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Study on the electrical characteristics between the atmospheric pressure plasma and the neutral gas flow
大気圧プラズマと中性流体間の電気的特性に関する研究

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The neutral gas flow along an atmospheric-pressure plasma flare was visualized using a Schlieren optical system with a high-speed camera. It was observed that a turbulent neutral gas flow was induced during the production of the plasma flare. By using externally applied voltage, the neutral gas flow with the atmospheric pressure plasma was turbulent to the electrode.

1. Introduction

Recently, plasma production experiments have been carried out under atmospheric-pressure with the aim of applying the results to improved combustion[1)], medical equipments[2,3)], material surface processing, and so forth. In many cases, the atmospheric-pressure plasma is produced using rare gases or nitrogen[4)], which flow through the equipment[5)]. Interaction phenomena between charged particles and neutral particles are very important, since the particle number of ambient gases is much larger than that of charged particles. In this study, we visualized the behavior of neutral gases along a plasma jet using a Schlieren optical system with a high-speed camera. Especially, it has been studied the effect on neutral gas flow by externally applied voltage.

2. Experimental Setups

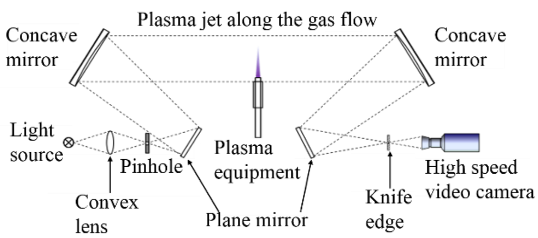

Fig. 1. Schematic drawing of Schlieren optical system and high-speed video camera setting.

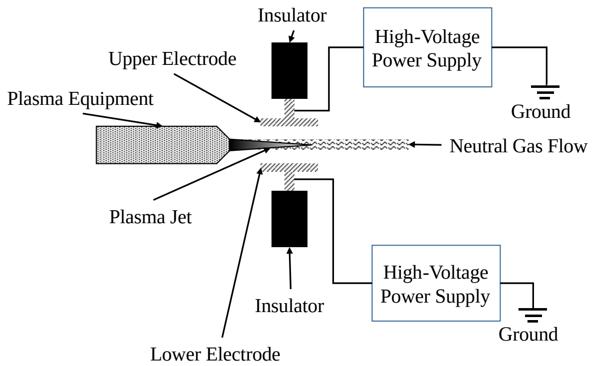

Fig. 2. Schematic drawing of a externally applied voltage system.

A Schlieren optical system and a high-speed video camera are used for visualization study of neutral gas flow. The former is composed of continuum light source (Xe lump) and convex lens, pinhole and concave mirror, and knife edge. The later is composed of Photron SA-X2. Here, frame rate is set up 20,000 frame/s, and exposure time is set at 1/32000 second. The image resolution is 768 (horizontal) × 624 (vertical) pixels. This system is schematically illustrated in Fig. 1. The external applied voltage system is introduced to produce an electric field around the neutral gas flow. This device is composed of two electrode and two high-voltage power source, these are independent of each other. Distance between the electrodes is set to 10 mm. The shape of electrode is disk-shaped, and the diameter is 10 mm. This system is schematically illustrated in Fig. 2. High voltages are applied to each electrode independently. In these experiments, a plasma equipment based on the dielectric barrier discharge is used[6]. A cylindrical quartz tube used as a dielectric, and the gas flows through the tube. A powered electrode is installed in part of the dielectric, and is completely covered by the dielectric and a grounded electrode. This type of plasma source produces glow like plasma with good directivity that in principle, does not undergo a transition to an arc discharge. The peak-to-peak voltage $V_{p\text{-}p}$ applied to the electrode is varied from 6 to 15 kV, and the frequency range of the sinusoidal wave is 66 kHz.

3. Experimental Results

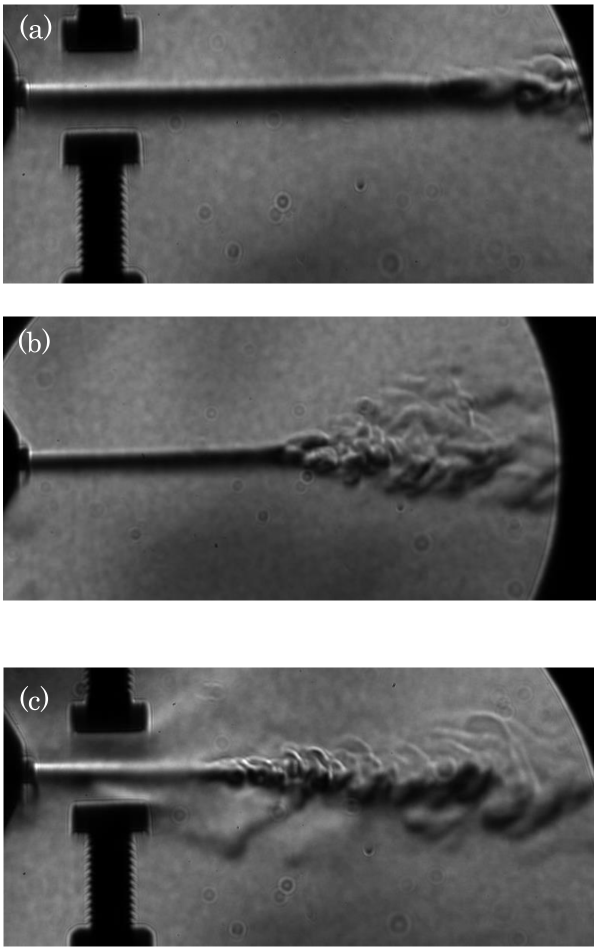

Fig. 3. Schlieren images of the helium gas flow, (a) without plasma and with externally applied voltage system, electrodes are earth potential, (b) with plasma and without externally applied voltage system, and (c) with plasma and with externally applied voltage system, electrodes are earth potential.

Figure 3(a) shows a Schlieren image of the helium gas flow without the atmospheric pressure plasma, setting with externally applied voltage system. The turbulent point is approximately 50 mm from nozzle. In the case of without plasma, the neutral gas flow of 2.0 l/min is laminar. Figure 3(b) shows a Schlieren image of the helium gas flow with the atmospheric pressure plasma of $V_{p\text{-}p}$ ~ 8 kV. The helium gas flows straightly, and turbulent point is shorten and becomes approximately 30 mm from nozzle. Figure 3(c) shows a Schlieren image of the helium gas flow with the atmospheric pressure plasma of $V_{p\text{-}p}$ ~ 8 kV, and electrodes of externally applied voltage system are earth potential. The turbulent point of helium gas flow is approximately 20 mm from nozzle. The turbulent point is shorten than the case without externally applied voltage system moreover, the neutral gas flow of behavior is affected by the electrode of earth potential.

4. Conclusions

It was visualized that the behavior of neutral gases along a plasma flare using a Schlieren optical system with a high-speed camera. The neutral gas flow without plasma of 2.0 l/min is laminar. However, with plasma, the neutral gas flow becomes turbulent. The behavior of neutral gas flow with plasma flare is affected by the space potential around the gas flow. From these phenomena, it is considered that ions in the neutral gas flow affected on the flow structure of the neutral gas.

Acknowledgments

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