Applied Surface Science 427 (2018) 141–147

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

$BiVO_4/\alpha$-Fe_2O_3 catalytic degradation of gaseous benzene: Preparation, characterization and photocatalytic properties

Rong Chen [a,b], Chengzhu Zhu [a,b,*], Jun Lu [c], Jun Xiao [a,b], Yu Lei [a,b], Zhimin Yu [d,**]

[a] School of Resource and Environmental Engineering, Hefei University of Technology, Hefei 230009, PR China
[b] Institute of Atmospheric Environment & Pollution Control, Hefei University of Technology, Hefei 230009, PR China
[c] Center of Analysis & Measurement, Hefei University of Technology, Hefei 230009, PR China
[d] Department of Biological and Environmental Engineering, Hefei University, Hefei 230601, PR China

ARTICLE INFO

Article history:
Received 28 July 2017
Received in revised form 17 August 2017
Accepted 24 August 2017

Keywords:
$BiVO_4$
α-FeOOH
α-Fe_2O_3
Benzene
Photocatalytic degradation
Synergistic effect

ABSTRACT

A new type of composite photocatalyst, $BiVO_4/\alpha$-Fe_2O_3, was successfully prepared by using hydrothermal-calcinations method and the catalysts were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), UV–Vis reflection spectrometer (DRS), X-ray photoelectron spectroscopy (XPS), and N_2 adsorption–desorption measurement (BET), respectively. It was displayed that the α-Fe_2O_3 had no effect on the crystal phases of $BiVO_4$ but obviously enhanced the photocatalytic activity of the $BiVO_4$. The composite α-FeOOH/$BiVO_4$ with the mass ratio of 5:5 and the calcinations of 350 °C had the highest photocatalytic activity. The degradation rate of benzene was up to 66.87% when initial benzene concentration was 100 mg/m^3 and after 365 nm UV irradiation 210 min $^{\bullet}O_2^-$ and h^+ played a key role in the photo-degradation of benzene, and the enhanced performance of $BiVO_4/\alpha$-Fe_2O_3 composite could be attributed to the synergistic effect between α-Fe_2O_3 and $BiVO_4$.

1. Introduction

VOCs especially benzene, xylene, and toluene from industrial processes, transport, and house-hold activities frequently released into the environment [1,2] and have become a kind of the most common and serious air pollutants and threatened human health [3,4]. Therefore, it is urgent to develop new or improve existed treatment technologies to control VOCs pollution.

Up to date, Photocatalytic technology with many advantages such as environment-friendly, no secondary pollution, and effective degradation of low concentrations of pollutants [5,6], has been become a very attractive and promising technology for VOCs treatment. A large number of studies have explored the photocatalytic degradation of VOCs by using TiO_2 or TiO_2 complexes with other materials [7,8]. However, the large band gap (3.2 eV) of TiO_2 limits its application [9], it needs to develop a new type of visible light catalyst [10].

$BiVO_4$, a new type of catalyst, has a narrow band gap, good visible light absorption, and stable photo corrosion resistance [11]. There were three crystal types of $BiVO_4$, including the tetragonal zircon, monoclinic scheelite, and tetragonal scheelite structures, in which monoclinic phase (m-$BiVO_4$) has the highest photocatalytic activity [12]. However, the photocatalytic activity of m-$BiVO_4$ is seriously affected by the recombination rate of photo-generated electron-hole pairs [13]. As a consequence, many studies have combined $BiVO_4$ with other materials to reduce the recombination rate of photo-generated electron-holes pairs. For example, Li et al. [14] synthesized a novel hetero-structured $BiVO_4/FeVO_4$ composite by using hydrothermal method and found the activity of $BiVO_4/FeVO_4$ was significantly higher than that of single $BiVO_4$ or $FeVO_4$. Wang et al. [15] obtained the Cu-$BiVO_4$ composite photocatalyst and found that the photocatalytic activity was significantly enhanced under visible light irradiation due to the effective separation of electron-hole pairs.

