Correlation of Striated Discharge Patterns With Operating Conditions in Helium and Argon Atmospheric-Pressure Plasma Jets

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***Abstract*—This paper presents the evolution of striated discharge patterns in helium and argon atmospheric-pressure plasma jets as a function of gas flow rate and driving voltage. The striated patterns have been observed in helium and argon plasma jets at gas flow rates above 5 and 3 L/min, respectively. The striation patterns appear over the entire voltage range used for investigation (from 4 to 8 kV) in the helium plasma jet, whereas in the argon plasma jet, striation patterns appear over a limited voltage range (from 5.5 to 6.5 kV).**

***Index Terms*—Atmospheric pressure discharge, ionization propagation wave, striated discharge patterns.**

TO OPTIMIZE these plasma sources for biomedical applications, plasma characteristics should be investigated under various operating conditions. One of the most puzzling phenomena is the striated discharge pattern in many atmospheric- pressure plasmas. At certain operating conditions, it has been observed that a stable discharge is transformed to a discharge with striated patterns [1]–[3]. Many striated patterns have been reported in direct-current (dc), low-frequency dielectric barrier, and microwave-excited discharges [1]–[3]. In this paper, the correlation of striated discharge patterns with driving voltage and gas flow rate is investigated in helium (He) and argon (Ar) atmospheric-pressure plasma jets (APPJs).

To generate He and Ar APPJs, a cylindrical aluminum tube with 1.5-mm inner diameter was employed as a power electrode, and it was housed within a Teflon tube [4]. The Teflon tube had a grounded ring electrode at the bottom part. A sinusoidal high-voltage power supply (20 kHz) was connected to the powered electrode. The gas flow rates of He and Ar were varied from 1 L/min (9.44 m/s) to 9 L/min (94.36 m/s), and their driving voltages were varied from 4 to 8 kV. The striated discharge patterns were visually inspected by a digital camera (Canon EOS 450D).

Fig. 1 shows the transformation of discharge shapes in He and Ar APPJs as a function of gas flow rate and driving voltage. In the He plasma jet, striated discharge patterns were observed over the entire range of an investigated driving voltage (from 4 to 8 kV) for flow rates above 5 L/min, and it became distinct at the 7-L/min He flow rate (see Fig. 1). The appearance of the striated discharge patterns in the He APPJ was closely related to the transition from laminar to turbulent modes of flow, which was associated with shortening in the plasma jet length at 5 L/min (47.18 m/s). However, in the case of the Ar plasma jet, striated discharge patterns were observed over a limited driving voltage range (from 5.5 to 6.5 kV) for flow rates above 2 L/min (18.87 m/s). This gas velocity is similar to the gas velocity at which striated patterns have been reported in a dc glow discharge [1]. At a gas flow rate of 3 L/min, the striated discharge patterns became dominant (see Fig. 1). It was seen that in both He and Ar APPJs, striated discharge patterns were faded away when gas flow rate was increased. Increase in driving voltage has no effect on striated discharge patterns in the He APPJ, whereas in the case of the Ar APPJ, the striated discharge patterns disappeared at a high voltage (see Fig. 1). This observation is in contrast to the previous studies, where it was seen that various striated discharge patterns are usually enhanced with increase in the input power [1]–[3].

Fig. 2 shows the distance between the striated patterns in He and Ar APPJs. The He plasma jet had three bright plasma layers at 4.7 kV and 7 L/min. However, five bright plasma layers were noticed in the Ar APPJ at 5.6 kV and 3 L/min. The distance between the bright plasma layers in the He plasma jet was larger than that in the Ar plasma jet. This fact can be attributed to the high ionization energy of He (24.59 eV) compared with that of Ar (15.76 eV). Moreover, the Ar APPJ had more clear and stable striated discharge patterns compared with the He APPJ.

In conclusion, striated discharge patterns have been observed in He and Ar APPJs. An ionization propagation wave caused by the electron kinetics contributes to the striation formation in many cases; however, detailed physics of striation are not fully understood yet. It was confirmed that striations are significantly affected by the gas flow rate only in the He plasma jet, whereas both gas flow rate and driving voltage influenced the appearance of striations in the Ar plasma jet.

