Visible light induced Photocatalytic Degradation of AOII Dye on Bi_2O_3

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Abstract. Visible light induced photocatalytic oxidation degradation of Acid Orange II dye was discussed. Bi_2O_3 was chosen as the photocatalyst. SEM showed that Bi_2O_3 powders were of about 7 to 8 um in size. It was porous and AOII could be effectively adsorbed on the surface of Bi_2O_3. And then the absorbed AOII was degraded by the generated oxidants such as hydroxyl radicals ·OH and superoxide radicals·O_2^- under the visible light irradiation. Additionally, the influence factors were further discussed to optimize the control parameters. About 97.6% of AOII could be degraded within 30 min in the visible light induced photocatalytic process under the conditions of AOII concentration 10 mg/L, Bi_2O_3 dosage 0.12 g and the initial pH 3.

Introduction

Over the past decades, heterogeneous photocatalysis has attracted increasing attention in the field of environmental applications for its photodegradation of undesirable organics in aqueous solutions [1-3]. Among which, TiO_2-based photocatalysis is wildly used because TiO_2 is a cheap, stable, and nontoxic catalyst. Typically, TiO_2 is used in the form of nanoparticles with very high surface area. This allows a direct contact with a large amount of the surrounding media and therefore an excellent mass transfer. However, only UV light less than 387 nm can excite TiO_2 because of its wide band gap (3.2eV). UV accounts for only less than 5% of the total solar light energy and the cost of artificial UV light source is high. Thus, visible light induced photocatalytic technology caused extensive concern. In an attempt to maximize the utilization of solar radiation, there are sustained researches into visible light photocatalysts, such as bismuth oxide (Bi_2O_3). Due to a variety of possible types of light excitation, Bi_2O_3 has a broad range of band-gap values (Eg = 2-3.96 eV). The fundamental optical transition is of an indirect type with Eg = 2.7-2.8 eV, ensuring considerable photocatalytic activity for Bi_2O_3 under visible light irradiation [4-8].

Herein, Bi_2O_3 was selected as visible light photocatalyst and azo dye of Acid Orange II (short for AOII) was selected because AOII was one of common and representative species in wastewater. The influence factors of catalyst dosage, initial pH and AOII concentration were discussed in details to provide the feasibility to Bi_2O_3 visible light photocatalytic degradation of AOII.

Experimental

Experimental Device

The photocatalytic device was mainly composed of a quartz reactor, a light source and a magnetic stirrer. The volume of the quartz reactor was 130 mL. Xenon lamp (150 W) was placed at a distance of 10 cm from the quartz reactor. The Bi_2O_3 powders were commercial products (Sinopharm Chemical Reagent Co., Ltd). A filter was placed between the xenon lamp and quartz reactor in order to expose the visible light with wavelengths greater than 420 nm.

Analytical Methods

The values of pH were adjusted with 1 M NaOH or 0.5 M H_2SO_4 using a WTW meter. Desired samples taken from the sampling point were filtered through a 0.45 μm membrane. AOII concentration

is measured by UV Spectrophotometry at the significant absorption peak of 484nm.The surface morphology of Bi_2O_3 powder was measured by JSM-6380LV scanning electron microscope with the operating voltage of 30 kV.