Goethite (α-FeOOH), as a mineral material, has attracted wide attention because of its nanometer scale, high specific surface area, and high chemical activity [16]. Liang et al. [17] synthesized X-type hollow α-FeOOH and transformed into X-type hollow α-Fe_2O_3 by calcinations at 500 °C. The α-Fe_2O_3 nanocrystals were found to exhibit excellent photocatalytic activity for RhB degradation. Other

* Corresponding author at: School of Resource and Environmental Engineering, Hefei University of Technology, Hefei 230009, PR China.
** Corresponding author.
E-mail addresses: czzhu@hfut.edu.cn (C. Zhu), yuzhimin@hfuu.edu.cn (Z. Yu).

http://dx.doi.org/10.1016/j.apsusc.2017.08.153
0169-4332/

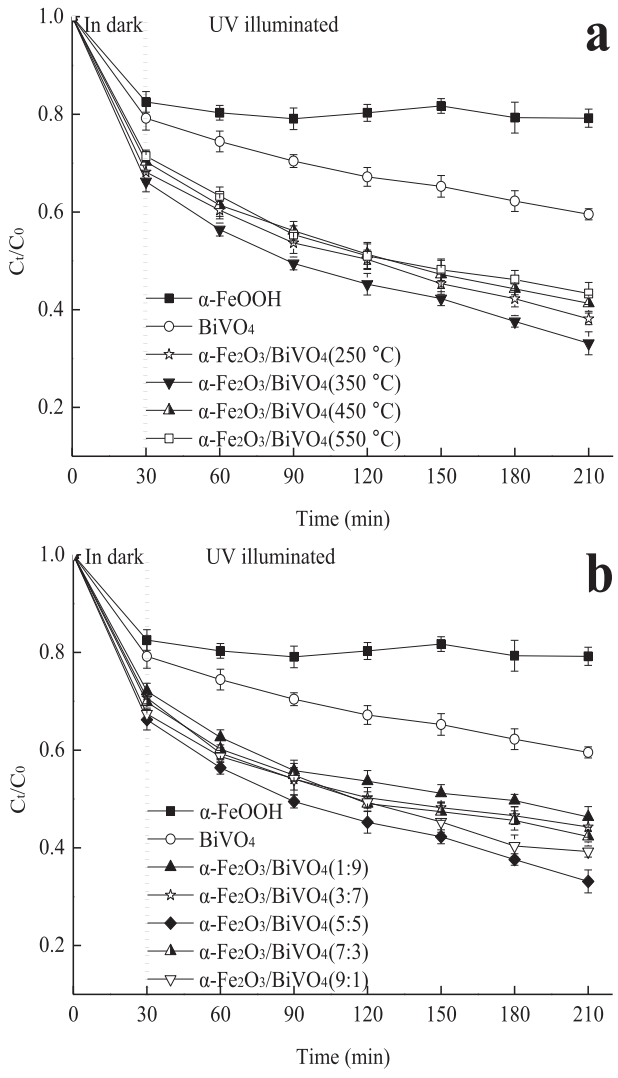

Fig. 1. (a) The calcined at different temperatures and (b) effect of different goethite loading mass on benzene photodegration activity.

