Basic Study on EHD Flow Induced by Pulsed Power Microplasma

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Introduction

For active air-flow control applications, dielectric barrier discharge (DBD) plasma actuators offer advantages such as no moving parts, fast response due to the fact that are electrically energized and simple construction.

When to a plasma actuator high voltage is applied, a high electric field ionizes the air near the plasma actuator. Ions are drifted by the Coulomb force. While traveling through the air, ions collide with neutral gas molecules and transfer their momentum to neutral molecules induced air flow called ionic wind. This kinetic force induced by Coulomb force is known as Electrohyorodynamics (EHD) phenomenon.

DBD Plasma actuator energized by high voltages such as 10 kV for active flow control has been studied. In this study, the micro scale DBD plasma actuator was fabricated and investigated. Due to the micro scale gap, our microplasma actuator could be driven at 1 kV, relativity low voltage.

Experimental Setup

(1) Microplasma actuator

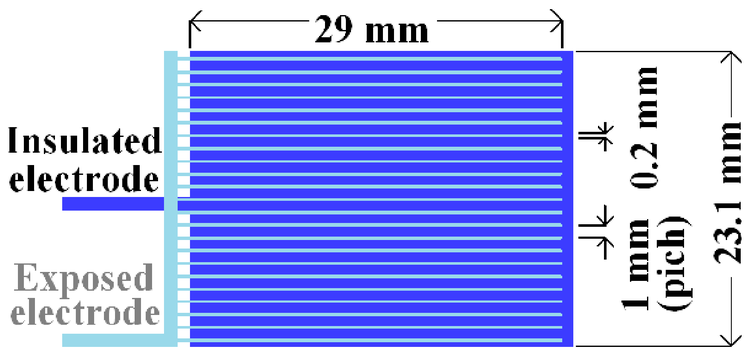


Fig. 1 Geometry of microplasma actuator.

Geometry of microplasma actuator in this study is shown in Fig. 1. Alternating stripe like electrodes are placed above a plate like electrode having a dielectric layer of 25 μm thicknesses in between. As a result, DBD could be generated about 1 kV, relativity low discharge voltage. It contributes make it easily to insulate of high voltage line or miniaturize the power supply.

(2) Experimental Setup

Plasma actuator was energized by a high-voltage bipolar pulse. Tracer particle (OD 50 μm) was distributed on a plasma actuator and its movements were observed while driving microplasma actuator.

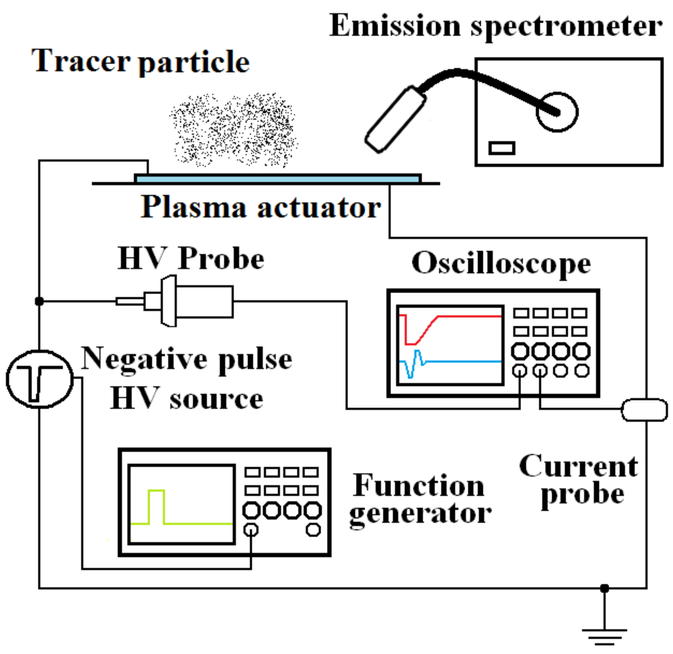


Fig. 2 An experimental setup.

