

Decomposition of volatile organic compounds by new type of DBD reactor using the adsorbent

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Abstract: The effect of a new type of the packed-bed dielectric barrier discharge reactor on decomposition of volatile organic compounds adsorbed on adsorbent surface was investigated. The ozone consumption was not proportional to the ozone generation. Nevertheless, a lot of highly energetic species could be generated by the segmented electrode, and it could accelerate the decomposition of toluene. In conclusion, the toluene could be more mineralized in the segmented electrode at the same energy.

Keywords: Segmented electrode, DBD plasma, Ozone, Highly energetic species.

1. Introduction

The methods such as thermal oxidation, adsorption, catalytic oxidation, biological treatment and non-thermal plasma treatment generally have the poor energy efficiency in terms of low concentration of VOCs [1-3]. Among them, non-thermal plasma has some advantages: energy consumption is smaller than thermal treatment [4]; The thermodynamically unfavourable reactions could be initiated at the low temperature and atmospheric pressure [5,6]; structure is simple [7]; the plasma reactor can combine easily with adsorbent and catalyst [8]. Nevertheless, some disadvantages limit still its decomposition efficiency: energy efficiency is still low [9]; Unwanted by-products are produced [8]. Nowadays plasma treatment combined with catalyst has been to solve the disadvantages. Meanwhile, some researchers have studied on the structure of reactor to increase efficiency. For example, the structure of reactor and electrode could influence the decomposition efficiency [10-12]. However, it is difficult to compare the results of each experiment because of the different experimental conditions such as reactor size and structure, plasma state and power supply, etc. In this study, we develop plasma device to decompose VOCs generated at the low concentration. The DBD reactor having the divided electrodes was compared with a conventional DBD reactor in terms of the decomposition of toluene. Here, the effect of this segmented electrode was investigated, considering mineralization, CO₂ selectivity, generation and consumption of ozone, organic intermediate as by-products and energy yield.

2. Experimental

An alumina tube (outer diameter: 15 mm, thickness: 2.5 mm) was used, and a stainless-steel rod (thickness: 4 mm) and stainless-steel pipe (inner diameter: 15 mm, length: 100 mm) were used as a ground electrode and high voltage electrode, respectively, as shown in Fig. 1. The high voltage electrodes were divided into several parts. The total length was same, and the high voltage electrode was connected to single power supply in all reactors. Also, the plasma zone was filled with 4 g of zeolite to increase residence time as shown in Fig. 1. An experimental method was composed of two processes in this experiment. The first stage was an adsorption without discharge and

the second stage was a decomposition with a pure air flow of 1 L/min for 1 hour. In the adsorption stage, a liquid toluene was injected into 1 L/min of air and adsorbed on the zeolite for 2 minutes. Finally, 0.334 mmol of toluene was adsorbed on the surface of zeolite. In the decomposition stage, the adsorbed toluene was treated for 1 hour under the plasma with changing the applied voltage from 13 to 16 kV.

3. Results and discussion

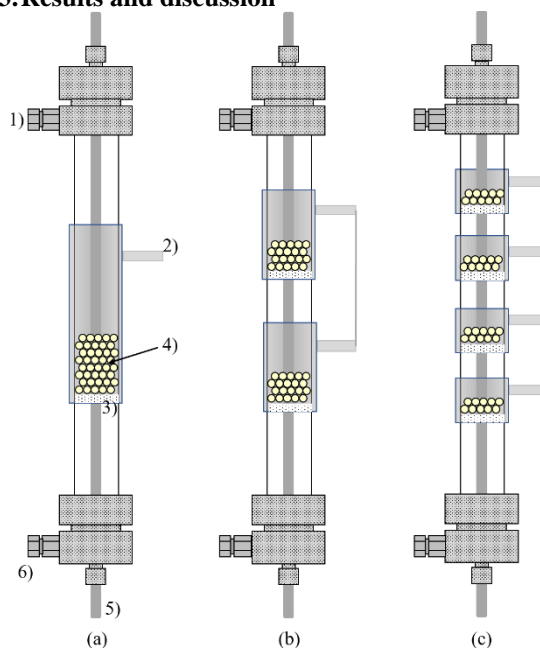


Fig. 1. Detail of each reactor; 1) gas inlet, 2) high voltage electrode, 3) glass filter, 4) zeolite, 5) ground electrode, 6) gas outlet

Fig. 2 shows the ozone concentration in each reactor with increasing the specific input energy density (SED). The ozone was more generated in the reactor 3 at the same SED although the applied voltage of reactor 3 was lower than that of reactor 1 and 2. It could be considered the difference between applied voltage and plasma current resulted in this phenomenon. In this experiment, the ap-

plied voltage was enough high to produce ozone. The effect derived from the increased plasma current in reactor 3 had a large effect on ozone generation. This phenomenon had an effect on the mineralization, CO₂ selectivity. Fig. 3 and 4 show mineralization and CO₂ selectivity of each reactor with different SED. The trend of mineralization was similar with the ozone generation in each reactor. Interestingly, the CO₂ selectivity was much higher with dividing high voltage electrode. It increased until almost 100 % as shown in Fig. 4. Fig. 5 shows the ozone concentration un-consumed at all applied voltages. In each reactor, the more ozone was consumed at the higher applied voltage. Interestingly, the ozone consumption was almost similar although the more ozone was generated, compared with each reactor. It is considered that the ozone consumption was limited because a part of toluene adsorbed on the zeolite could be exposed to the ozone.

