Catalysis Communications 69 (2015) 63–67

Contents lists available at ScienceDirect

Catalysis Communications

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

Short communication

Visible-light driven C@TiO_2 porous films: Enhanced photoelectrochemical and photoelectrocatalytic performance

Yan-Yan Xu [a], Si-Qi Lu [a], Yan-Zhen Zheng [a,b,*], Hua-Bin Fang [a], Xia Tao [a,**], Jian-Feng Chen [a,b]

[a] State Key Laboratory of Organic–Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China
[b] Research Center of the Ministry of Education for High Gravity Engineering & Technology, Beijing University of Chemical Technology, Beijing 100029, China

ARTICLE INFO

Article history:
Received 4 February 2015
Received in revised form 29 April 2015
Accepted 27 May 2015
Available online 29 May 2015

Keywords:
Visible light
Carbon modified TiO_2 film
Photoelectrocatalytic
Photoanode

ABSTRACT

Visible-light driven C-modified TiO_2 film (C@TiO_2 film) was prepared on a conducting substrate and studied as photoanode for photoelectrochemical and photoelectrocatalytic (PEC) properties. The as-prepared material was characterized by SEM, TEM, XRD, and diffuse reflectance spectra. The C@TiO_2 film with multiporous structure exhibited enhanced electrochemical properties and excellent PEC performance, with a seven-fold improvement of photocurrent intensity as compared to unmodified TiO_2. The PEC improvement may be resulting from extended visible light-harvesting, low electron transfer resistance, and promoted photocurrent response. This study could provide a new perspective on preparing high performance photoelectric catalyst films.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Titanium dioxide (TiO_2) has been extensively investigated as a photoanode for photoelectrocatalytic (PEC) organic pollution abatement owing to its high activity, good chemical and photonic stability, and low cost [1–3]. However, a drawback, regarding commercially available TiO_2, is that it is mainly active in the UV that accounts for less than 5% of the total solar radiation [4,5]. To improve the optical response and photocatalytic activity of TiO_2 over the entire solar spectral range, numerous efforts have been made to vary the chemical composition and structure of TiO_2 by cation or anion doping, heterojunctions and band engineering that generate donor or acceptor states in the band gap [6–14]. Very recently, surface modification of TiO_2 by carbonaceous species aimed at solving the above problem has been proposed and attracted much attention [15–18]. The most advantageous morphology i.e., a core–shell structure, where nanometer-sized carbon species covers the TiO_2 nanoparticles with a thin homogeneous coating layer, maximizing heterojunction functionality without loss of light absorption, has been achieved by synthesizing nanostructured modified TiO_2 using the sol–gel combustion method [19]. In this system, a porous shell for reactant and product molecules/ions to pass through as well as an intimate interface for charge transfer between the core and the shell have also been realized simultaneously. However, most reported surface-modified TiO_2 photocatalysts for removal of recalcitrant organic pollutants were used in the format of suspensions mediated by powder species [20,21]. In practical application, TiO_2 based films are more viable due to their easy separation recovery and simple post-treatment process [8,9,22,23]. Furthermore, the application of an additional bias voltage can further accelerate charge separation and reduce unwanted charge recombination processes, consequently promoting the photocatalytic oxidation degradation efficiency of pollutants [3,8,9]. Thus, a systematical and profound investigation on the synthesis, characterization and PEC performance of carbon modified TiO_2 films is highly desired.

In this study, visible-light driven electrode films i.e., C-modified TiO_2 films (denoted as C@TiO_2) by the packing of TiO_2 nanocrystal core nanoparticles wrapped with an amorphous carbon layer on a conducting substrate were prepared and studied as photoanode for degradation of organic pollutant. The C@TiO_2 films exhibited multiporous structure, extended visible light-harvesting, low electron transfer resistance, and promoted photocurrent response. As a proof-of-concept, we demonstrated that C@TiO_2 photoanodes exhibited excellent PEC performance toward the degradation of organic pollutants such as rhodamine B (RhB) and 1-naphthol(1-NP) under visible light by applying a small bias voltage (1.0 V).

2. Experimental

2.1. Preparation and characterization of C@TiO_2 films

C@TiO_2 nanoparticle was prepared by smoldering combustion sol–gel synthesis as previously reported [19]. The experiment details were described in the Supplementary materials. Then the as-prepared

* Correspondence to: Y.Z. Zheng, State Key Laboratory of Organic–Inorganic Composites, Beijing University of Chemical Technology, Beijing 100029, China.
** Corresponding author.
E-mail address: taoxia@mail.buct.edu.cn (X. Tao).

http://dx.doi.org/10.1016/j.catcom.2015.05.018
1566-7367/© 2015 Elsevier B.V. All rights reserved.