Results and discussion

(1) Electrical characteristics

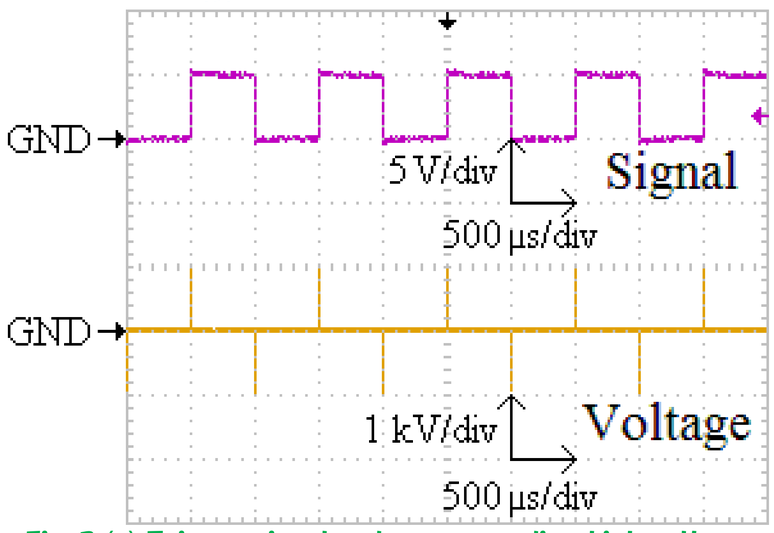
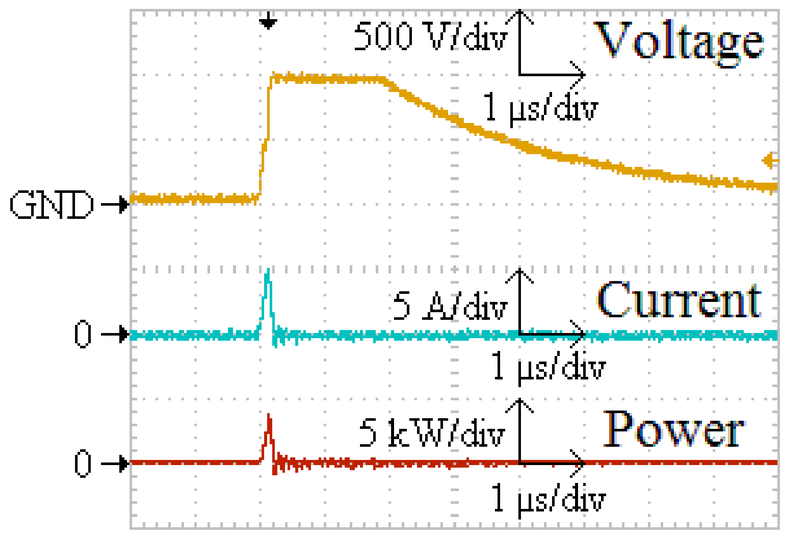
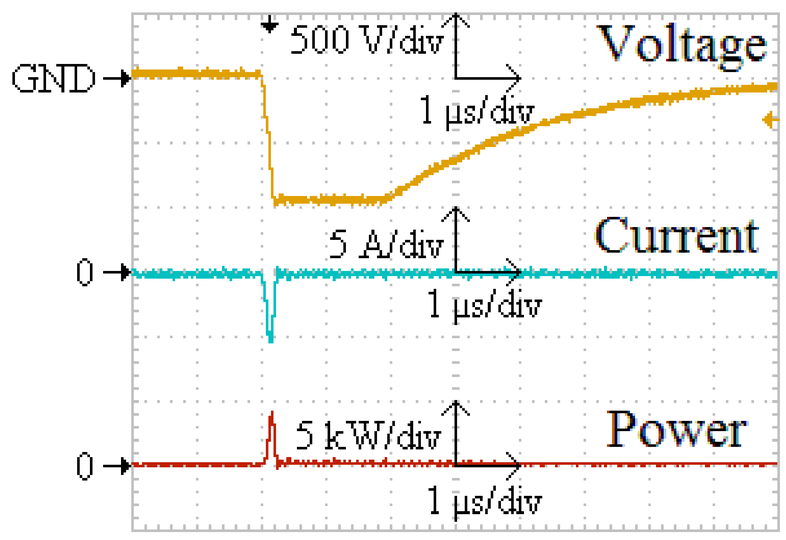


Fig. 3 (a) Trigger signal and corresponding high voltage pulse.



