Basic study of atmospheric microplasma effect on the pressure loss

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INTRODUCTION

Fluidic control is an important factor for improving efficiency for various machines. To control a fluid, many mechanical actuators were already proposed and used effectively. The mehcanical actuators have some disadvantages such as secondary flow or complicated mechanism. Recenty, actuators which are used plasma are investigated actively to control flows. Comparing with the mechanical actuators, plasma actuator has some advantages due to its simple structure. Fig. 1 shows the principle of the plasma actuator.

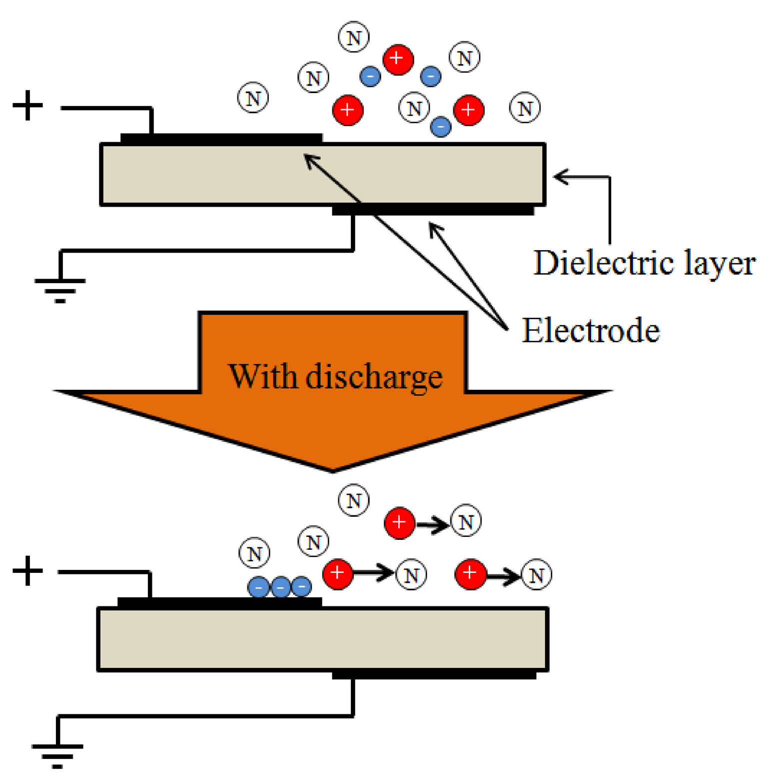

Fig. 1 Principle of the plasma actuator.

For applying to industries, atmospheric pressure plasma is required to minimize cost or size. Microplasma is atmospheric pressure nonthermal plasma which requires relatively low discharge voltage, and a type of dielectric barrier discharge which has micro meter gap. The effect of gas flow by atmospheric microplasma was experimentally investigated.

METHODS

(1) Microplasma Electrodes

A schematic image of microplasma electrodes is shown in Fig. 2. Microplasma was generated with a pair of electrodes which covered with dielectric layer and faced each other with a spacer (thickness 100 μm) in between.

