Characteristics of ionic wind induced by multi-electrode microplasma

多電極マイクロプラズマに生じるイオン風の特性

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In this study, ionic wind induced by multi-electrode microplasma was investigated for flow control. By driving the electrodes independently, flow direction could be controlled. Ionic wind induced by the microplasma was measured by the Particle Image Velocimetry (PIV) method. By applying sinusoidal voltage 1.4 kV, 20 kHz, to the multi-electrode type microplasma electrodes, ionic wind velocity order of 1 m/s was obtained. Electric signal drive was transferred to the electrode instantly. Although, 100 ms were required to the ionic wind to achieve a constant a value due to the atmospheric air's viscosity.

1. Introduction

The control of the fluids flows by active and flexible methods contributes to the improvement of efficiency for various machines. Recently, a non-thermal plasma device called plasma actuator has been studied for active flow control. Advantages of the plasma actuator include 1) No-moving parts, 2) Simple construction 3) Thickness under 1 mm [1]. Figure 1 shows a typical plasma actuator. The principle of plasma actuator is the generation of air flow called ionic wind caused by plasma due to the momentum transfer from accelerated ions to neutral molecules [2]. Suction to the plasma region and blowing from the plasma region were generated.

In this study, a multi-electrode microplasma actuator was developed and investigated. By driving the each electrode selectively, flow direction could be controlled without changing electrode geometry.

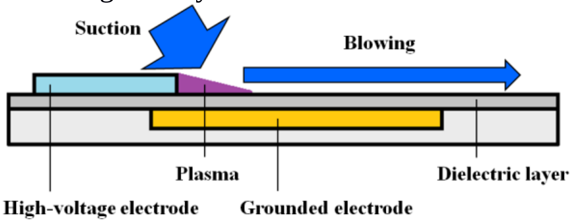

Fig. 1 A schematic of typical plasma actuator.

2. Experimental setup

Multi-electrode microplasma actuator is shown in Fig. 2. Lower electrode was connected to the ground. Upper electrode consisted in 4 independent electrodes. These electrodes could be energized independently, and flow direction could be controlled. Figure 3 shows the experimental setup for visualization of the air flow. Flow was visualized by the Particle Image Velocimetry (PIV). Sub-micron incense smoke was used for tracer particle. Nd YVO_4 532 nm laser was utilized to visualize the flow. The phenomenon induced by the microplasma actuator was measured by a high-speed camera.

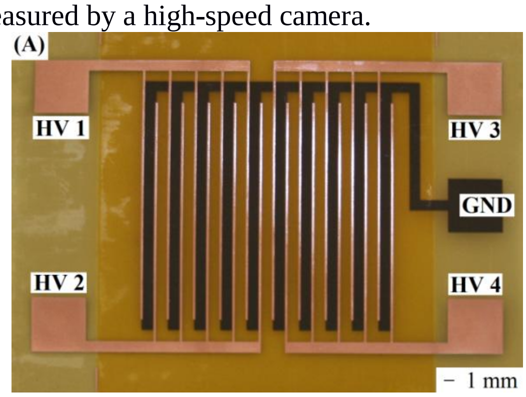

Fig. 2 The image of multi-electrode microplasma actuator.

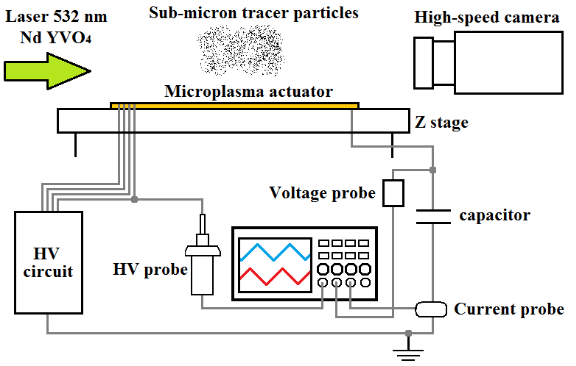

Fig. 3 The experimental setup for the flow visualization.

3. Results and discussions

Upper electrodes were energized at 1.4 kV, 20 kHz sinusoidal high-voltage. Discharge power by one electrode was 2.5 W measured by the Lissajous figure. When two electrodes were energized, power consumption was 5.0 W.

