Plasma Jet-to-Jet Coupling Behavior Between Two Plasma Jet Arrays for Surface Treatments Requiring Strong Discharge Process

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***Abstract*— The plasma jet-to-jet coupling behavior between two plasma jet arrays is investigated. A plasma array structure consisting of two plasma jet arrays and a double electrode configuration is used as an ambient plasma source and shown to generate a strong plasma emission. Since the proposed plasma device is able to generate an intense plasma emission without any external ground electrode, it is a promising tool for surface treatments and modifications that require a strong discharge process, regardless of the dielectric property of the target material.**

***Index Terms*— Atmospheric-pressure plasmas, plasma devices, plasma properties.**

IN PREVIOUS studies, we presented an intense plasma emission formed by plasma jet-to-jet coupling from various circular array configurations at atmospheric pressure and proposed its potential application in surface treatments/modifications that require a strong discharge process with a simple structure [1], [2]. When using plasma jet-to-jet coupling to achieve an intense plasma emission, the plasma array device requires a single electrode configuration and external ground electrode located several centimeters apart from the array [1]. Despite the generation of an intense glow plasma plume with lots of reactive chemical species in ambient air, the requirement of an external ground electrode can become an obstacle for certain surface treatment applications. When certain materials are treated, the placing of the target material on the ground electrode means the dielectric constant of the target affects the plasma jet-to-jet coupling and the whole discharge process. Accordingly, to generate a stable intense plasma plume, regardless of the dielectric property of the target material, this paper investigated plasma array structures with a double electrode configuration using two intense plasma arrays.

Manuscript received November 9, 2013; revised March 6, 2014; accepted April 28, 2014. Date of publication May 22, 2014; date of current version October 21, 2014. This work was supported in part by the DGIST Research and Development Program, Ministry of Science, ICT and Future Planning under Grant 14-BD-06, and in part by the Kyungpook National University Research Fund in 2013.

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Digital Object Identifier 10.1109/TPS.2014.2322631

Fig. 1(a) shows the atmospheric pressure plasma arrays with a double electrode configuration. The proposed plasma array consists of two plasma arrays with eight glass tubes where in each array one center glass tube is encircled by the other seven tubes. The center glass tube has a 2-mm inner diameter (ID) and 3-mm outer diameter (OD), while the seven outer glass tubes have a 1-mm ID and 2-mm OD. Copper tape, used as the electrode, is wrapped around each tube 10 mm from the end of the tube. The eight tubes are then combined using carbon tape and copper tape, with the end of the center tube protruding 1 mm compared with the outer tubes for a stable plasma operation. The two identical plasma arrays are located with an angle of 60° and the focal point for each central plasma jet targeted 10 mm from the end of each device. Thus, the overall form of the proposed array device looks like a V-shaped configuration, as shown in Fig. 1(a). The electrode of one plasma array provides a sinusoidal high-voltage waveform, while the electrode of the other array provides a ground level (0 V). The sinusoidal voltage is applied with a peak value of 7.5 kV and frequency of 32 kHz. High-purity helium gas (>99.997%) is used as the discharge gas, and an identical gas flow rate of 2.5 slm (standard liter per minute) is applied to both element plasma devices. In experiments, the proposed plasma array device with a symmetrical two electrode arrangement generated a stable intense plasma emission in ambient air, as shown in Fig. 1(a). Importantly, along with the plasma generation sustained by the alternating direction of the electric fields between the two electrodes, as shown in the upper subfigure of Fig. 1(a), numerous reactive species in the plasma medium were also propelled toward the focal points of the two plasma jets based on the direction of the gas flows and then spread to the target material, as shown in the lower subfigure of Fig. 1(a). Despite an equal flow of gas through the eight glass tubes, the outer tubes did not produce strong individual plumes. Instead, the plasma flows from the outer tubes were drawn into the central plume, which in turn was amplified. Observations also confirmed a much more incandescent plasma jet from the center tube of the array, when compared with a conventional single atmospheric pressure plasma jet.

