet propagates after the secondary discharge. It seems that the opposite ionization front is appeared after the voltage reversion and the secondary discharge in the tube, correspondingly.

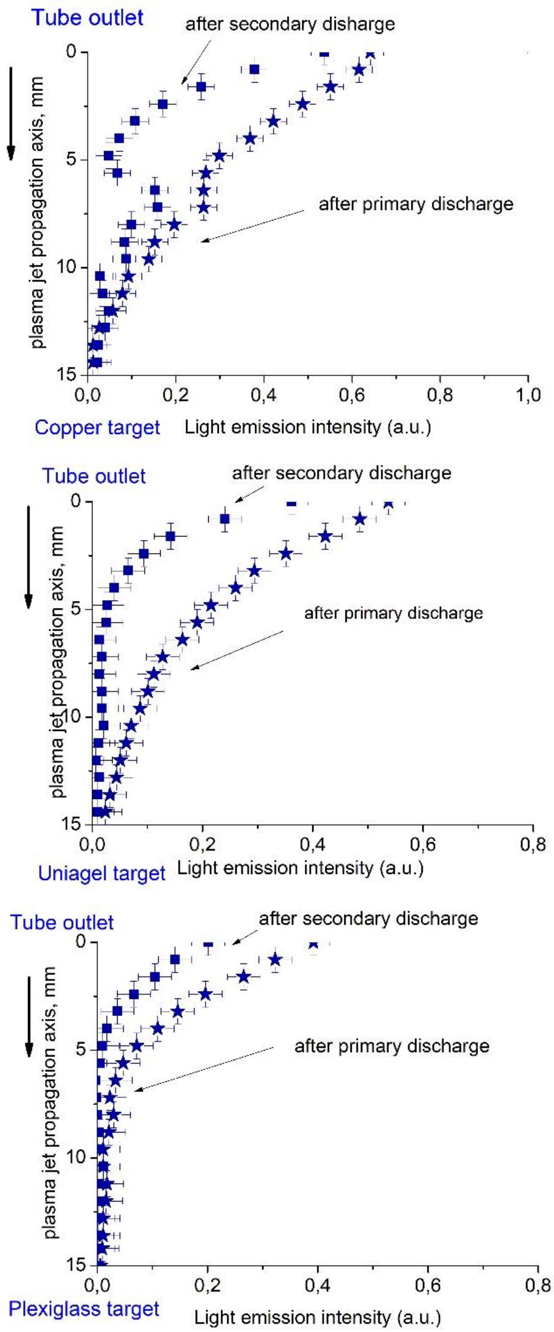

Figure 4. Light emission intensity of the plasma jet along the propagation path to the targets with different conductivity (copper, Uniagel and plexiglass).

Thus, it can be concluded that the conductivity of the target affects both the jet current amplitude and the light emission intensity along the plasma jet propagation path. The higher conductivity corresponds to a greater jet current amplitude and a longer jet length. Besides it was found out that several intensity peaks could be observed on a plasma propagation axis in the presence of the grounded target, i.e. the presence of the target can lead to the appearance of the reverse ionization front. This was especially well seen in the case of the target with a highly conductive metal target. It can be explained by the greater difference in the conductivity of the plasma ionization channel stayed after the ionization front and the target conductivity.

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