Air flow induced by plasma flows is mainly from upper electrode to lower one. Thus, by driving the HV 1 and HV 3, right-ward flow could be generated. Fig. 4 shows visualized right-ward flow. Suction to the left-edge plasma was occurred. Suction and blowing at each plasma region were observed. And, right-ward blowing from right-edge plasma was generated.

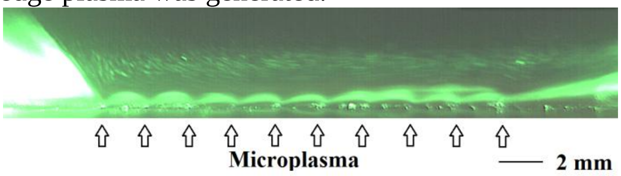

Fig. 4 Visualized right-ward flow

Fig. 5 shows 2D the flow vector distribution. Flow was increased by moving to the right. At right edge, 0.5 mm height of the device, a flow of 1.1 m/s was obtained

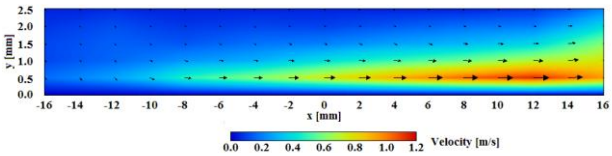

Fig. 5 Flow distribution of right-ward flow

Furthermore, velocity profile at x = 12 mm is shown in Fig. 6. Maximum flow velocity was 1.4 m/s at 0.25 mm height from the wall. This figure shows force induced by plasma could be up to 0.25 mm from the wall, flow at upper field was caused by atmospheric air's viscosity.

When HV 2 and HV 4 were driven, opposite left-ward flow was generated. Owing to the symmetric electrode configuration, reversal flow distribution was obtained, compared as right-ward flow.

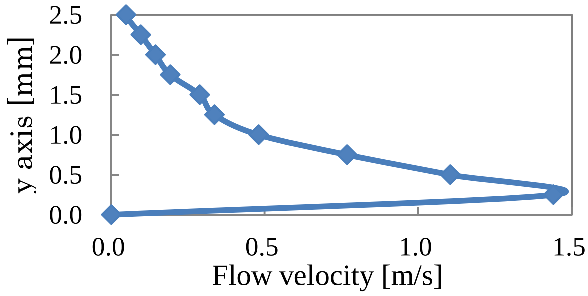

Fig. 6 Velocity profile at x = 12 mm.

Previous two flows were parallel to the wall. On the contrary, by driving HV 1 and HV 4, perpendicular flow to the wall was obtained. Flow direction was from both edges to center. At center, two flows collided and up-ward flow was generated. Fig. 7 shows up-ward flow distribution. At center, 0.5 mm height of the device, 0.8 m/s up-ward flow was obtained. The 2D flow Vector was distributed symmetrically due to the symmetric electrode configuration.

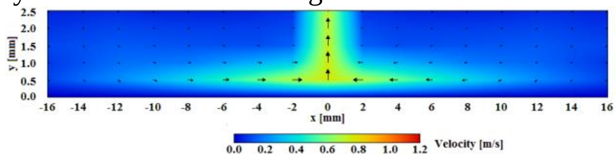

Fig. 7 Flow distribution of up-ward flow

When HV 2 and HV 3 were driven, flow direction was from center to both edges. At center, down flow was generated to satisfy the equation of continuity. 2D vector distribution of down-ward flow is shown in Fig. 8. Flow velocity was about 0.2 m/s at center, 0.5 mm height of the plasma actuator.

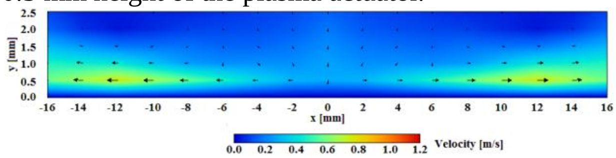

Fig. 8 Flow distribution of down-ward flow

4. Conclusion

In this study, multi-electrode microplasma actuator was investigated. By driving four HV electrodes independently, four types of flows were generated. Right-ward and left-ward flows were horizontal flows and up-ward and down ward flows were perpendicular flows. Flow velocity was on the order of 1 m/s.

References

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