Intense Ar Plasma Array Jet With Ring-Type Focusing Electrode

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***Abstract*— A new plasma array jet with an additional ring-type focusing electrode is proposed to obtain an extended and intense Ar plasma jet focused on a central glass tube at atmospheric pressure. To investigate the role of the ring-type electrode, the sinusoidal voltages of 9 kV and frequency of 30 kHz were applied to three different electrode configurations, such as only ring-type electrode, only probe-type electrodes, and both the ring- and probe-type electrodes. As a result, the ring-type electrode is confirmed to play a significant role in spatially focusing the charge particles ignited by the exposed probe-type electrodes, thereby producing a stable and intense Ar plasma jet under atmospheric pressure.**

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

VARIOUS helium plasma jet arrays based on the interactions between individual jets in an array, such as electrostatic, hydrodynamic, and photolytic interaction have recently been reported [1]–[5]. Yet, it is difficult to produce an intense Ar plasma jet in the central tube because the mass of argon atoms is heavier and the corresponding drift velocity in electric fields is slower than that of helium atoms [6]. Accordingly, this paper proposes a plasma jet array that produces an extended and intense Ar plasma jet in the central tube of a honeycomb-shaped array by adopting a ring-type electrode plus probe-type electrodes.

The proposed array jet consists of seven hollow glass tubes, where one central tube is encircled by six peripheral glass tubes, as shown in Fig. 1. All the glass tubes have the same outer diameter of 3.0 mm and inner diameter of 1.5 mm. Copper tape, 5-mm wide, is used as the ring-type focusing electrode and is wrapped around all the array tubes 15 mm from the end of the tubes. Meanwhile, copper wires, used as the probe-type electrodes, are located inside all seven glass tubes. The copper wire, 0.5 mm in diameter, stops 15 mm from the end of each glass tube, as shown in the lower insets of Fig. 1. Ar gas (UHP grade, 99.999% purity) with a gas flow rate of 3.5 slpm is used as discharge gas. With a peak value of 9 kV and frequency of 30 kHz, the sinusoidal voltage is simultaneously applied to both the ring-type and the probe-type electrodes. Despite this low-driven voltage and frequency in ambient air, the intense atmospheric pressure Ar plasma jet was obtained, as shown in Fig. 1. To investigate the role of the ring-type electrode, the sinusoidal voltages of 9 kV and frequency of 30 kHz were applied to the three different electrode configurations, such as only ring-type electrode [Fig. 2(a)], only probe-type electrodes [Fig. 2(b)], and both the ring- and probe-type electrodes [Fig. 2(c)], respectively. Other conditions of Fig. 2 were exactly the same as those of Fig. 1. As shown in Fig. 2, the Ar plasma jets were produced in either probe-type electrode or combined probe- and ring-type electrodes except only ring-type electrode case. However, both cases of Fig. 2(b) and (c) showed quite different discharge characteristics depending on whether a sinusoidal voltage was applied to the ring-type electrode or not. When applying the sinusoidal voltage only to the probe-type electrodes, the plasma discharges were simultaneously initiated in all seven glass tubes and each plasma jet experienced severe electrostatic repulsion force inside the tubes [2], [3]. Consequently, as shown in Fig. 2(b), relatively intense Ar plasma jets were observed only from the three glass tubes, whereas the other jets from four glass tubes adjacent to the three tubes were extinguished due to the electrostatic repulsion among the plasma jets [2], [7]. In contrast, the simultaneous application of the sinusoidal voltage to both the ring- and probe-type electrodes could induce the different discharge initiations between the central jet and the other six peripheral jets, thus resulting in weakening the electrostatic repulsion force exerted among the plasma array jets. Finally, as shown in Fig. 2(c), the six peripheral plasma jets were observed to extend toward the glass side, even though the plasma intensities were very weak. These nonextinguished plasma jets would enable the supply of the charged particles produced in the six peripheral plasma jets into the central jet, thereby resulting in obtaining the intensified central plasma jet [4], [7].

The comparative study on the three different electrode configurations of Fig. 2 confirms that the simultaneous application of the sinusoidal voltage to both the ring- and probe-type electrodes contributes to intensifying the central plasma jet, thereby succeeding in obtaining the stable and strong Ar plasma in the central tube.