Fig. 1(b)–(d) showed the top views of the generated plasma jets with different flowed angles of a discharge gas. When the angle between two plasma arrays was smaller than 55°, two plasma arrays were located in close proximity to each other and produced irregular discharges among adjacent their outer

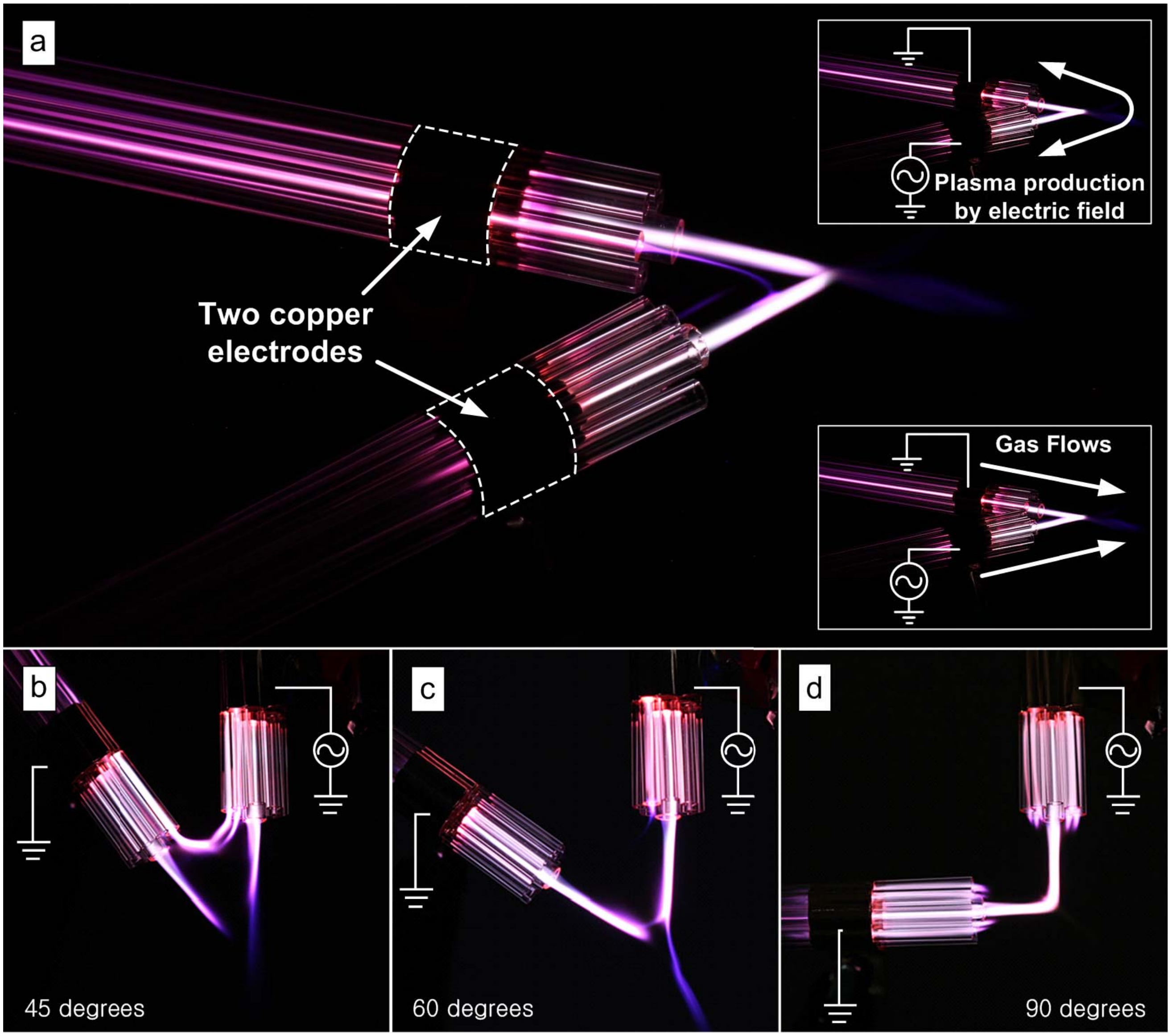

Fig. 1. (a) Atmospheric pressure plasma arrays with double electrode configuration. The proposed plasma jet device consists of two intense plasma arrays with multiglass tubes positioned in an overall V-shape to create a focal point for the plasma jets. Generated plasma jets with different flowed angles of a discharge gas, (b) 45, (c) 60, and (d) 90.

tubes, instead of an intense plasma jet as shown in Fig. 1(b). When the angles were 55°–90°, the intense plasma jet was stably generated as shown in Fig. 1(c) and (d). Besides, the optical intensity of plasma emission at the focal point was found to be almost identical regardless of included angles in this experimental condition. When the gas flowing angle changed to obtuse angles, the gas flows started being in the opposite direction and the plasma jet turbulence can be severe. Thus, plasma array configuration with the obtuse angle was shown to be not suitable for effective surface treatment by plasmas. The proposed plasma jet device can be used to treat materials with numerous chemical species by strong discharge process, regardless of the dielectric property of the target material.

References

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