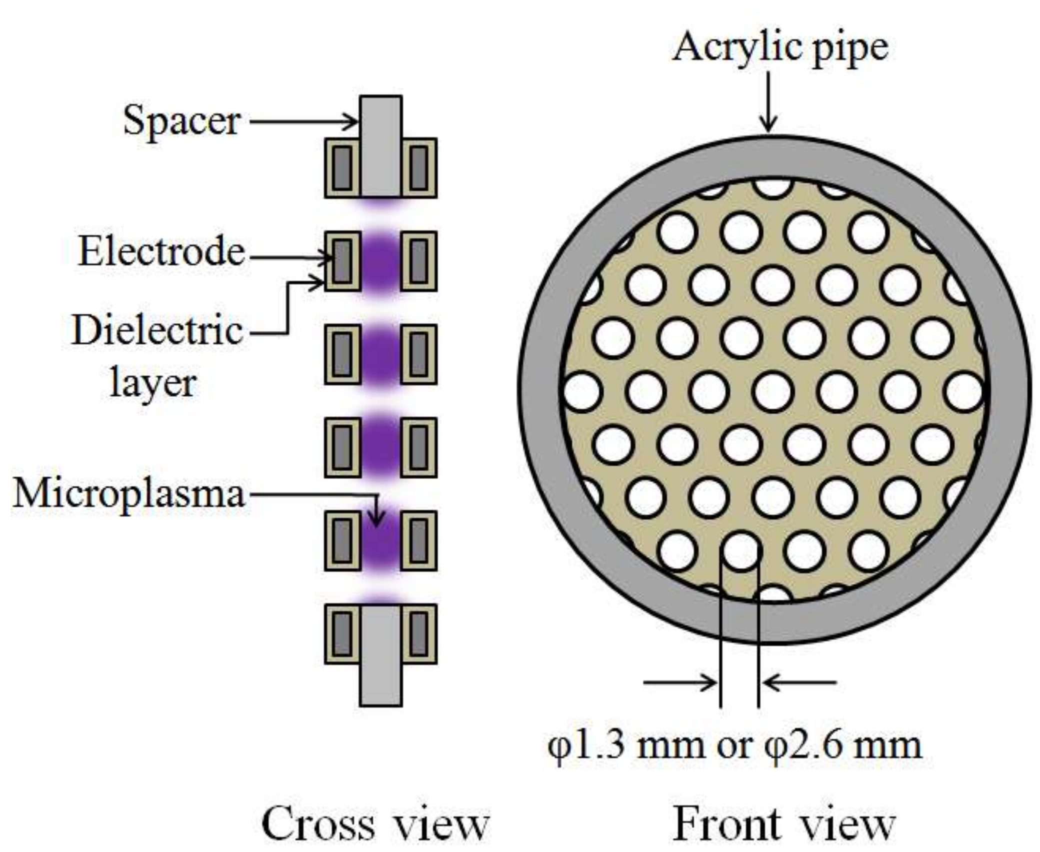

Fig. 2 Microplasma electrodes.

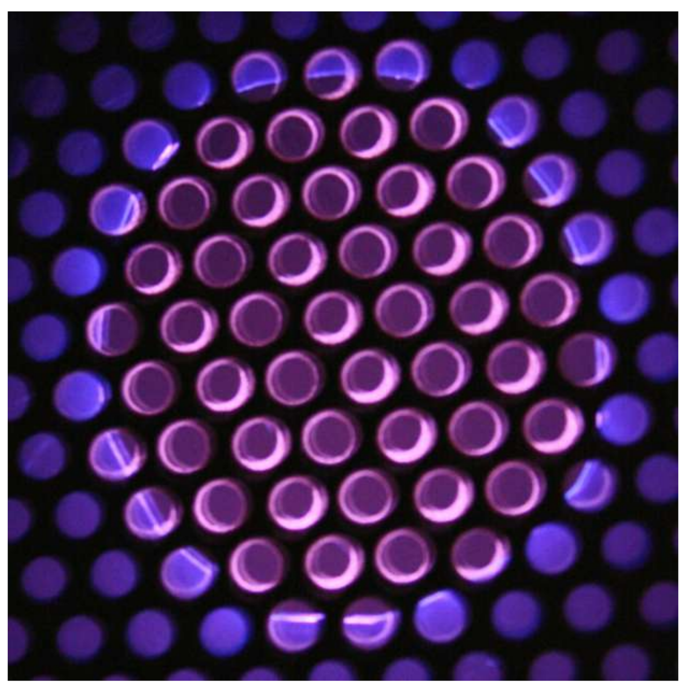

Fig. 3 An image of microplasma during discharge (about 1.2 kV).

Depending on this electrodes constitution, microplasma which used this experiment could be suppressed to a relatively low discharge voltage (around 1 kV) and cut down its power consumption and size.

Fig. 4 shouws a current-voltage characteristic at discharge voltage of 1.4 kV. Spike current occured at rise and decay points of discharge voltage. This is a typical waveform of dielectric barrier discharge.

