Applied Catalysis A: General 417–418 (2012) 26–36

Contents lists available at SciVerse ScienceDirect

Applied Catalysis A: General

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

Comparative study on UV and visible light sensitive bare and doped titanium dioxide photocatalysts for the decomposition of environmental pollutants in water

G. Veréb[a], Z. Ambrus[b], Zs. Pap[a,c], Á. Kmetykó[a], A. Dombi[a], V. Danciu[c], A. Cheesman[d], K. Mogyorósi[b,*]

[a] Research Group of Environmental Chemistry, Institute of Chemistry, University of Szeged, H-6720 Szeged, Dom ter 7, Hungary
[b] Department of Inorganic and Analytical Chemistry, Faculty of Sciences and Informatics, University of Szeged, H-6720 Szeged, Dom ter 7, Hungary
[c] Faculty of Chemistry and Chemical Engineering, Babes-Bolyai University, Arany János 11, RO-400028 Cluj-Napoca, Romania
[d] Department of Applied and Environmental Chemistry, Faculty of Sciences and Informatics, University of Szeged, H-6720 Szeged, Rerrich Bela ter 1, Hungary

ARTICLE INFO

Article history:
Received 22 July 2011
Received in revised form 8 December 2011
Accepted 10 December 2011
Available online 20 December 2011

Keywords:
Flame hydrolysis
Doped titania
Noble metal deposition
Photocatalysis
Visible light

ABSTRACT

In this study the efficiency of different bare, doped and composite photocatalysts were compared, under UV and visible light irradiation in order to show a detailed picture of the relative performance of the best photocatalysts developed in our laboratories and the mostly investigated reference titanias. The syntheses of our photocatalysts were optimized in order to achieve maximum photocatalytic activity under UV and visible light irradiation. Non doped commercial (Aeroxide P25, Aldrich anatase) and synthesized titanias (produced by sol–gel and flame hydrolysis techniques) and nitrogen, iron, iodine doped and silver or gold deposited titanium dioxides were investigated with two model pollutants (phenol and oxalic acid) under identical experimental conditions. The material properties of these selected photocatalysts were thoroughly characterized by X-ray diffraction, diffuse reflectance spectroscopy, transmission electron microscopy, X-ray photoelectron spectroscopy, X-ray fluorescence spectroscopy and BET methods. The highest degradation rate of phenol was determined for the flame made titania sample with relatively low specific surface area (20 m^2/g) when UV irradiation was applied. In contrast with that, our nitrogen doped photocatalyst with high specific surface area (139 m^2/g) was the best for phenol degradation under visible light irradiation. Although the most efficient oxalic acid mineralization occurred with noble metal photodeposited samples under UV irradiation, this type of modification was detrimental when VIS irradiation is applied. The decomposition rate of oxalic acid was high under VIS irradiation using the iron and nitrogen doped photocatalysts. For both substrates and irradiation conditions our best photocatalysts were found to be significantly more active than Aeroxide P25 TiO_2. Intermediate studies revealed that phenol degradation resulted in dihydroxy benzene intermediates, such as pyrocatechol and hydroquinone both under UV and visible light irradiation with our TiO_2-N photocatalyst. The results of this comparative study could promote the determination of the optimal synthesis conditions of titanium dioxide based photocatalysts for a given organic pollutant in water.

1. Introduction

Recent improvements in the photocatalytic performance of titanium dioxide have focused on controlling particle size, phase composition, particle shape and effective visible light absorption. Photocatalysts, produced by new synthesis methods, are being designed with high levels of crystallinity and small particle size in order to maximize the photocatalytic decomposition of selected organic model pollutants. Ryu and Choi [1] found that among many good commercially available photocatalysts, the flame-made Degussa P25 titanium dioxide showed the best photocatalytic performance under UV irradiation for the majority of organic substrates in aqueous solutions. P25's activity was only exceeded by some commercially available photocatalysts (Hombikat UV100 and Ishihara ST-01) and this is attributed to their higher specific surface area particularly when carboxylic acids (dichloro acetic acid, formic acid) or anionic substrates (acid orange 7, sodium dodecylsulphate) were studied [1]. Flame-made titania photocatalysts synthesized on laboratory scale were found to be very efficient for poorly adsorbing substrates, such as phenols [2–4]. It was recently demonstrated by Ohtani et al. [5] that the high activity of Degussa P25 TiO_2 is not related to the rutile content as previously suggested. The effective UV catalytic process for the weakly adsorbing substrates is attributed to the high anatase content with relatively large nanoparticles [1]. Our novel sol–gel synthesis method combines the rapid heating and short exposure in the furnace (RHSE)

* Corresponding author. Tel.: +36 62 544 334; fax: +36 62 420 505.
E-mail address: k.mogyorosi@chem.u-szeged.hu (K. Mogyorósi).

0926-860X/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.apcata.2011.12.018