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신 개념의 광촉매 응용 공기정화시스템

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New Photocatalytic Systems for Air Purification

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Abstract

Photoelectrocatalytic system is based on the idea that the photogenerated electrons in a layer of TiO_2 would move toward a cathode with application of high voltage across the TiO_2 coated aluminum plate. In this system, aluminum plate is used as a substrate for TiO_2 and also serves as a cathode. According to our scheme, moving photogenerated electrons toward a cathode would have the same effect as moving these electrons away from the holes, which would have the effect of retarding recombination of photogenerated electrons with holes. Recent experiments on benzene and toluene showed higher rates of removal with high voltage on compared to high voltage off, which supported our scheme partially.

1. Introduction

Much attention has been given to titanium dioxide(TiO_2) due to its outstanding photocatalytic properties. Nevertheless, its industrial applications such as degradation of pollutants[1,2] are limited due to low catalytic performances associated with electron-hole recombination and the requirement of UV light[3,4]. Discharged photoelectrocatalytic system was recently designed in this group for the purpose of increasing the photoreactivity by trapping electrons generated in TiO_2 upon UV illumination, and this system was used for the degradation of benzene. Discharged photoelectrocatalytic system maximizes the photocatalytic activity by retarding electron-hole recombination, thereby increasing the lifetime of holes responsible for the mineralization of benzene. In the discharged photoelectrocatalytic system, benzene degradation rate increased with an increase in applied voltage on the aluminum plate. Overall, the rates of degradation of benzene were higher under the condition of simultaneous UV illumination and applied voltage in comparison to the conditions of either UV illumination only or applied voltage only. Our system also demonstrated generation and consumption of ozone(O_3) by discharge effect and by photocatalytic effect, respectively[5].

2. Experimental

The photocatalyst used in this study was sol type titanium dioxide suspended in alcoholic solvent, and it was mixed with silicon binder solution(silicon, alcohol,water, acid) to increase the coherence of titanium dioxide on the substrate, aluminum plate. The mixed photocatalyst solution was well coated on the aluminum plate by drying at 120℃ for 30mins in the air without calcinations. The photocatalyst coated aluminum plate was then used as cathode for discharged photoelectrocatalytic system and Cu-bar with pins was used as anode. High Voltage DC bias was used for discharge in the system, and voltages of 3000V and 5000V were applied to observe the effect of the electric field on the rate of reaction. Xenon lamp was used as UV source for the

illumination of the photocatalyst coated aluminum plate. Photoelectrocatalytic degradation of benzene was carried out in a 10*l* batch reactor at 20℃ and 1atm . Initial benzene concentration in air was 1vol% and variationsof benzene concentration were measured by Gas-Chromatograph(HP6890).

3. Results and Discussion

Fig. 1. shows the results of the degradation of benzene as a function of the reaction time for three cases of operating conditions: (a)discharge only(plasma effect), (b)UV illumination only(conventional photocatalytic effect) and (c)discharge with UV illumination(photoelectrocatalytic effect). The degradation rate of case(c) was much higher than either case(a) or case(b), showing the most powerful catalytic activation. Between case(a) and case(b), the degradation rate of case(b) was slightly higher than that of case(a). An explanation for the most powerful activation in case(c) can be found in the trapping of excited electrons from electron-hole pairs, and such an effect retards electron-hole recombination, thereby increasing the lifetime of holes capable of mineralizing benzene into carbon dioxide(CO_2) and water(H_2O). As shown in Fig. 2., the amount of ozone(O_3) produced in the discharged system could be reduced by UV illumination onto TiO_2, which was demonstrated by a dramatic decrease in ozone concentration immediately following illumination of UV light. Recently, the plasma system(discharge system + TiO_2 without UV illumination) as well as electrostatic precipitator based on the discharge system are being launched as advanced air cleaning system. In both the cases, the amount of ozone drawn out of the air cleaner is not negligible, and it can be potentially harmful for people in the confined space under cooling or heating for extended period of time. Here, discharged photoelectrocatalytic system will be an answer to such health hazardous problems. Fig. 3. shows that benzene degradation rates increasewith increase in the applied voltage on the aluminum plate in the discharged photoelectrocatalytic system, and this demonstrates that higher electric field induces larger number of trapped electrons on the aluminum plate and stronger plasma effect, leading to increased degradation of benzene.

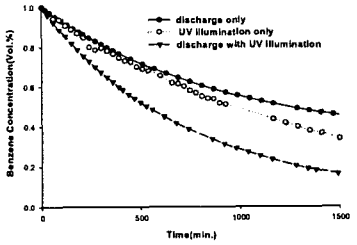

Fig. 1. Photodegradation of benzene as a function of reaction time.

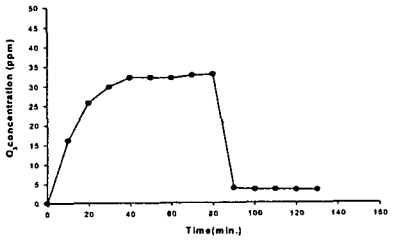

Fig. 2. O_3 Concentration resulted from benzene decomposition by discharge and photocatalysis

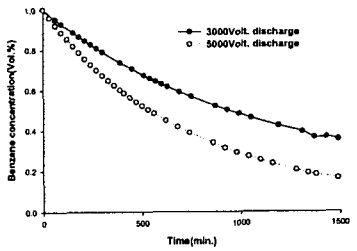

Fig. 3. Photodegradation of benzene by applied voltage.

4. Conclusions

The rates of degradation of benzene increase significantly in a high voltage discharged photocatalytic system consisting of TiO_2 coated aluminum plate cathode, Cu bar anode, power supply and UV lamp, and longer lifetime of holes generated in TiO_2 due to reduced electron-hole recombination is given as an explanation for such an observation. Our system produces ozone by high voltage discharge, however, it is consumed photocatalytically in the same system, and therefore, the amount of O_3 coming out of our system is quite low and controllable. In addition, our high voltage discharged system consumes little amount of electricity (2-4W), compared to the UV lamp, thus making it energy efficient.

References

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