Journal of Environmental Chemical Engineering 4 (2016) 2170–2177

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

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

Visible light-driven photocatalytic degradation of rhodamine B and industrial dyes (texbrite BAC-L and texbrite NFW-L) by ZnO-graphene -TiO_2 composite

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A R T I C L E I N F O

Article history:
Received 8 January 2016
Received in revised form 7 March 2016
Accepted 29 March 2016
Available online 29 March 2016

Keywords:
ZnO-graphene-TiO_2
Photocatalytic degradation
Rhodamine B
Catalyst

A B S T R A C T

Visible light-responsive ZnO-graphene-TiO_2 (ZGT) composite catalyst was successfully synthesized via a simple solvothermal process. The intrinsic characteristics of as-obtained samples were examined using a variety of techniques including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy dispersive X-ray spectroscopy (EDS). The band gap energies of the samples were evaluated by UV–vis diffuse reflectance spectroscopy (UV-vis DRS). The photocatalytic activities of as-obtained catalysts were assessed based on the degradation of rhodamine B (RhB), texbrite BAC-L (TBAC) and texbrite NFW-L (TNFW) under visible-light irradiation. ZGT exhibited higher visible-light-activated photocatalytic activity than did other samples (ZGT (7.97×10^{-4} min^{-1}) > ZG (3.43×10^{-4} min^{-1}) > graphene (2.43×10^{-4} min^{-1}) > TiO_2 (2.22×10^{-4} min^{-1}) > ZnO (1.87×10^{-4} min^{-1})). In addition, ZGT showed higher enhanced photocatalytic degradation of RhB than did other dyes (RhB (7.97×10^{-4} min^{-1}) > TNFW (5.20×10^{-4} min^{-1}) > TBAC (2.48×10^{-4} min^{-1})). It is therefore evident that the synthesized ZGT can be used as a high performance catalyst for dye wastewaters. Moreover, the detailed photocatalytic mechanism of the photodegradation process is discussed.

1. Introduction

Dyes and pigments are widely used in various industries to make precise colors in manufactured products and in biological laboratories for analytical purposes or as biological stains [1]. Rhodamine B (RhB) is a fresh peach-colored synthetic dye widely used as a colorant in the manufacturing of textiles, leathers, paints, and foods, and in laboratories [2]. The discharge of RhB into the aquatic environment results in wastewaters with high toxicity and low transparency. Moreover, it can irritate the eyes, skin, and respiratory system and it is carcinogenic and toxic to the reproductive and nervous systems [2]. Therefore, it is necessary to remove this contaminant from wastewater before releasing water into the environment to protect both the environment and human beings.

Several common wastewater treatment technologies for RhB dye have been studied, such as extraction [3], electrochemical oxidation [4], ion flotation [5], ion exchange membrane [6], sonocatalytic degradation [7], advanced oxidation process [8], swirling jet-induced cavitation and hydrodynamic cavitation [9,10], membrane [11], adsorption [12–14] and photocatalytic degradation [15–17]. Of the above technologies, photocatalytic degradation is the most effective method of converting toxic organic contaminants into carbonaceous products [18]. Some other techniques merely transfer dye pollutants from one phase to another, and the pollutants are not well degraded or removed. Therefore, many scientists prefer the photocatalytic degradation process.

Various composite catalysts have been considered for photocatalytic degradation of rhodamine B dye, such as graphitic carbon nitride/reduced graphene oxide (g-C_3N_4/rGO) [19], SnO_2/ZnS [20], Y_2InSbO_7 and Y_2GdSbO_7 [21], CoFe/SBA-15 catalyst coupled with peroxy-monosulfate [22], WO_3 [23], PPy/$Bi_2O_2CO_3$ [24], HgI_2 [25], PbS/QDs-Bi_2WO_6 [26], Ag@AgBr-intercalated $K_4Nb_6O_{17}$ composite [27], $ZnFe_2O_4$ [28], La_2O_3/Ag_3VO_4 [29], pure bismuth ferrite ($BiFeO_3$) [30], Fe_2O_3-Kaolin [31], g-C_3N_4/SiO_2-HNb_3O_8 [32], Fe_3O_4@SiO_2@ZnO-Ag core-shell microspheres [33], Ag_3PO_4 dispersed on exfoliated bentonite (EB-Ag_3PO_4) [34], and Ag@AgBr/SBA-15 [35]. However, because these composite materials have some drawbacks such as the need for UV activation and complex

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http://dx.doi.org/10.1016/j.jece.2016.03.045
2213-3437/