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Citation	The 6th International Symposium on Biomedical Engineering, , ,
Pub. date	2021, 12

Development of a multilayer dielectric barrier discharge device for high flow medical exhaust gas decomposition

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Introduction: Volatile organic compounds (VOCs) are widely used in various fields such as medicine and industry. However, since these VOCs are often harmful to the human body and are also causative agents of photochemical oxidants and suspended particulate matter, it is necessary to decompose them to below the standard value before releasing them into the atmosphere. Traditionally, VOCs have decomposed using combustion and photocatalytic methods. The combustion method decomposes VOCs with fuel at high temperatures of 600-800°C. This method is suitable for gas decomposition at high flow rates and high concentrations but is not suitable for gas decomposition at low concentrations due to the high energy consumption. The photocatalytic method, on the other hand, is a method of decomposition by the oxidizing action of photocatalyst, which has low running cost and is suitable for gas decomposition at small flow rates and low concentrations but is not suitable for large flow rates. In recent years, atmospheric pressure and low-temperature plasmas have been attracting attention as a low-energy method for decomposing gases with large flow rates and low concentrations. We are developing a large volume processing system using a large dielectric barrier discharge.

Results of decomposition rates for single layer and double layer dielectric barrier discharge device: Figure 1 shows a schematic of the developed single layer device. The single layer device consists of a high voltage electrode, a grounding electrode, and a dielectric. A space for gas flow is provided between the two dielectrics using a spacer, and the gas to be treated flows through the space to generate plasma for decomposition treatment. In the single layer system, the plasma generation area is 100 mm wide, 250 mm long, and 2 mm thick, while in the double layer device, the plasma generation volume is twice that of the single layer device. In our previous study, we used toluene mixture as the target of gas decomposition. In each device, the flow rate was 50 L/min, the concentration was 100 ppm, and the applied voltages were 14 kV, 18kV, and 22 kV. Figure 2 shows the decomposition results of the single layer and double layer device. The maximum decomposition rate was observed when 22 kV was applied, which was about 50 % for the single layer device and about 60 % for the double layer device. The decomposition rate of the double layer device was improved by about 10% compared to the single layer device. This result confirms the superiority of the multilayer device. In a similar experiment normally conducted, the flow rate is about 1L/min at most, but with this device, a decomposition experiment was realized at a flow rate of 50L/min. On the other hand, considering the actual situation in the world, we would like to achieve decomposition at a flow rate of several thousand L/min.

Design and development of a 10-layer dielectric barrier discharge system: After confirmed the superiority of the multilayers, a 10-layer dielectric barrier discharge device was designed and developed for practical use and to achieve even higher flow rates. First, we designed a 10-layer device. Its conceptual diagram is shown in Fig. 3. Then, before fabricating the system, we used fluid analysis software to simulate whether the gas would flow uniformly from the first to the tenth layer. It was confirmed that the gas flowed uniformly from the first to the tenth layer. Based on the results of this fluid analysis, we developed a 10-layer device. In this device, the specifications allowed us to check the discharge of each layer at the gas outlet side, and when we applied voltage, we were able to confirm that plasma was generated in each layer without any problems. Finally, as an initial experiment, we conducted a decomposition experiment using this device. The experimental conditions were the same for the single layer and double layer, and the results were compared. The decomposition results are shown in Fig. 4, where the decomposition rate is 92 % at 22 kV, indicating a high efficiency of decomposition.

Summary and Future Plans: First, the results of the decomposition experiments were compared using a single layer device and a double layer device, and the advantages of using a multilayer device were demonstrated. Next, we designed a 10-layer device and conducted fluid analysis and confirmed that the gas flowed evenly through each layer. The decomposition experiment was conducted using a 10-layer treatment system, and the decomposition rate was about 92 %. As a future prospect, we would like to conduct decomposition experiments under even higher flow rates for practical use.

Biography: Yuito Mori was born in Fukuoka, Japan, in 1997. He received his B.E. in Advanced Production Information Systems Engineering Course at National Institute of Technology, Ariake College, Fukuoka, in 2020. He is now a master's course student at Tokyo Institute of Technology majoring in Electrical and Electronic Engineering, Yokohama, Japan.

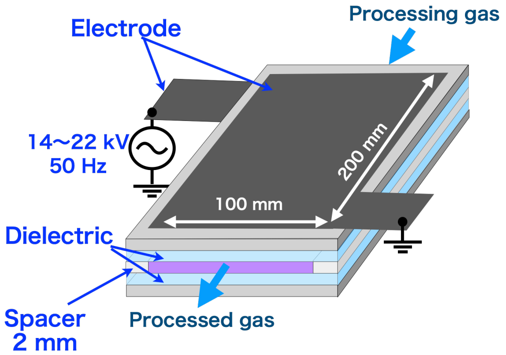

Figure 1. Schematic diagram of dielectric barrier discharge device

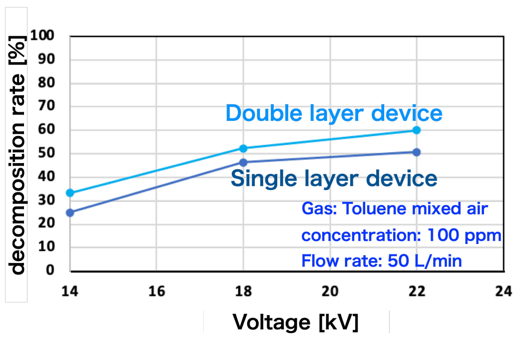

Figure 2. Decomposition rate results for single layer and double layer devices

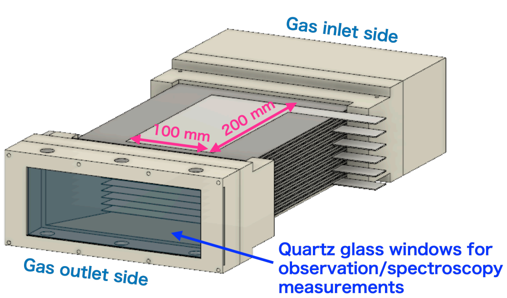

Figure 3. Schematic diagram of the 10-layer device

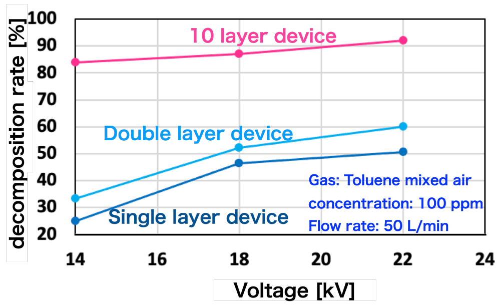

Figure 4. Decomposition rate results for 10-layer device