(a) Positive pulse



(b) Negative pulse

Fig. 4 Waveform of pulse voltage and corresponding current and power.

DBD by microplasma actuator was observed by applying bipolar high-voltage pulse. Fig. 3 shows a 5 V trigger signal and the corresponding high- voltage pulse. When signal was rising, positive high-voltage pulse was generated. When signal was falling, negative high-voltage pulse was generated. Peak voltage was 1 kV and pulse frequency was 1 kHz .

Pulse width of high-voltage was 3.6 μs. At the high-voltage peak value, corresponding current and power could be up to 5.0 A and 4.5 kW, respectively. Energy consumption by applying one short pulse was about 1 mJ at both polarity. Average power consumption was calculated by the product of 2 mJ and pulse frequency of 1 kHz and was estimated at about 2 W.

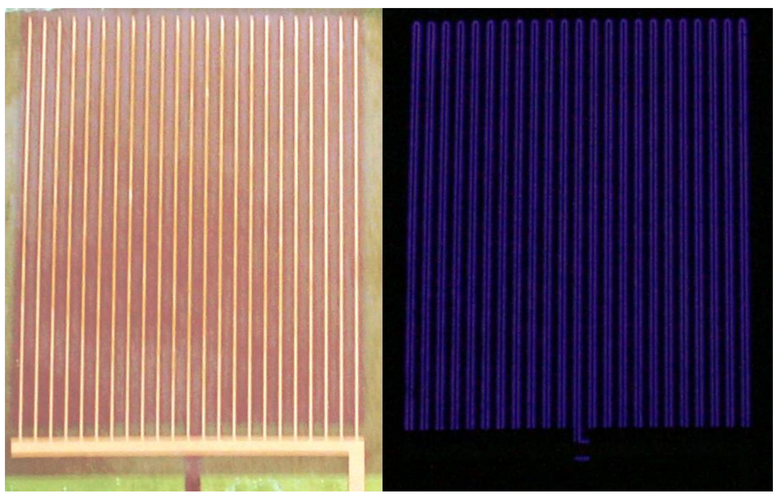


Fig. 5 Photograph of the light emission from microplasma actuator.

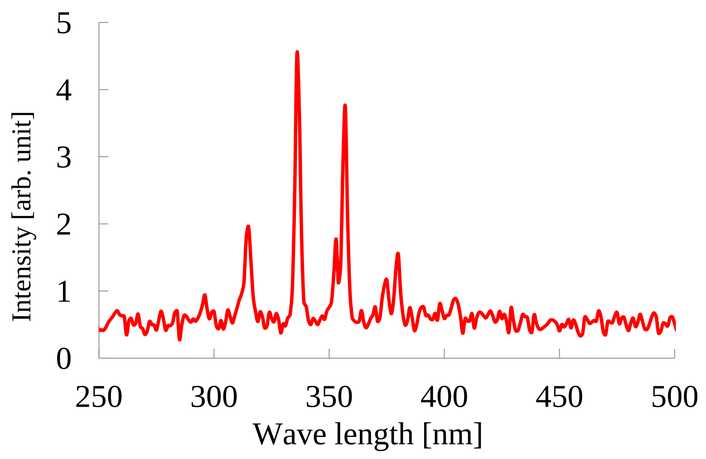


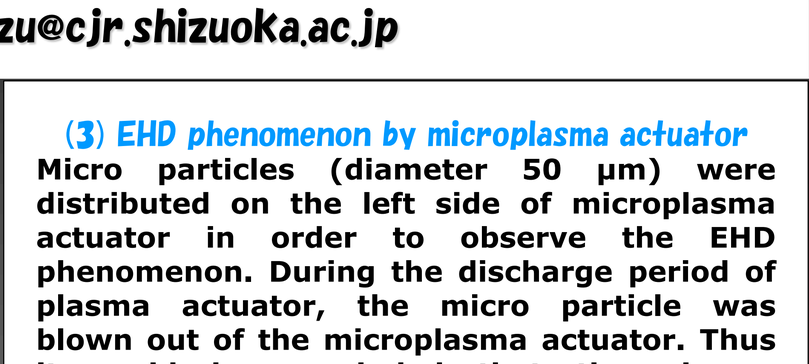
Fig. 6 Emission spectra of microplasma actuator in atmospheric air.