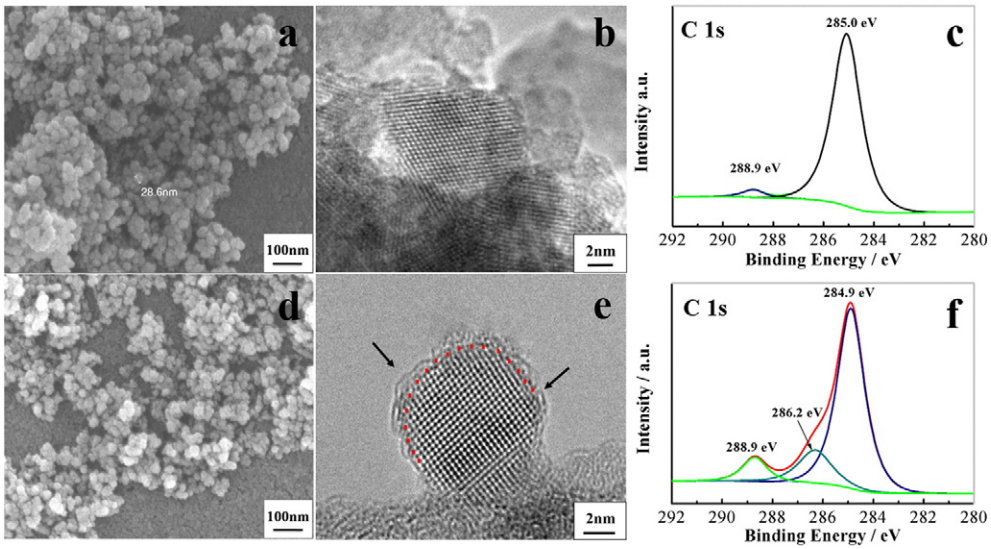

Fig. 1. SEM and TEM images of ref-TiO_2 (a & b) and C@TiO_2 (d & e) particles. Inset showing that an amorphous shell marked by dotted line covers the crystalline TiO_2 particles. Peak deconvolution of C 1s XPS core-level spectral from ref-TiO_2 (c) and C@TiO_2 (f).

C@TiO_2 powder, ethyl cellulose and terpineol with a weight ratio of 1:0.15:3 were mixed to form a viscous mixture. After that the C@TiO_2 films were fabricated by using a doctor-blade method, followed by heat treatment at 350 °C for 1 h and then 450 °C for 20 min. The C@TiO_2 films were observed by FESEM, XRD, UV–vis spectrophotometer.

2.2. Photoelectrochemical characterization of C@TiO_2

The photoelectrochemical performance of the C@TiO_2 films was evaluated using a three-electrode configuration with C@TiO_2 electrode, a saturated calomel electrode (SCE), and Pt wire as working, reference, and counter electrodes, respectively. The supporting electrolyte used here was in 0.5 M Na_2SO_4 solution. All the potentials were referred to SCE electrode unless otherwise stated in this paper. The visible light source was obtained from 300-W Xe lamp with a 420 nm cut-off filter. The light intensity was set to 100 mW/cm^2 (1 sun). Electrochemical impedance spectra (EIS) were recorded in the frequency range of 0.1–10^5 Hz, and the photocurrent densities were measured with the bias potential in the range of −0.4 to 1.0 V.

2.3. PEC degradation experiments

PEC degradation experiments were carried out in a three-electrode system with C@TiO_2 as photoelectrode, and the active area was 2.0 × 2.0 cm^2 under illumination of the same light sources as the photoelectrochemical characterization experiments. A potentiostat model DJS-292C was employed to bias the C@TiO_2 working electrode. The PEC activities were estimated by the degradation of RhB (0.5×10^{-5} M) and 1-NP (1.0×10^{-4} M) solution, respectively. Prior to irradiation, the dye solution was stirred in the dark for 30 min to ensure the establishment of an adsorption/desorption equilibrium. At a

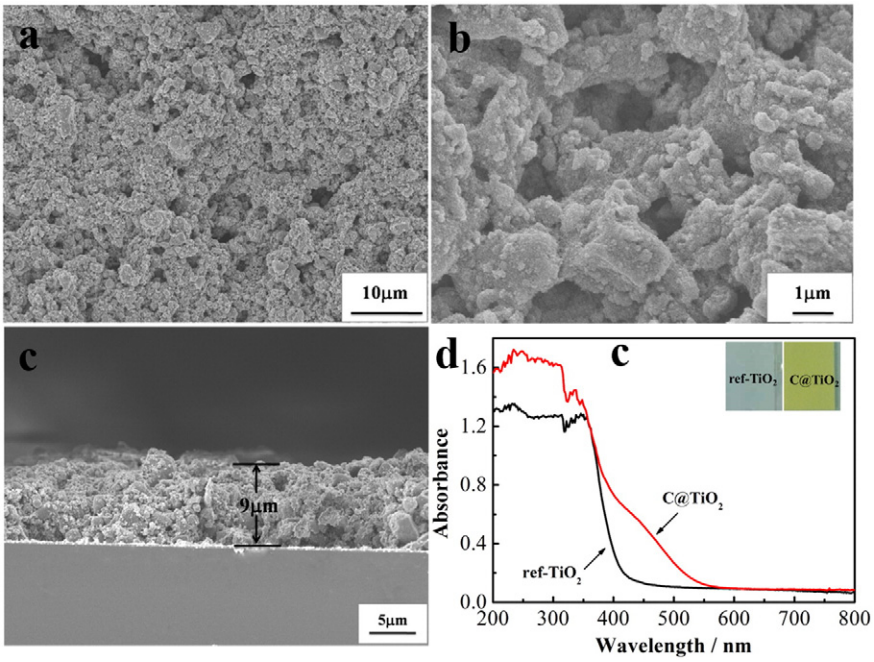

Fig. 2. Top-view (a & b) and cross-sectional (c) SEM images of C@TiO_2 films; (d) optical absorption spectra of ref-TiO_2 and C@TiO_2 films. The inset showing the color change of films.

Download English Version:

https://daneshyari.com/en/article/49352

Download Persian Version:

https://daneshyari.com/article/49352

Daneshyari.com