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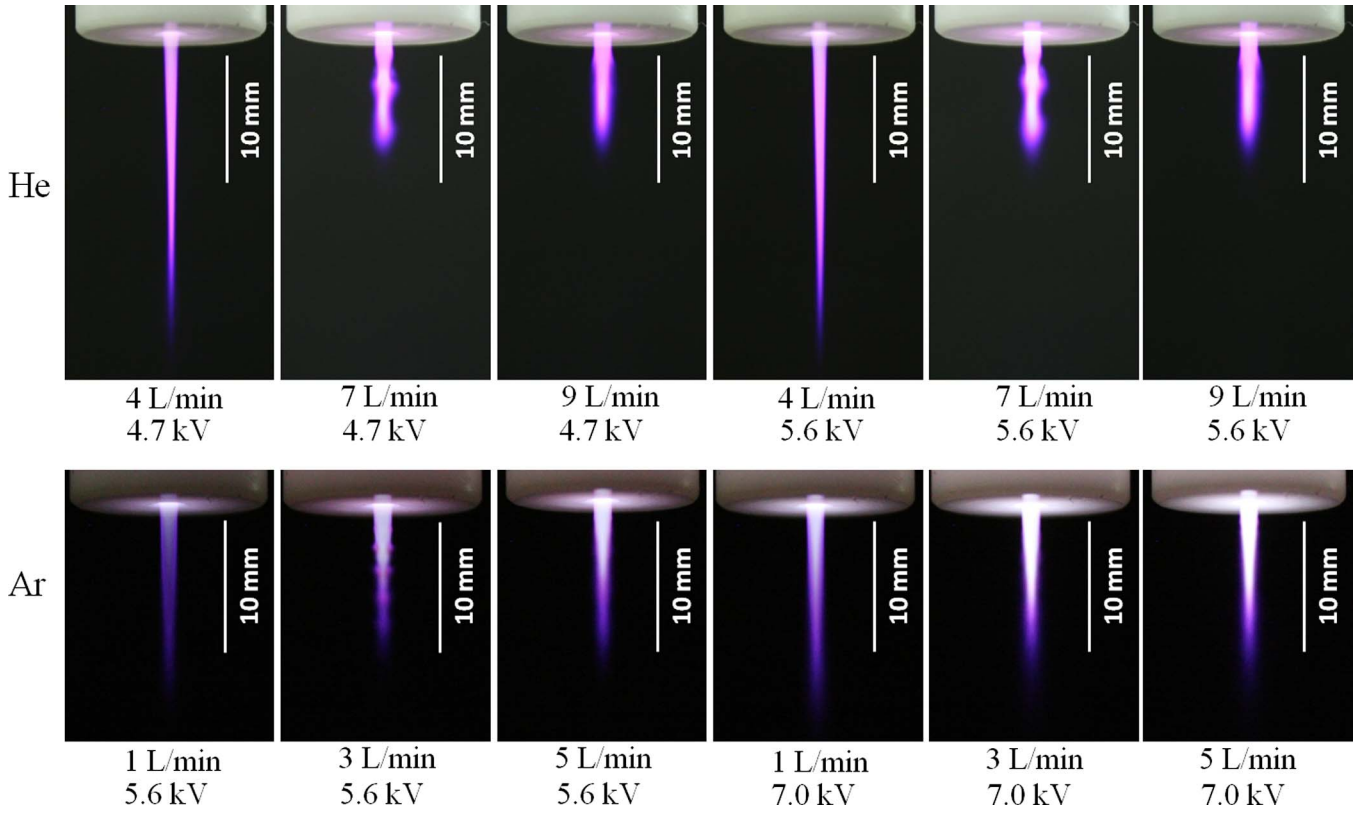

Fig. 1. Development of striated discharge patterns corresponding to the gas flow rate and driving voltage in He and Ar plasma jets. (The exposure time of the digital camera is 1 s for He plasma and 1/3 s for Ar plasma.)

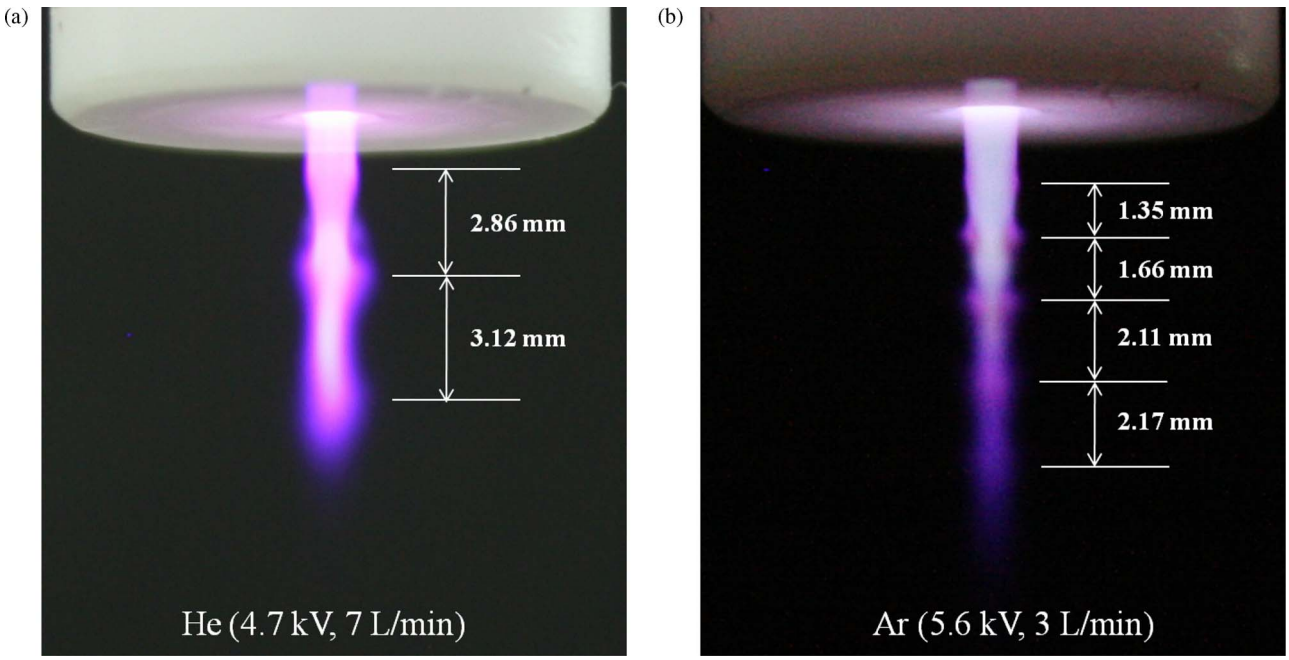

Fig. 2. Striated discharge patterns in (a) the He APPJ at 4.7 kV and 7 L/min and (b) the Ar APPJ at 5.6 kV and 3 L/min.

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