Fig. 5 shows photograph of light emission by driving microplasma actuator. Light emission of DBD was observed at edge of the exposed electrode. Emission spectra were measured by emission spectrometer during discharge is shown in Fig. 6. Discharge gas was ambient air thus the highest peaks corresponds to N_2 Second Positive Band System and were measured at 315, 337, 357, 375, and 380 nm.

(3) EHD phenomenon by microplasma actuator

Micro particles (diameter 50 μm) were distributed on the left side of microplasma actuator in order to observe the EHD phenomenon. During the discharge period of plasma actuator, the micro particle was blown out of the microplasma actuator. Thus it could be concluded that the plasma actuator generates kinetic force at surface region. This micro size plasma actuator could be used as surface flow modification such as separation flow control or drag reduction.

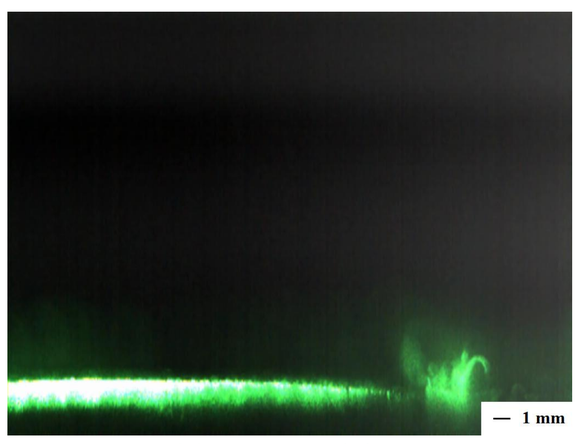
(a) Before driving (b) After 40 s driving



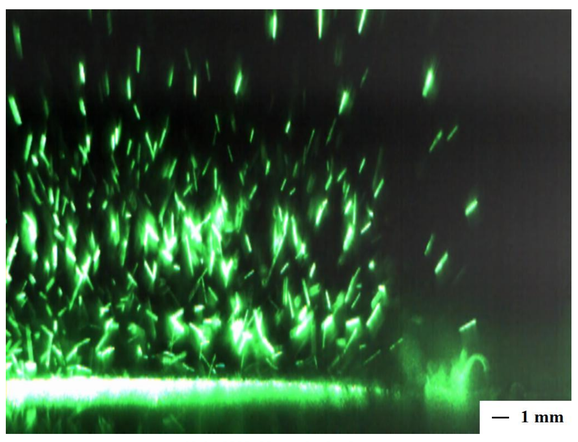
(c) After 80 s driving (d) After 120 s driving

Fig. 7 micro particle distribution.

Movement of micro particles while driving microplasma actuator was measured by high-speed camera. Fig. 8 (a) and (b) shows the movement of micro particles before driving plasma actuator and while driving plasma actuator, respectively. Micro particles were blown off and their velocity was about 1 m/s reaching up to 10 mm height by supplying high-voltage pulse.



(a) Before driving



(b) While driving

Fig. 8 Movement of micro particle.

Conclusions

In this study, EHD phenomenon induced by micro-scale plasma actuator was investigated and following conclusions were obtained

1) Microplasma actuator could be driven at 1 kV pulsed-voltage and its average power was 2 W.
2) By energizing the microplasma actuator, micro particles with diameter of about 50 μm were blown off from microplasma actuator with a velocity of about 1 m/s and reaching up to 10 mm height.

Acknowledgement

The authors would like to thank Prof. Sanada of Shizuoka University and Prof. Yonoda of The University of Electro-communications for the fruitful discussions.