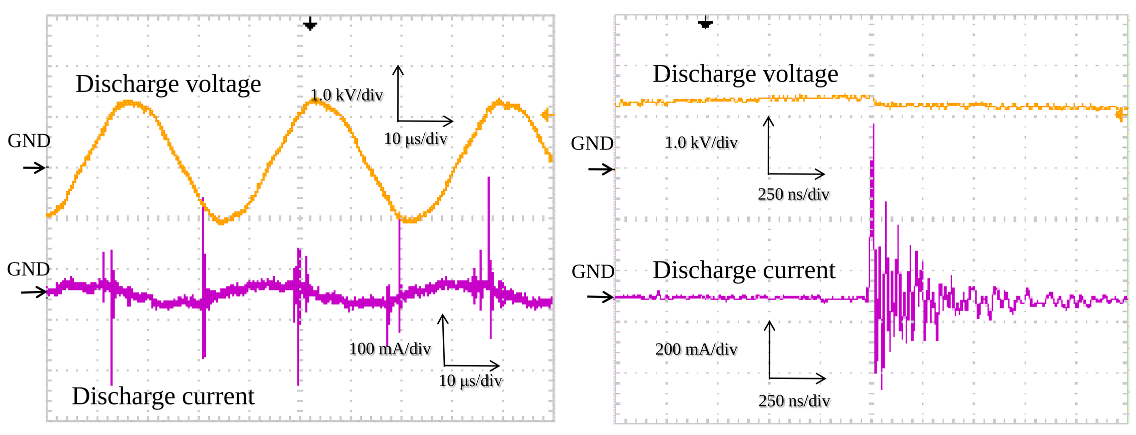

Fig. 4 Current-voltage characteristic.

(2) Experimental setup

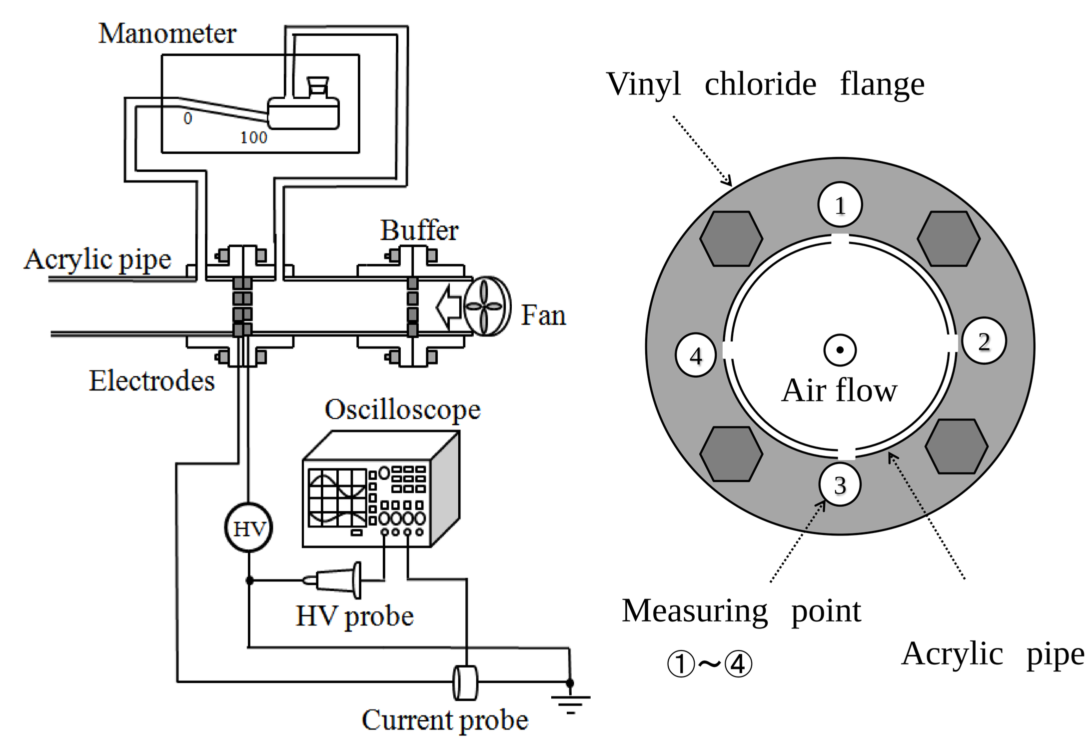

Fig. 5 Experimental setup.

A neon transformer was used as a power supply for microplasma generation. An AC high volatage energized the electrodes and could generate microplasma and ionic wind between electrodes. That ionic wind could impact the air flow in the acrylic pipe. A manometer was used to measure the pressure difference and observe how the flow was changed by passing through electrodes.