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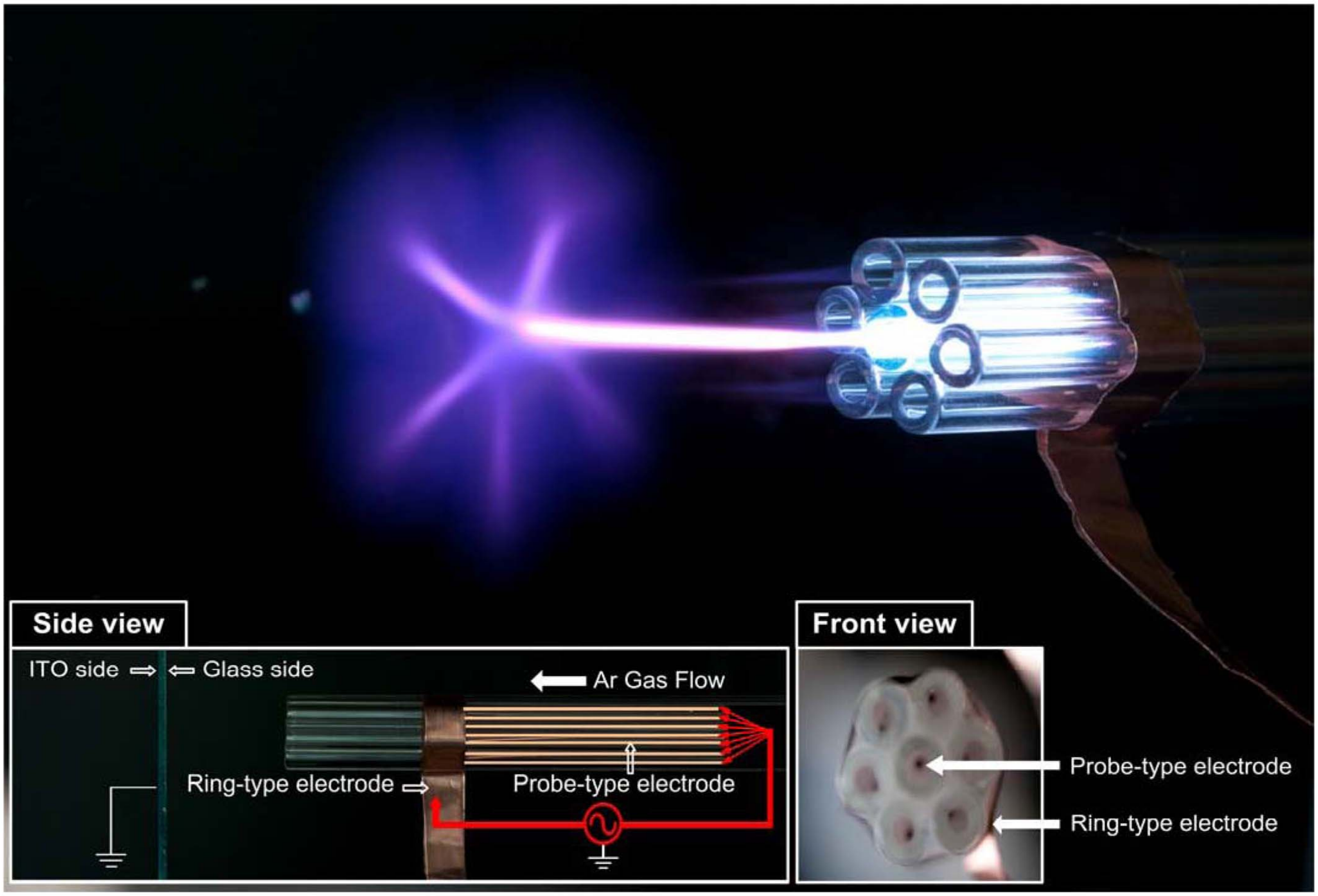

Fig. 1. Ar atmospheric pressure plasma array jet with ring-type focusing electrode. Proposed plasma jet device consists of plasma arrays with a ring-type focusing electrode outside and probe-type electrode inside to create an intense atmospheric Ar plasma jet.

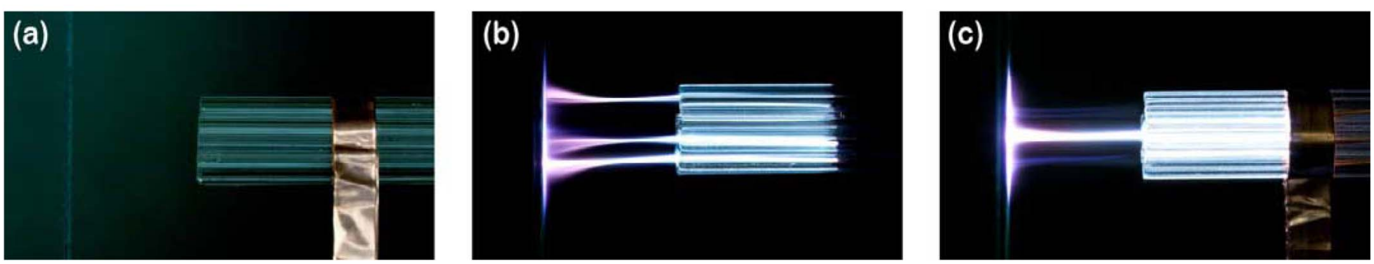

Fig. 2. Photographs of Ar plasma array jets with three different electrode types. (a) Only ring-type electrode. (b) Only probe-type electrode. (c) Both the ring- and probe-type electrodes.

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