Results and discussion

Characterization of Bi_2O_3

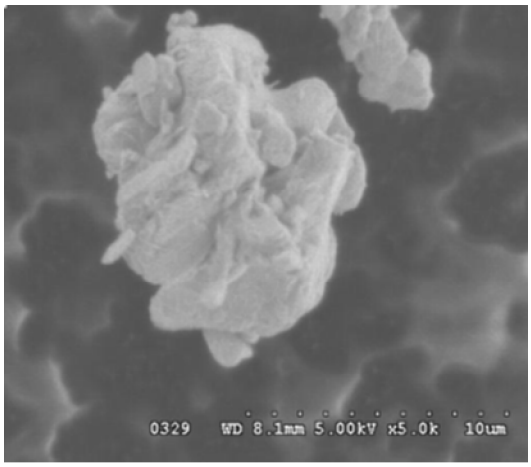

Fig.1 The SEM image of Bi_2O_3

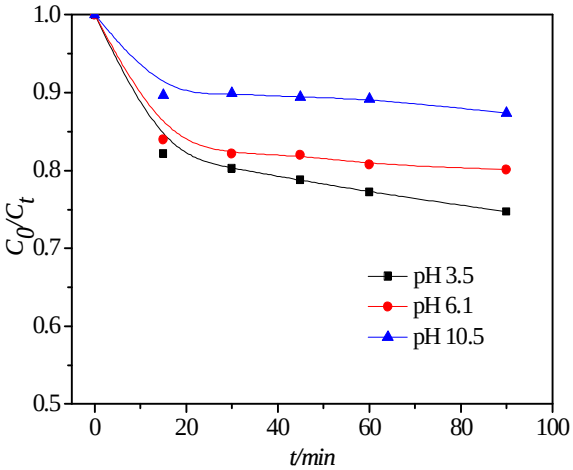

Fig.2. Adsorption of AOII at different pH

SEM of Bi_2O_3 was shown in Fig. 1. It could be clearly seen that Bi_2O_3 powders are of about 7 to 8 um in size. It was porous and had a high specific surface area. Thus, organics could be adsorbed on the surface.

Adsorption of AOII

Under the condition of AOII concentration 10 mg/L, Bi_2O_3 dosage 0.24 g and reaction time 90 min, the adsorption behaviors were studied at different pH in Fig. 2. It was shown that the adsorption of AOII decreased with the increase of the pH values. At pH of 3.5, about 25% of AOII could be removed by adsorption within 90 min, while only 12% could be adsorbed at pH of 10.5. It was also seen that the adsorption efficiency increased little after 30 min. Thus, the following photocatalytic experiments were carried out after an adsorption of 30 min.

Removal of AOII in several processes

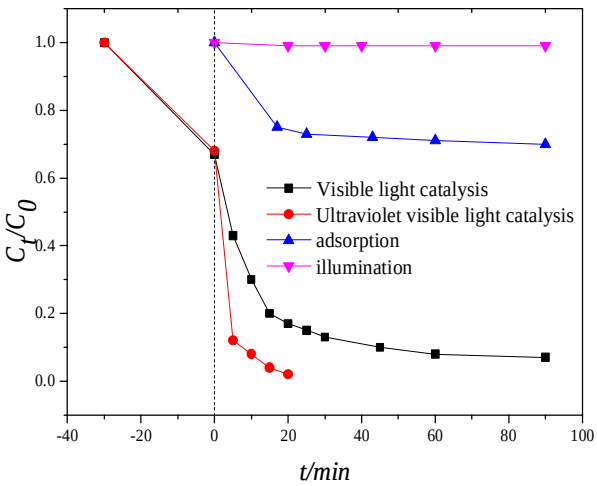

Fig.3. Removal of AOII in several processes

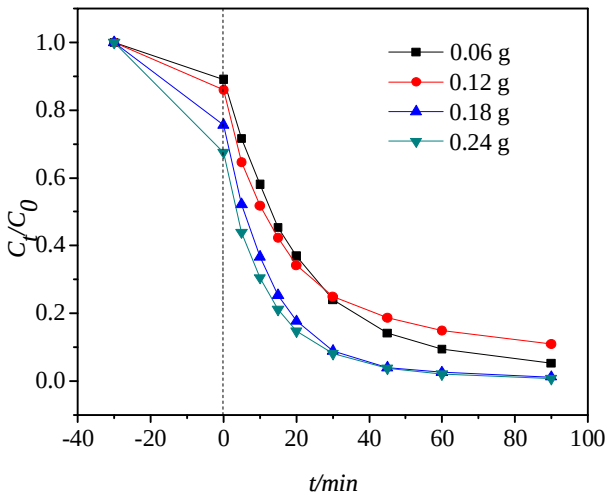

Fig.4.Effect of dosage of Bi_2O_3

Similarly, adsorption, visible light irradiation, visible light photocatalysis and UV light photocatalysis on AOII removals were performed respectively and the results were shown in Fig. 3. It could be seen that only irradiation by visible light could not degrade AOII. And about 25% of AOII

could be removed by adsorption within 90 min. As to visible light photocatalytic process, above 95% of AOII could be degraded within 90 min. Under the irradiation of visible light, many strong oxidative radicals were produced on the surface of Bi_2O_3, which could effectively degrade the AOII. Thus, Bi_2O_3 is a very good visible light catalyst. Although complete AOII degradation could be performed within 20 min in the UV light induced photocatalytic process, visible light was still selected as light source. This is because that UV light only accounted for a very small part of the sun light and visible light induced photocatalytic process has a broader prospect.

Visible light induced photocatalytic degradation of AOII

Effect of Dosage of Bi_2O_3

In the visible light induced photocatalytic process (AOII concentration 10 mg/L, initial pH 6.1), the effect of catalyst dosage was discussed as shown in Fig. 4. It showed that the efficiencies of AOII degradation were about 34.8%, 39.8%, 51.5%, 54.8% within 10 min at the dosage of 0.06g, 0.12 g, 0.18 g, 0.24 g. The degradation efficiencies reached above 90% in 30 min at the dosage 0.18 g and 0.24 g. The results showed that the dosage of Bi_2O_3 was an important factor to affect the degradation efficiency. On one hand, the increase of Bi_2O_3 dosage would also promote the generation of hydroxyl radicals ·OH and superoxide radicals·O_2^-, which were the important oxidants in the photocatalytic process.