Table 1 Experimental conditions.

Discharge voltage [kV]	1.0 ～1.4
Gas velocity [m/s]	1.5 (Re num. : 5,000) 3.5 (Re num. : 13,000)
Hole size of electrodes [mm]	1.3 (aperture ratio : 45.7 %) 2.6 (aperture ratio : 41.0 %)
Discharge gap [μm]	100
Frequency [kHz]	27

RESULT

Fig. 6 shows the pressure loss of electrodes itselves. The pressure loss of each hole size electrode was increased with increacing flow velocity.

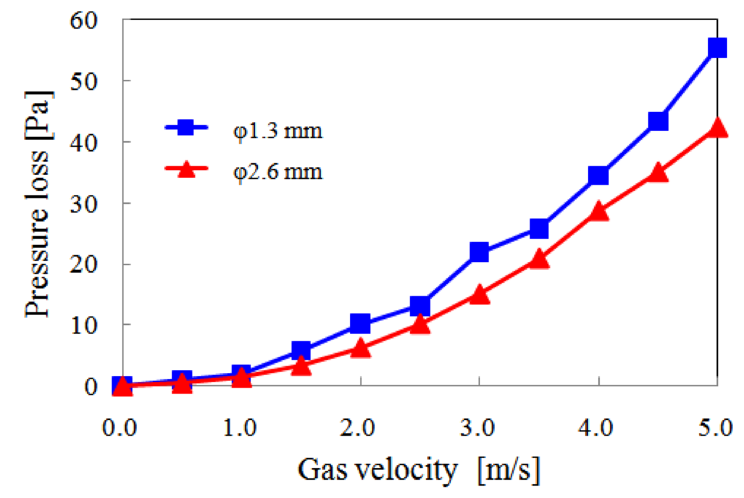

Fig. 6 A relationship between flow rate and pressure loss.

Table 2 The pressure loss of electrodes.

Hole size [mm]	Gas velocity [m/s]	Pressure loss [Pa]
1.3	1.5	5.8
	3.5	25.8
2.6	1.5	3.4
	3.5	20.9

A relationship between pressure loss and discharge voltage at 1.5 m/s is shown in Fig. 7 and at 3.5 m/s is shown in Fig. 8.

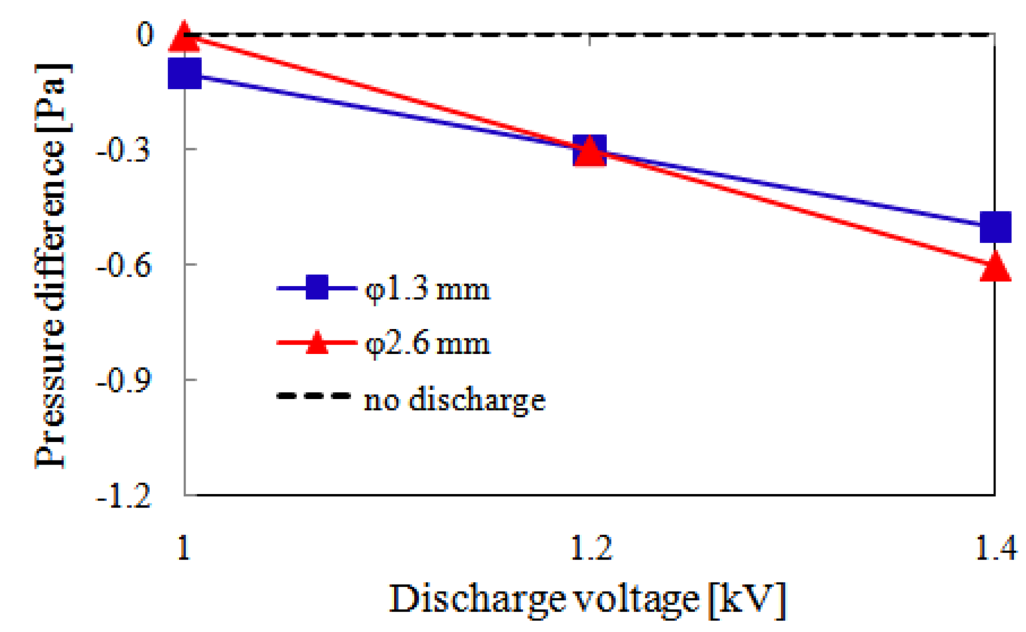

Fig. 7 A relationship between pressure loss and discharge voltage at 1.5 m/s.

