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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation, entitled "Development of Large-flow Plasma Source Based on Dielectric Barrier Discharge and Its Application to Air Pollutant Degradation", focuses on the development of large-flow plasma sources based on dielectric barrier discharge (DBD), and includes six chapters.

In Chapter 1, “Introduction”, the wide application of low-temperature atmospheric-pressure plasma in various fields has been described. Meanwhile, the advantages of the DBD-based technologies as a promising option for the degradation and remediation of volatile organic compounds (VOCs) in air pollution control are also discussed, with comparisons to other conventional treatment methods.

In Chapter 2, “Literature review of the previous studies on DBD-based air pollutant abatement”, a comprehensive review of the published papers on DBD-based air pollutant abatement is summarized. In addition to introducing the fundamental characteristics of DBD on VOC degradation, the degradation pathways for toluene in DBD plasma driven by humidified air plasma are discussed, which are initiated by four main reactions, namely electron impact reactions, oxidation via radicals, excited-molecule reactions, and ion-molecule reactions. On the other hand, the drawbacks of the plasma systems in previous studies are also discussed, and it is found that the limited treatment capacity of less than a few L/min or lower, lack of knowledge on the decomposition characteristics at large flow rates, etc. are the main obstacles hindering the practical application of DBD plasma technology for VOC abatement.

In Chapter 3, “Design and characterization of single- and two-layer large-flow DBD reactors”, two types of large flow DBD reactors that have been developed in this study are described, specifically single- and two-layer DBD reactors. These reactors can treat exhaust gases at flow rates that are two orders of magnitude greater (up to 110 L/min) than those of small-flow DBD reactors, which are typically limited to 1 L/min or lower. Additionally, they achieved a high decomposition rate of 59.5% on toluene with an initial concentration of 100 ppm when a power of 41 W was applied in the two-layer case. Using the two reactors, the degradation performance of toluene treatment was analyzed at large flow rates (10 to 110 L/min), including the decomposition rate and energy efficiency at different processing parameters. Moreover, by comparing the degradation performances of the two reactors, the feasibility and superiority of the multilayer configuration in the large-flow DBD reactors intended for use in VOC abatement were verified. Meanwhile, the experimental results revealed that the performances of large-flow DBD in toluene degradation displayed similar characteristics to those of small-flow DBD reactors in laboratory scale.

In Chapters 4, “Design and characterization of ten-layer upgraded large-flow DBD reactors”, an upscaled multilayer reactor, namely a large-flow, ten-layer DBD reactor with a processing capacity of up to 1,000 L/min is described, which has been designed and

fabricated based on the above findings and serves as an upgraded version of the single- and two-layer DBD reactors in Chapter 3. The flow path design of the ten-layer DBD reactor was validated and optimized by CFD simulations and empirical measurements. Stable and uniform plasma generation was achieved in each layer at large flow rates of up to 1000 L/min. In addition, multi-gas plasma generation using various gases such as air, argon, helium, nitrogen, oxygen, and carbon dioxide has also been achieved with the ten-layer DBD reactor, which is expected to inspire various potential applications. These results confirmed the effectiveness and feasibility of the ten-layer multilayer configuration for upscaling DBD reactors for large-flow gas treatment.

In Chapter 5, "Decomposition characterization of the ten-layer upgraded large-flow DBD reactor on toluene", the decomposition characteristics of toluene treatment at large flow rates (50 to 1,000 L/min) with the ten-layer DBD reactor were studied and summarized. A decomposition rate of 55% at 245 L/min and 22 kV with a corresponding energy efficiency of 36.3 g/kWh was achieved in the ten-layer DBD reactor, which was in good agreement with the single- and two-layer DBD cases, corroborating the rationality and effectiveness of the design scheme of multilayer for DBD reactor configurations. Moreover, a decomposition rate of 35% at 22 kV with a corresponding energy efficiency of 48.3 g/kWh was achieved at a large flow rate of 520 L/min, which meets the Acute Exposure Guideline Level (AEGL 1: 67 ppm) for toluene established by the National Institute of Health Sciences in Japan.

In Chapter 6, "Overall Summary", the results obtained in this study are described, and at the same time, future plans for further optimization of large-flow DBD plasma systems and prospects for their practical application are discussed.

In conclusion, these findings and the proposed design methodology for upscaling and developing large-flow DBD plasma sources provide fundamental data and present guidelines for the practical implementation of the DBD plasma-based systems, especially for environmental protection such as exhaust gas purification, outdoor and indoor air pollution mitigation, wastewater treatment, CO_2 reduction, etc.