



Mesoporous I-Ag codoped titania and alumina modified titania catalysts: Synthesis, characterization and photocatalytic properties

Liang Liao, Conrad W. Ingram *

Department of Chemistry and Center for Functional Nanoscale Materials, Clark Atlanta University, GA 30314, USA

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ABSTRACT

Mesoporous iodine and silver codoped titania and alumina modified titania photocatalysts were synthesized by a two-step surfactant-templated hydrothermal route and characterized by X-ray diffraction, XPS, UV–visible diffuse reflectance spectroscopy and nitrogen adsorption. The mesoporous materials had surface areas of 2.6–5.3 times that of Degussa P25. The I-Ag codoped mesoporous titania samples exhibited a bicrystalline framework of rutile and anatase with rutile fractions of 23% and 26%, respectively, whereas the alumina-containing I-Ag codoped materials yielded anatase as the only crystalline phase. The I-Ag codoped photocatalysts with Ag/Ti mole ratio of 1.6% and 2.0% showed catalytic activity 3.3 times and 12 times higher than Degussa P25 under halogen visible and visible light (>400 nm) in photodecomposing methyl orange, respectively. The high performance of I-Ag codoped titania and alumina modified titania photocatalysts under visible light is attributed to the combined effects of large surface area, lower band gap energies and mesoporous structure.

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1. Introduction

Increasing interest in the field of photocatalysis has motivated the design of new photoactive catalysts in the past decades as photocatalysis has potential in utilization of solar energy. As one of the most promising photocatalysts titania has been widely investigated for its attractive applications in water splitting and mineralization of toxic organic substances [1,2]. It offers many advantages as a photocatalyst, such as, high efficiency, good stability, ready availability, and nontoxicity. However, a major disadvantage for the titania photocatalyst is its large band gap (3.2 and 3.0 eV for anatase and rutile, respectively), which hampers its use in visible light and its application is mostly constrained to the ultraviolet (UV) light range. To extend its application into the dominant visible light range of solar energy, one strategy is to reduce its band gap by doping with metal and/or nonmetal elements.

Doping with transition metals, such as Cr, Co, V, and Fe, extends the spectral response of TiO₂ well into the visible region and enhances the photoreactivity [3,4,5]. However, transition metal ion-doped TiO₂ suffers from some serious drawbacks, such as thermal instability and low quantum efficiency of the photoinduced charge carriers (electron–hole pairs) [6]. TiO₂ has also been doped with metallic Ag, Au, and Pt particles to serve as electron sinks to reduce the rate of electron and electron/hole recombination

allowing electron holes to migrate to the surface and carry out chemistry [7,8–10].

There are numerous recent reports on nonmetal-doped TiO₂, with elements such as nitrogen [11,12] sulfur [13], and halogens [14], which effectively narrows the band gap of TiO₂ (<3.0 eV) and enhanced photocatalytic activity [15,16,17]. Moreover, band gap narrowing emanates from the electronic perturbations caused by change of the lattice parameters and/or the presence of the trap states within conduction and valence bands of TiO₂. Consequently, the photons of lower energy (>420 nm) can induce electron–hole pairs in TiO₂. These photoinduced electrons and holes, which are in fact very powerful reducing and oxidizing agents, migrate to the surface of TiO₂ and eventually become available for direct or indirect consecutive reduction and oxidation reactions. Furthermore, because of the presence of some trap states within the band gap of titanium dioxide, the lifetime of the so-called photoinduced charge-carriers increases in such a way that it predominates over the fast charge-recombination process, thereby resulting in an enhanced visible light reactivity.

It is highly anticipated that doping TiO₂ with an appropriate combination of metals and/or nonmetals would, of course, result in more efficient photocatalysts under visible light for a desired application. N–F-codoped TiO₂ photocatalysts demonstrated an enhanced photoreactivity in visible light [18]. These recent efforts and strategies have revealed that codoping TiO₂ with a metal and a nonmetal can result in the development of additional visible light active photocatalysts [19,20].

Despite all the advances in chemical/physical modifications, a nonporous photocatalyst still suffers from limited light

* Corresponding author. Tel.: +1 404 880 6898; fax: +1 404 880 6890.
E-mail addresses: lishcon@gmail.com, cingram@cau.edu (C.W. Ingram).