ARTICLE IN PRESS
Journal of Saudi Chemical Society (2017) xxx, xxx–xxx

King Saud University
Journal of Saudi Chemical Society
www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Microwave-hydrothermal synthesis and photocatalytic properties of biomass charcoal/TiO_2 nanocomposites

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Received 8 July 2017; revised 4 September 2017; accepted 11 September 2017

KEYWORDS

Microwave-hydrothermal;
Titanium dioxide;
Biomass charcoal;
Nanocomposites;
Photocatalytic

Abstract Biomass charcoal-doped titanium dioxide (C/TiO_2) composites were proposed by microwave-hydrothermal and calcination method using tetrabutyl titanate as the titanium source and lignin as the carbon source. TiO_2 crystals with different morphologies could be successfully adsorbed onto the surface of biomass charcoal. These products were investigated by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), thermogravimetric analysis (TG), derivative thermogravimetric (DTG), UV–vis diffuser flection spectroscopy (UV–vis), Fourier transform infrared spectroscopy (FT-IR), and Brunauer–Emmett–Teller (BET). The photocatalytic activities of the as-obtained composites were checked under visible light irradiation. The results showed that both the microwave-hydrothermal temperature and time played an important role in the microstructure and photocatalytic activity of the samples. The rapid microwave-hydrothermal with the thermal post-treatment provides a promising route for the fabrication of biomass charcoal-doped nanocomposites materials.

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Peer review under responsibility of King Saud University.

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https://doi.org/10.1016/j.jscs.2017.09.003
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1. Introduction

Carbon materials are widely used in metallurgy, chemical industry, machinery, electronics, aviation, and other fields due to their excellent heat resistance, high thermal conductivity, good chemical inertness, and high electrical conductivity [1]. Biomass such as forestry biomass, agricultural waste, aquatic plants, biomass energy plants, has been used as resources for the preparation of carbon materials [2]. Various carbon materials can be produced from biomass, reducing production costs and achieving sustainable development of carbon materials [3].

In general, lignocellulosic biomass mainly consists of cellulose (40–50%), hemicellulose (10–25%), and lignin (25–40%) [4]. Lignin, as the second abundant natural raw aromatic (phenol) polymer, which is primarily composed of three phenylpropanoid monomers including p-coumaryl alcohol, guaiacyl, and syringyl [5]. It has a strong affinity for the positively charged metal ions and its molecule with phenolic hydroxyl group, alcoholic hydroxyl group, and carboxyl group can chemically react with other polymers to form the composites [6]. Lignin, a by-product of pulping process, usually acquired from paper-making black liquor. Lignin is to serve as a precursor of biomass charcoal due to its high carbon content and similar molecular structure to bituminous coal. More importantly, lignin has been widely used in batteries [7], adsorbents and dispersants [8], and bioplastics [9], because of its advantages such as soft, non-toxic, biodegradable, and light weight.

Titanium dioxide (TiO_2), as one of broad band gap semiconductor materials, is widely used in energy and environmental protection fields because of its high catalytic activity, high chemical resistance, non-toxic to human body, and low cost [10]. However, broad band gap (3.2 eV) of TiO_2 leads to low sunlight utilization rate, largely limiting its applications in photocatalytic fields. It reported that all the light absorption ability of catalysts, energy levels and the process of production, recombination, separation, migration and capture of photoproduction carriers, affect the photocatalytic efficiency. Therefore, a series of modification methods such as metal doping [11], nonmetal doping [12], rare earth doping [13], and surface sensitization [14] were used to effectively improve spectral response and catalytic activity of TiO_2. Among the non-metal-doped TiO_2 photocatalysts, C-doped TiO_2 has been suggested as the best one with regard to band gap narrowing [15–17]. Shi et al. synthesized carbon-doped titania hollow spheres with three-dimensional network structure using carbon spheres as template, which possessed more high visible light-induced photocatalytic activity than commercial P25 [18]. Lin et al. reported the visible-light-induced photocatalytic degradation of ethylene using a C-doped TiO_2 catalyst by the sol-gel method [19]. Wang et al. also applied the sol-gel method to prepare carbon-TiO_2 nanoparticles with high photocatalytic activity [20]. However, few studies have been reported on the synthesis of biomass charcoal/TiO_2 composites by the microwave-hydrothermal and calcination method serving lignin as carbon precursor.

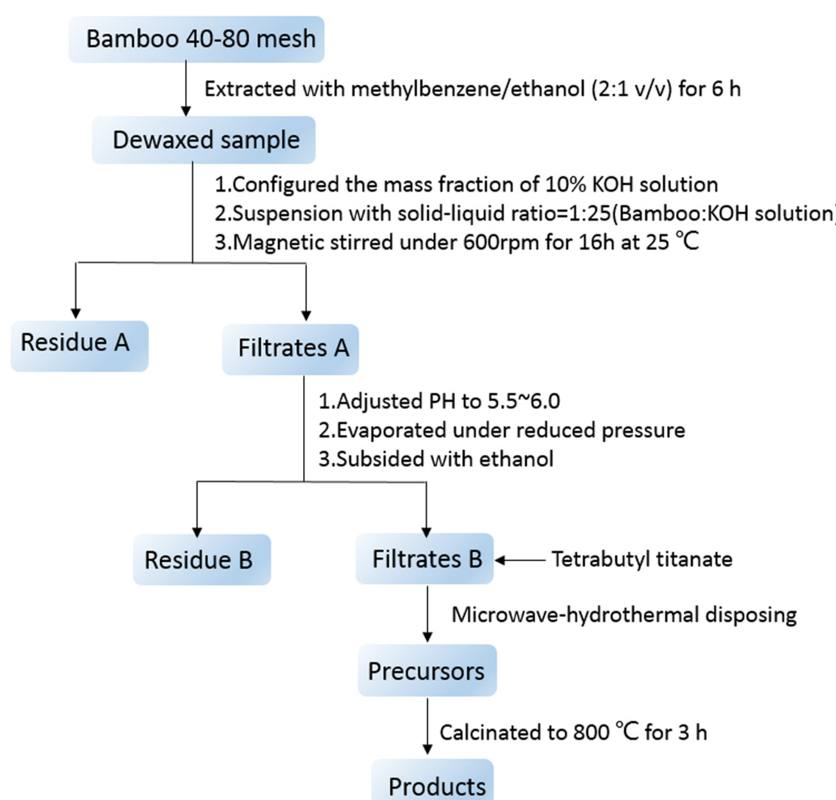

Fig. 1 Experimental details of the synthesis of biomass charcoal/TiO_2 composites.