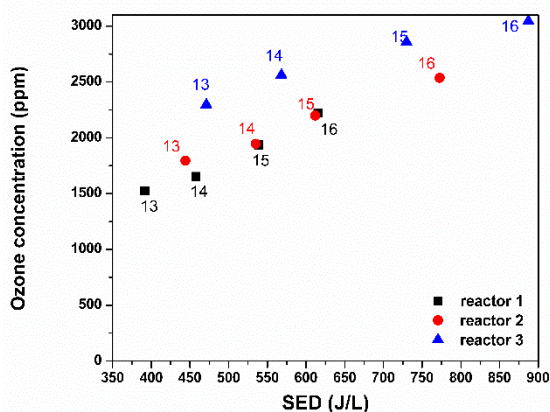


Fig. 2. Ozone generation with increasing SED.

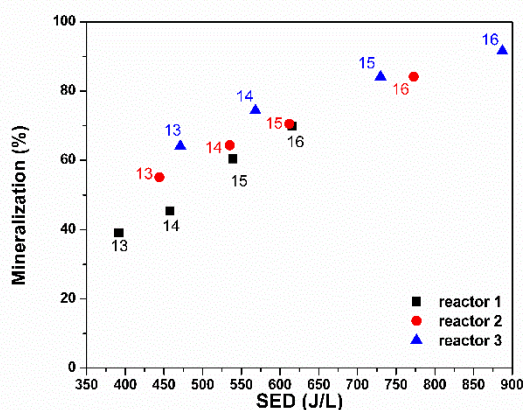


Fig. 3. Mineralization with increasing SED.

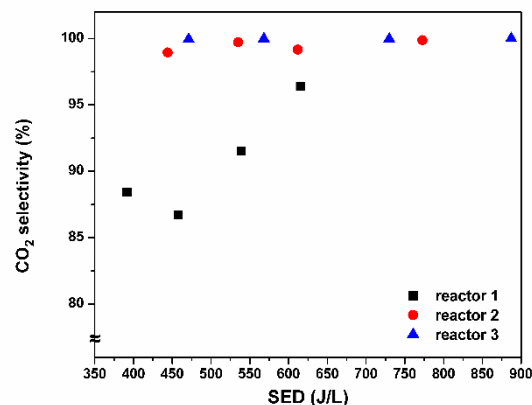


Fig. 4. CO₂ selectivity with different SED.

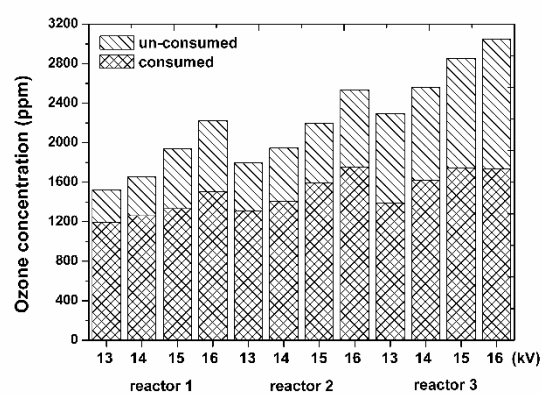


Fig. 5. Ozone un-consumed in each reactor.

4. Conclusion

To improve the removal efficiency of adsorbed toluene, the segmented electrodes were introduced in this study. The segmented electrodes had a positive effect on the increase of ozone generation at the same SED, compared to the conventional electrode. Although the ozone was more generated, it didn't affect significantly the toluene decomposition because the exposed area of adsorbed toluene to the ozone was constant. On the contrary, the plasma current had a positive effect on the decomposition of toluene. In conclusion, the reactor having the segmented electrode showed a good efficiency in terms of the toluene decomposition.

5. References

- [1] Y. Cheng, H. Hea, C. Yang, G. Zeng, X. Li, H. Chen, G. Yu, *Biotechnol. Adv.* 34, 6 (2016).
- [2] B. Dou, Ch. Wang, Q. Jia, J. Li, *J. Electrostat.* 71, 5 (2013).
- [3] X. Tang, F. Feng, L. Ye, X. Zhang, Y. Huang, Z. Liu, K. Yan, *Catal. Today* 211, 1 (2013).

- [4] Y. Guo, X. Liao, M. Fu, H. Huang, D. Ye, J. Environ. Sci. 28, 1 (2015).
- [5] B. Eliasson, U. Kogelschatz, IEEE Trans. Plasma Sci. 19, 6 (1991).
- [6] D. Mei, X. Zhu, C. Wu, B. Ashford, P. T. Williams, X. Tu, Appl. Catal., B 182 (2016).
- [7] A. M. Vandenbroucke, R. Morent, N. D. Geyter, C. Leys, J. Hazard. Mater. 195, 15 (2011).
- [8] M. Bahri, F. Haghighat, S. Rohani, H. Kazemian, Chem. Eng. J. 320, 15 (2017).
- [9] H. L. Chen, H. M. Lee, S. H. Chen, M. B. Chang, S. J. Yu, S. N. Li, Environ. Sci. Technol. 43, 7 (2009).
- [10] N. Jiang, C-X Hui, J. Li, N. Lu, K-F Shang, Y. Wu, A. Mizuno, J. Phys. D: Appl. Phys. 48, 40 (2015).
- [11] H. Zhang, K. Li, C. Shu, Z. Lou, T. Sun, J. Jia, Chem. Eng. J. 256, 15 (2014).
- [12] L. Sivachandiran, F. Thevenet, A. Rousseau, Chem. Eng. J. 270, 15 (2015).