Evaluation on ionic wind generated with a ring-shaped DBD device having an exhaust nozzle

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Abstract*—A ring-shaped dielectric barrier discharge (DBD) with an auxiliary grounded electrode (the third electrode other than the binate electrodes to produce DBD) was explored as a small ionic wind device. The inner diameter of the ring-shaped DBD electrode ranged from 3.18 to 9.54 mm. Ionic wind was firstly produced toward the center of the ring, resulting in a upward axial flow. A disk provided with an opening as an outlet of the flow (called 'lid' in this study) was placed over the DBD electrode. The auxiliary electrode was formed at the outlet. Their diameter (*D*) ranged from 1.0 to 4.0 mm. Results showed that grounding the auxiliary electrode significantly enhanced the wind speed and flow rate produced by the DBD device. These values varied with the distance between the surface on which the DBD electrode was placed and the lid (indicated by *H*—described in Experimental Methods in detail) and *D*. The outlet acted like a nozzle even when the auxiliary electrode was not grounded and accelerated flow speed at some conditions of *D* and *H*. The enhancement effect of grounding the auxiliary electrode was larger with smaller *H* because of strengthened electric field. For the DBD electrode of 6.35 mm inner diameter as an example, grounding the auxiliary electrode enlarged a maximum flow speed and flow rate from 1.6 m/s to 3.6 m/s and 130 ml/min to 780 ml/min, respectively. And as a result, energy conversion efficiency from discharge to flow power was enlarged by a factor of 30.

I. INTRODUCTION

Devices that generate ionic wind (or electrohydrodyanmic flow) have several advantages over conventional air movers, most notably their silent operation, short response time, and lack of moving parts. These advantages have led to interest in integrating them in various fields, including the control of boundary layer separation from airfoils, improvement of electrostatic precipitators, and the enhancement of convective heat transfer. This study focuses on a DBD generated with ring-shaped electrodes [1] to produce thin air jets for applications such as cooling.

We explore the impact of placing grounded auxiliary electrodes above the center of the ring-shaped DBD to determine its effect on the air jet’s speed and flow rate. Recently, it has been shown that including auxiliary electrodes downstream of the discharge-producing electrodes can enhance airflow by essentially extending the active area for the Coulombic body force of the discharge [2—4].

II. Experimental Methods

Figure 1 shows a schematic of the flow generating device tested in this study. As illustrated in Fig. 1, the basic structure consisted of a circular plastic substrate, containing DBD electrodes, and a plastic disk, referred to as the lid, with an opening at its center placed above the plastic substrate. The DBD was generated by ring shaped electrodes to produce surface DBDs on the plastic substrate. These surface DBDs produced an ionic wind pointed radially inward along the surface of the plastic substrate. At the center of the plastic substrate and ring electrodes, the radially inward ionic wind converged and was redirected perpendicular to the substrate. This orthogonal air flow was accelerated through an outlet nozzle in the lid to produce an air jet.

The exact geometry and dimensions of the ring-shaped DBD jet unit are shown in Fig. 2. The DBD was generated on the surface of the plastic substrate. A grounded electrode made from copper foil with a thickness of 0.0381 mm and a diameter D_1 was placed on the top surface of the plastic substrate (as shown in the inset), and an electrical terminal made from silver conductive paint passed through the bottom of the plastic substrate to make contact with the grounded electrode. Three sheets of polyimide (Kapton adhesive tape with a thickness of 0.0254 mm) with diameter D_2 were used to cover the grounded electrode and acted as the dielectric layer. Finally, a stainless-steel ring-shim with a thickness of 0.0381 mm was attached on top of the polyimide and used as the discharge electrode. Three different sets of electrodes (types 1—3), each of which has unique diameters, were used and are summarized in Table 1.

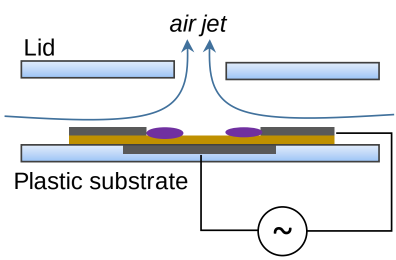

Fig. 1. Illustration showing ionic wind air jet produced by ring electrode DBD.

TABLE 1: DIMENSIONS OF THE ELECTRODE SETS

	Discharge electrode		Ground electrode	Dielectric Layer
Unit type	Inner diam. (mm)	Outer diam. (mm)	D_1 (mm)	D_2 (mm)
Type 1	3.18	4.77	4.76	7.5
Type 2	6.35	9.53	9.53	15
Type 3	9.54	14.29	11.11	22.5

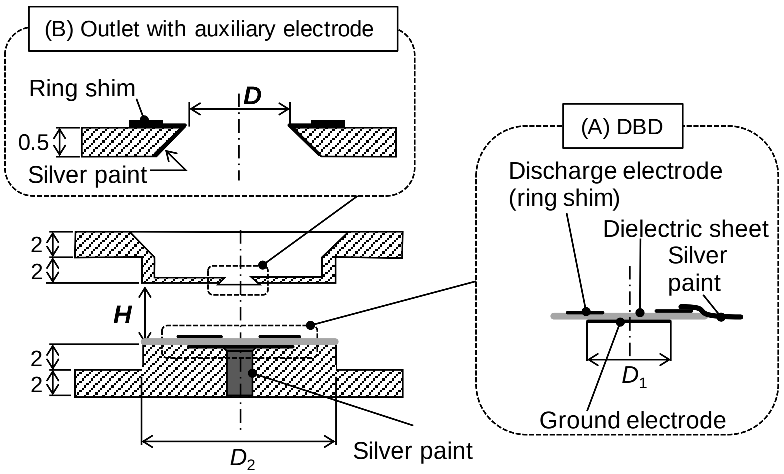

Fig. 2. Schematics of ring-shaped DBD jet unit. The DBD electrodes shown in Inset A are placed on top of the plastic substrate, and the silver paint electrical terminal makes contact with the ground electrode. The lid is positioned at a height *H* above the DBD and airflow coming radially inward produces an orthogonal vertical jet that is directed through the outlet. As shown in Inset B, the outlet includes an auxiliary electrode to help promote a stronger ionic wind through the outlet. All units are in mm.

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