Characteristics of Ozone Jet Generated by Dielectric-Barrier Discharge

Hideya Nishiyama, Hidemasa Takana, Shota Niikura, Hirofumi Shimizu, Dai Furukawa,
Tomoki Nakajima, Kazunari Katagiri, and Yoshikatsu Nakano

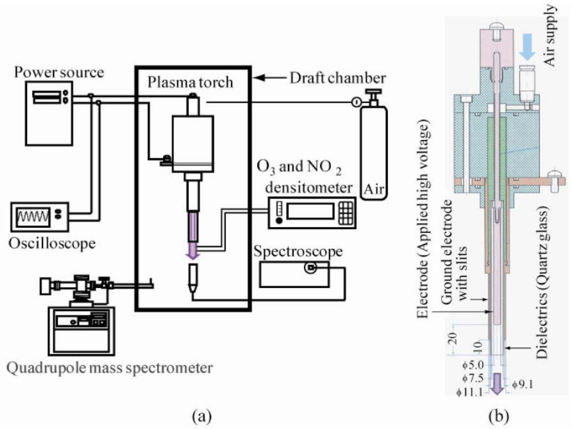
***Abstract*—The characteristics of ozone jet generated by atmospheric-pressure coaxial dielectric-barrier discharge has been experimentally clarified through the visualization of discharge and also by the measurement of ozone concentration for various operating conditions, such as applied voltage, frequency, and gas flow rate. It is shown that the ozone production is highly controllable with applied voltage, and 1500 ppm of ozone can be produced at the input power as low as 72 W.**

***Index Terms*—Air plasma flow, applied voltage, dielectric-barrier discharge (DBD), flow rate, ozone.**

RECENTLY, the plasma-assisted combustion technology has been particularly paid attention in aerospace and automobile engineerings [1]. It has been made clear that ozone and radicals, such as O and OH, mainly play an important role in the combustion enhancement assisted by plasma [2], [3]. Besides this promising application of ozone to the combustion assist, ozone has been widely used in industries for such as bleaching or oxidizing purposes, sterilization, and NOx removal from exhaust gases [4].

In this paper, atmospheric-pressure dielectric-barrier discharge (DBD) in coaxial configuration is utilized from the viewpoint of small input power and easy controllability of ozone and radical productions for various kinds of industrial applications. The characteristics of ozone jet produced by atmospheric-pressure DBD are clarified in detail by the experimental analysis.

Fig. 1(a) and (b) shows the schematic illustrations of experimental apparatus [5] and coaxial-air DBD torch, respectively. The experimental apparatus consists of pulsed power supply, coaxial-air DBD torch, and the air-supply system. The electrodes are made of copper, and only outer grounded electrode is coated with 0.8-mm-thick quartz glass of dielectric-barrier material. The outer electrode has slits for the clear observation of discharge emission and spectroscopy measurement in the discharge region. The gap between inner electrode and surface of the glass is 1.25 mm. The quartz glass is longer than the outer electrode by 10 mm. The applied sinusoidal voltage is from 16 to 32 $\mathrm{kV_{pp}}$ at the frequency ranging from 100 to 2000 Hz. The dry air flows between electrodes, and its flow rate is changed in the range of 1.0–9.0 L/min. The surrounding gas is air at room temperature and atmospheric pressure. The produced radicals and other chemical species in the air flow are measured by quadruple mass spectrometer or ozone densitometer at 20 cm downstream from the torch exit.



(a) (b)

Fig. 1. Schematic illustrations of (a) experimental setup and (b) atmospheric-pressure coaxial DBD plasma torch.

Fig. 2 shows the discharge photographs of air plasma flow generated by DBD for various applied voltages at the constant flow rate of 6.0 L/min. The radiation intensity increases, and discharge extends more to the downstream with increasing applied voltage. Plasma is generated quite uniformly in azimuthal direction. Strong radial luminescence in the electrode gap corresponds to streamers, and surface discharge develops on the surface of quartz glass at the edge of outer electrode. The emission intensity of the second positive system of nitrogen (337.1, 357.6, 380.5, and 405.9 nm) transition from the $N_2(C^3\Pi_u)$ to $N_2(B^3\Pi_g)$ has been measured by the optical-emission-spectroscopy measurement.

