Particle image velocimetry analysis of dielectric barrier discharge plasma actuators

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Abstract: A surface dielectric barrier discharge (sDBD), one of the atmospheric pressure plasma devices, is utilized as a flow control device using electrohydrodynamics [1,2]. The interaction of the sDBD was observed by applying an AC sinusoidal voltage. The plasma discharge was investigated with the variation of the electrode width, dielectric thickness, and electrode position. Particle velocity and distribution were analyzed using particle image velocimetry (PIV), which is a method to understand the flow behavior of various fluid components [3,4].

Keywords: Atmospheric pressure plasma, surface dielectric barrier discharge, particle image velocimetry

Controlling turbulence on the surface of airplanes and vehicles has been studied so far using electrohydrodynamics (EHD) [5]. Research into controlling turbulence has focused on managing thin boundary layers located close to the walls of bodies moving through the fluid. It will reduce drag and increases lifting power. By controlling turbulence, fuel consumption can be reduced, travel time reduced, and speed increased. For this purpose, research is undergoing to use of a plasma device [6].

The atmospheric pressure plasma has been actively utilized for EHD for several years. Surface dielectric barrier discharge (sDBD) is being studied as a device that controls airflow. As shown in Fig. 1, sDBD consists of two or more electrodes separated by various dielectrics such as Kapton polyimide tape and quartz. High voltage is applied to the exposed electrode, and the embedded electrodes are connected to the ground. Generally, a voltage in the kV range and a frequency in the kHz range are applied, and a plasma discharge occurs when the applied voltage is higher than the breakdown voltage. A dielectric plate is placed at the bottom, through which discharge occurs only at the exposed electrode.

In addition, as shown in Fig. 2, three electrodes can be used for more precise control than the case using two electrodes. A detailed comparison is possible through the change in the number of electrodes and the change in the dielectric thickness, the embedded electrode width, and the geometry of the electrodes. As shown in Fig. 1, plasma is discharged between the exposed and embedded electrodes.

No matter how well the plasma conditions are matched, the human eye is limited to checking the fluid flow regulated by the plasma. Momentum transfer can be investigated using particle image velocimetry (PIV) to observe flow motion. The PIV system repeats turning the laser on and off every ms scale. Using a high-speed camera, the movement of the particles reflected by the laser can be checked over time. Through this, the fluid movement of the induced fluid generated through plasma discharge can be grasped. PIV measurements are made near the plasma actuator's discharge region.

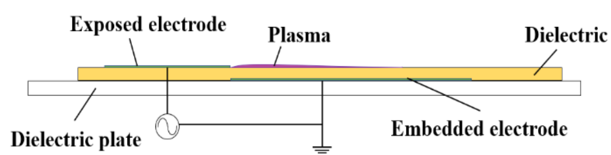

Fig. 1. Geometry of standard sDBD actuator

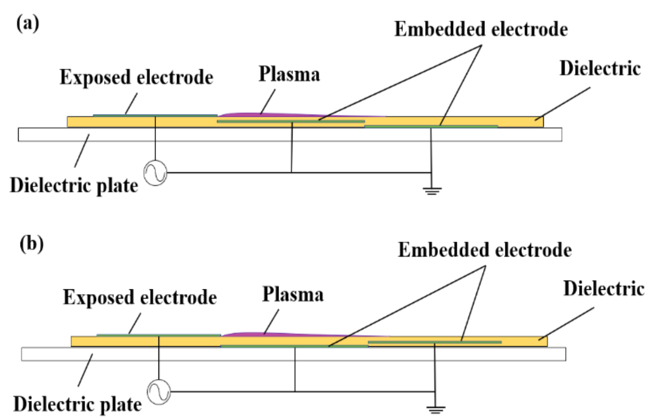

Fig .2 Geometry of three-electrode DBDs for (a) sequential structure, (b) non-sequential structure

Through this research, we will confirm the difference between the two-electrode case and the three-electrode case and what phenomenon occurs by each parameter and explain the change in fluid motion through the PIV system.

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