Enhanced photocatalytic degradation of gaseous benzene under ozoneproduced UV irradiation over transition metal modified TiO₂

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Introduction

Conventional photocatalytic oxidation process has disadvantages such as photocatalytic deactivation, recombination of electron-hole pair and low efficiency¹. Recently, vacuum ultraviolet (VUV) lamps were used to activate photocatalysts to improve the efficiency and stability²⁻⁴. Compared with most-widely used UV irradiation of 254 nm and 365 nm UV lamp, 185 nm UV lamps can not only irradiate photocatalyst but also generate active oxidants such as \cdot O and \cdot OH, thereby leading to higher photocatalytic activity⁵⁻⁷. However, massive ozone was also generated from 185 nm UV irradiation and only partial of it can be removed since TiO₂ has poor activity towards ozone decomposition. Residual ozone is toxic and harmful to the environment and the health of human being; meanwhile it is a strong oxidant and can be used to enhance the oxidation of pollutants.

In this study, Mn, Co, Cu, Ni and Fe modified TiO_2 were developed and used for enhanced photocatalytic degradation of gaseous benzene under ozone-produced UV irradiation. The capacity of various modified TiO_2 for benzene degradation and ozone elimination were compared.

Materials and Methods

1 wt. % transition metals (Mn, Co, Cu, Ni and Fe) modified TiO₂ were prepared by sol-gel method using tetrabutyl titanate and metal acetate as the precursor. A fixed bed continuous-flow reactor with 1 g photocatalysts was used for photocatalytic oxidation of benzene. A 1 L/min gas flow of 50 ppm benzene concentration and 50% humidity was irradiated by 185 nm UV light before being introduced into the catalyst bed. The concentration of benzene and ozone was monitored by GC and ozone analyzer online, respectively. The photocatalysts were characterized by SEM, XRD and BET surface area to obtain the structural and chemical information.

Results and Discussion

Figure 1 shows photocatalytic degradation of benzene over various transition metal modified TiO₂. It can be found that Mn-TiO₂ achieved the highest benzene removal efficiency of 58%. Co-TiO₂, Ni-TiO₂ and P25 have similar benzene removal efficiency (\sim 50%). It was dropped to about 45% over Fe-TiO₂ and pure TiO₂.

Massive ozone was also generated from 185 nm UV irradiation. It reached 138 ppm in the absence of photocatalysts. **Figure 2** shows decomposition rates of ozone in the presence of various transition metal modified TiO₂. They have similar order to benzene removal efficiency.

 $Mn-TiO_2$ with best ozone decomposition capacity achieved the highest benzene removal efficiency. No residual ozone was monitored in the presence of $Mn-TiO_2$ and $Co-TiO_2$. However, Fe-TiO₂ and pure TiO₂ with the poorest ozone decomposition capacity achieved the lowest benzene removal efficiency.



Figure 2. Decomposition rate of ozone over various transition metal modified TiO₂ Significance

Among transition metal modified TiO₂, Mn-TiO₂ achieved the highest performance for benzene removal and ozone decomposition. The catalysts with better capacity for ozone decomposition have higher benzene removal efficiency. Compared with 254nm-PCO, 185nm-PCO obtained more 20 times higher benzene removal efficiency.

References

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