Effect of initial pH Value

In the visible light induced photocatalytic process (AOII 10 mg/L, Bi_2O_3 dosage 0.12 g), the effect of different initial pH values was shown in the Fig. 5.

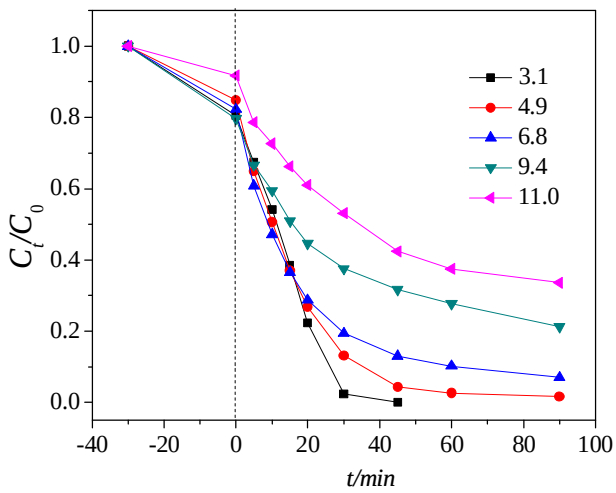

Fig.5. Effect of initial pH

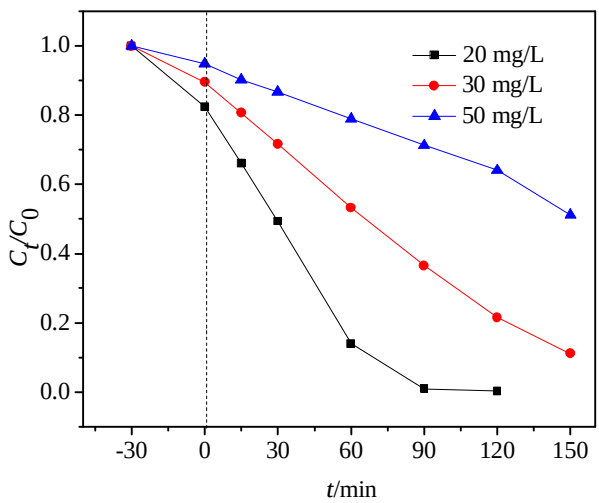

Fig.6. Effect of initial concentrate of AOII

The initial pH values of solution influenced the photocatalytic degradation greatly. It can be seen that the degradation efficiencies gradually reduced with the increase of the initial pH of solution. The degradation efficiency of AOII was up to 97.6% at the initial pH of 3.1 with 30 min, and the degradation efficiencies were about 86.5%, 76.4%, 52.8%, 42.1% respectively while pH was 4.9, 6.8, 9.4 and 11. It could be concluded that AOII preferred to photocatalytic degrade in the acid conditions.

Effect of Initial Concentration

In the visible light induced photocatalytic process (Bi_2O_3 dosage 0.24 g, initial pH 3.0), the effect of different initial concentrations of AOII was shown in the Fig. 6. It showed that the degradation efficiencies decreased gradually with the increase of AOII concentrations. At the AOII concentration of 20mg/L, the degradation efficiencies reached above 80% within 60 min and almost complete degradation was acquired within 120 min. While at the AOII concentration of 50mg/L, the degradation efficiency was less than 15% within 60 min and about 40% within 180 min. Therefore, the visible light induced photocatalytic oxidation was commonly used in the treatment of low concentration solution.

Conclusions

Visible light induced photocatalytic degradation of AOII on Bi_2O_3 was discussed in details and the conclusions were as follows:

(1) Bi_2O_3 could remove AOII from solution by adsorption effectively. And the adsorption capacity reduced gradually with the increase of initial pH. About 25% of AOII could be removed by adsorption at the initial pH of 3.5.

(2) Under the conditions of AOII concentration 10 mg/L, Bi_2O_3 dosage 0.12 g and the initial pH 3, about 97.6% of AOII could be degraded within 30 min in the visible light induced photocatalytic process.

(3) AOII was firstly adsorbed on the surface of Bi_2O_3 and then degraded by the generated oxidants (hydroxyl radicals ·OH and superoxide radicals·O_2^-) in the process.

Acknowledgements

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