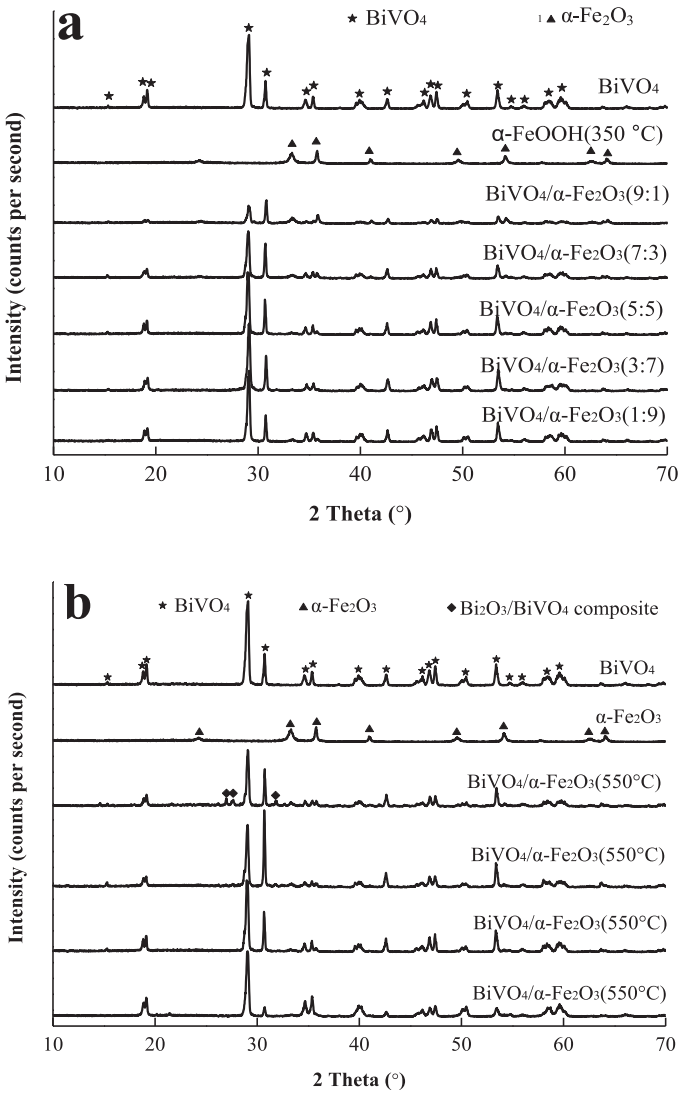

Fig. 2. (a) XRD spectra of different goethite loading mass on composite catalyst and (b) different calcined at different temperatures for composite catalyst.

scholars have also found that heat treatment of goethite on the preparation on highly active materials have an important role [18].

In the present study, gaseous benzene was used to represent VOCs, α-FeOOH as a precursor employed as supporting material for $BiVO_4$ by hydrothermal-calcination method, to obtain $BiVO_4$/α-Fe_2O_3 composite photocatalysts. The catalysts were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and N_2 adsorption/desorption (BET) UV–Vis diffuse reflectance (DRS) and X-ray photoelectron spectroscopy (XPS). The influence factors of catalyst preparation and the reaction mechanism of 365 nm photocatalytic degradation of benzene were systematically discussed.

2. Experimental sections

2.1. Preparation of catalysts

5 mmol $Bi(NO_3)_3{\cdot}5H_2O$ was dissolved in 15 mL of 2 mol/L HNO_3 solution with stirred, and then added a certain amount of α-FeOOH to continue stir 30 min to form A solution.

5 mmol NH_4VO_3 was dissolved in 15 mL of 2 mol/L NaOH solution to form B solution.

B solution was slowly dropped into A solution under strong magnetic stirring, the pH value of the mixture solution was adjusted to 5 with 2 mol/L NaOH solution, after stirring for 30 min, the mixture was transferred to 50 mL Teflon-lined stainless steel autoclave and heated to 180 °C for 12 h. The mixture was cooled to room temperature and the precipitate was filtered, washed several times with distilled water and ethanol, and dried in an oven at 80 °C for 10 h, then taken out and calcined at different temperatures for 2 h in muffle furnace and finally $BiVO_4$/α-Fe_2O_3 was obtained. The mass ratio of α-FeOOH/$BiVO_4$ was 1:9, 3:7, 5:5, 7:3 and 9:1, respectively. The pure $BiVO_4$ was also prepared by the same method without α-FeOOH.

2.2. Characterization methods

X-ray diffraction (XRD) patterns was recorded between 10° and 70° (2θ) at steps of 4°/min using a D/max-Rb diffractometer with Cu K_α radiation (50 kV and 100 mA).

The Brunauer–Emmett–Teller (BET) of samples was calculated from the N_2 adsorption plots of the catalysts by using a Quantachrome NOVA3000e analyzer.

X-ray photoelectron spectroscopy (XPS) was implemented on a surface analysis system (Escakab 250Xi, American) operating at 10^{-9} Pa with Al Ka radiation (1486.6 eV) and using the C 1s line at 284.8 eV as the standard.