Applied Catalysis A: General 450 (2013) 222–229

Contents lists available at SciVerse ScienceDirect

Applied Catalysis A: General

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

Application of TiO_2-containing mesoporous spherical activated carbon in a fluidized bed photoreactor—Adsorption and photocatalytic activity

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ARTICLE INFO

Article history:
Received 30 July 2012
Received in revised form 15 October 2012
Accepted 16 October 2012
Available online 10 November 2012

Keywords:
Adsorption
Photocatalysis
Spherical activated carbon
Titanium dioxide
Humic acid

ABSTRACT

A TiO_2-containing mesoporous spherical activated carbon (*meso*-TiO_2/SAC) with high adsorption capacity and photocatalytic activity was prepared using ion-exchange method and heat-treatment process. The prepared *meso*-TiO_2/SAC was characterized by SEM, TEM, EDS, XRD, and BET analysis. Results obtained showed that *meso*-TiO_2/SAC had a smooth spherical shape (0.30–0.45 mm) and TiO_2 with crystalline size of 10–30 nm was well dispersed on the spherical activated carbon. XRD study confirmed that TiO_2 existed in a mixture of anatase (83%) and rutile (17%) phase. The *meso*-TiO_2/SAC presented a high specific surface area of 1649 m^2/g. The *meso*-TiO_2/SAC was used for the removal of humic acid (HA) in a fluidized bed photoreactor, the rate of adsorption reaction of HA by *meso*-TiO_2/SAC followed the pseudo second-order kinetic, the adsorption isotherm fitted well to the Freundlich and Langmuir isotherm models. The maximum adsorption capacity of *meso*-TiO_2/SAC determined from Langmuir isotherm was 2.92 mg/g. The effect of the photocatalysis of HA by *meso*-TiO_2/SAC under UV irradiation was investigated under various conditions of varying catalyst dosage, initial HA concentration, and coexisting anion. HA was mineralized up to 80.3% under optimal experimental conditions for a catalyst dosage of 9 g/L and at an initial HA concentration of 20 mg/L. In the presence of coexisting anions, the degradation efficiency of HA was reduced to 72.1% and 72.8% for SO_4^{2-} and NO_3^-, respectively. In the cyclic reuse experiment, over 85% of the initial TOC and COD were removed after the eighth cycles, indicating the relatively high photocatalytic stability of *meso*-TiO_2/SAC. TiO_2 was not released from the spherical activated carbon during the photocatalytic reaction. The *meso*-TiO_2/SAC developed, therefore has potentials for practical applications in water treatment.

1. Introduction

Photocatalysis, one of the advanced oxidation processes (AOP), has been extensively studied to eliminate pollutants from water or wastewater in the presence of semiconductor catalyst and UV illumination [1–4]. Among various materials used as semiconductors, titanium dioxide (TiO_2) has been widely used for a broad range of applications because it is cheap, non-toxic, very active and stable in chemical reactions [1–3]. In practical applications, TiO_2 nanoparticle such as Deggusa P25, do present the problem of separation of TiO_2 particle from treated water. In other words, separation technologies such as membrane filtration are required [4] which may result in high cost for post-treatment process. Therefore, steps toward reducing the cost of post-treatment process have attracted recent studies to be focused on the use of porous materials such as activated carbon as a support for TiO_2 [5–11]. It has been reported that TiO_2 supported on activated carbon has synergistic effect based on the adsorption capacity of activated carbon and the photoactivity of TiO_2 [7]. Wang et al. [5] investigated TiO_2 deposited on activated carbon (TiO_2/AC) for the degradation of methyl orange and discovered that TiO_2/AC cacinated at 600 °C exhibited the best photocatalytic performance and that composite catalyst TiO_2/AC was better than the two mixtures (commercial TiO_2 with AC and synthetic TiO_2 with AC). Wang et al. [7] prepared composite photocatalysts TiO_2 immobilized on granular activated carbons with different porosities (TiO_2/AC). They found that the composite TiO_2/AC made from proper mesoporisity AC exhibited higher catalytic activity than the mixture of powdered TiO_2 with AC. However, the spherical activated carbon over the powdered and the granular activated carbons has the advantages of smooth surface, good fluidity, high mechanical strength, low resistance to liquid diffusion, and more controllable pore distribution [12,13]. TiO_2/SAC prepared through the ion-exchange method and heat-treatment process can immobilize titanium ion without a binder and also had spherical shape with clean surface [14]. The smooth surface can prevent problems of surface abrasion by inter-particle

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http://dx.doi.org/10.1016/j.apcata.2012.10.018