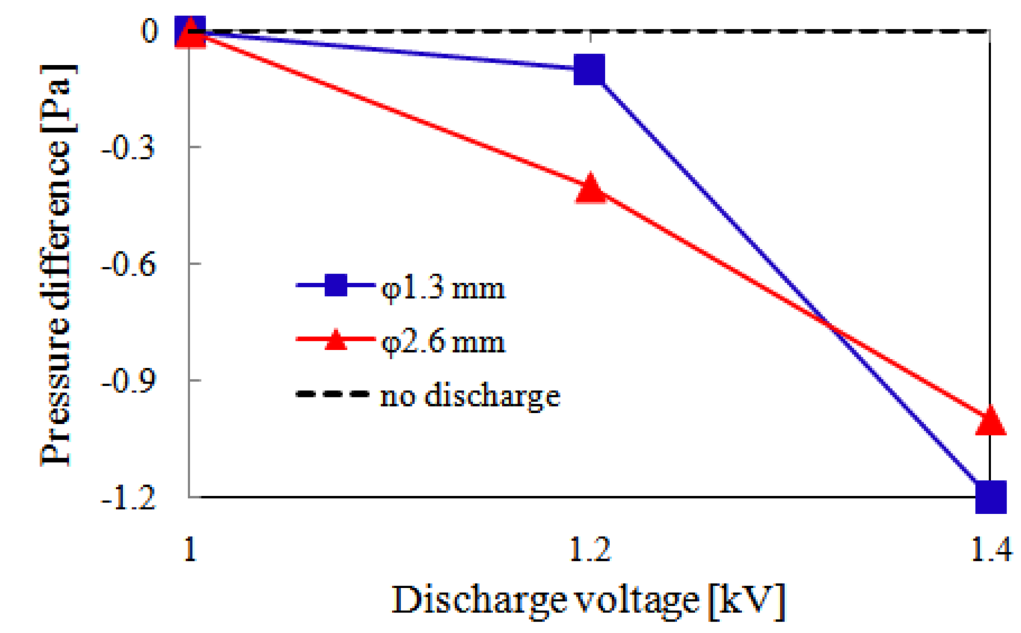

Fig. 8 A relationship between pressure loss and discharge voltage at 3.5 m/s.

A decrease of the pressure difference was equivalent to a decrease of the pressure loss at electrodes . A higher value was measured at 3.5 m/s comparing with 1.5 m/s. The maximum decrease of pressure difference (1.2 Pa) was observed for the electrodes with 1.3 mm holes diameter at 3.5 m/s. This was about 5% of total pressure loss. There were no significant differences of pressure change for both 1.3 mm and 2.6 mm holes electrodes.
Table 3 shows the reducing rate of pressure loss each hole size of electrode and flow rates.

Table 3 Reducing rate of pressure loss by atmospheric microplasma.

Hole size [mm]	Gas velocity [m/s]	Pressure difference at 1.4 kV [Pa]	Reducing rate of pressure loss [%]
1.3	1.5	0.5	8.6
	3.5	1.2	3.9
2.6	1.5	0.6	17.7
	3.5	1.0	5.7

CONCLUSIONS

In this study, the following conclusions were obtained.

1. Decrease of pressure loss was observed at the back and at the forth electrode for each hole size of electrode and air flow rates. Effect and possibility of fluidic control by atmospheric microplasma was confirmed at a relatively low discharge voltage.
2. A higher value of rate change of pressure difference was measured at 3.5 m/s for each hole size electrode. This result suggested a possibility of fluidic control by atmospheric microplasma for a fuild which has a relatively high Reynolds number.
3. The reducing rate of pressure loss with 2.6 mm hole size of electrode was higher than that of 1.3 mm hole size of belectrode. It could be considered that configuration of electrode is also one of important factors for fluidic control.
4. The reducing rate of pressure loss with 1.5 m/s was higher than that of 3.5 m/s for each hole size of electrode. This could be considered that a smaller Reynolds number is more effective than a higher Reynolds number.