Figs. 3 and 4 show the concentration of ozone as a function of applied voltage and flow rate, respectively. The concentration of ozone increases quite linearly with the applied voltage. This result shows the high controllability of ozone production by the applied voltage. At the input power as low as 72 W, 1500 ppm of ozone can be produced. For the gas flow rate larger than

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The authors are with the Institute of Fluid Science, Tohoku University, Sendai 980-8577, Japan (e-mail: nishiyama@ifs.tohoku.ac.jp; takana@paris.ifs.tohoku.ac.jp).

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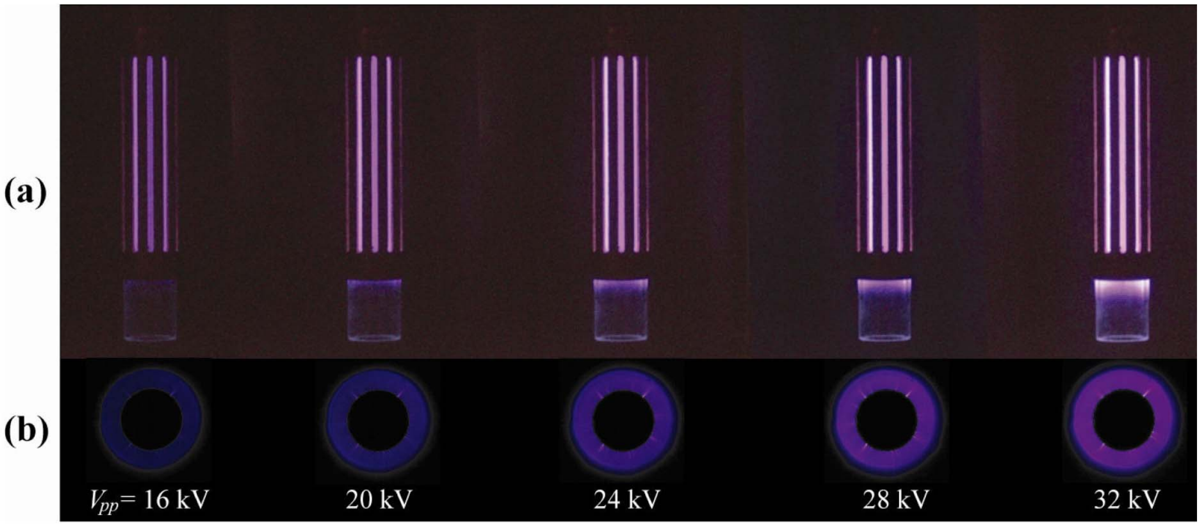

Fig. 2. Discharge luminescence for various applied voltages at $f = 1000$ Hz and $Q = 6.0$ L/min. (a) Side view. (b) Bottom view.

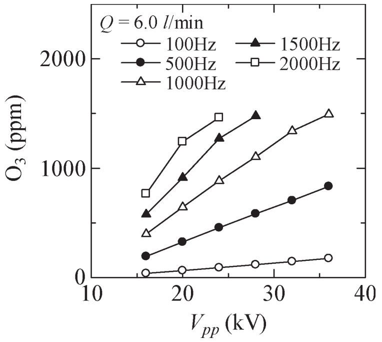

Fig. 3. Ozone concentration as a function of applied voltage for various pulse frequencies at $Q = 6.0$ L/min.

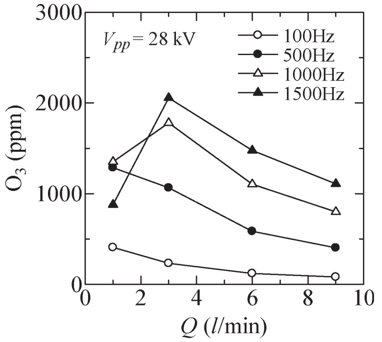

Fig. 4. Ozone concentration as a function of flow rate for various pulse frequencies at $V_{\mathrm{pp}} = 28$ kV.

3.0 L/min, the amount of produced ozone decreases with gas flow rate due to the decrease in net effective power. The amount of ozone increases with increasing frequency except for the flow rate of 1.0 L/min. This is because the heat decomposition of ozone becomes dominant at 1000 and 1500 Hz due to the insufficient cooling under 1.0 L/min.

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