Novel one step synthesis of Cr/TiO2 modified with SiO2 by Flame Spray Pyrolysis (FSP) for Liquid Phase Phenol Photodegradation under Visible Light.

Siva Nagi Reddy Inturi 1, Makram Suidan 2, Panagiotis G. Smirniotis 1

1 Chemical Engineering Program, Department of Biomedical, Chemical, and Environmental Engineering, University of Cincinnati, Cincinnati, OH 45221-0012, USA.
2 Engineering College and Architecture, American University of Beirut, Beirut 1107-2020, Lebanon.

Introduction

Photocatalysis has gained a substantial amount of attention due to its potential environmental applications towards water treatment, such as purifying polluted air and waste water streams, self-cleaning materials and the creation of new chemicals [1]. There has been a major attention towards the visible light photocatalysis of waste water due to its flexibility and cost-effective breakdown of harmful organic molecules at ambient conditions. Among the semiconductors known, TiO2 is widely used as catalyst for the environmental applications due to its resistance to corrosion, non-toxicity, physical and chemical stability and low cost. In order to succeed, it is essential to utilize the light source of satisfactory intensity so as to acquire energy that exceeds the TiO2 band gap energy (Ebg). However, the large band gap of the TiO2 (Ebg (anatase) = 3.2 eV), requires a wavelength of 400nm or less for the excitation of the catalyst Doping TiO2 with metal ions can enhance its photoactivity or even can enable its sensitization under visible light [2].

In earlier studies involving transition metal doped TiO2 [3-4], it was shown that among all the transition doped metals Cr had higher photocatalytic activity under visible light. There is not much literature available to study the secondary contamination caused by the metal leaching due to the catalyst and its effect due to the synthesis methods. Many synthesis methods of anatase TiO2 have been conducted by researchers such as inert gas condensation, sol-gel, solvo-thermal, flame synthesis by oxidation, oxidation–hydrothermal and hydrolysis precipitation of titanium alkoxides or inorganic salts. We know that the structural and surface properties of the materials are influenced by the synthesis methods employed.

Overall, there has been no catalyst prepared for work in the visible light, which would combine chemical stability and high activity. It was found that activity enhancement of titania when it was loaded onto zeolitic or mesoporous silica support. Traditional silica synthesis involves large no of steps and it is expensive. In the present study mainly aimed at investigating the influence of the aqueous photodegradation of phenol under visible light (wavelength >400 nm) with SiO2 incorporated with Cr and TiO2 by Flame Spray pyrolysis (FSP).

Materials and Methods

The synthesis procedure for the flame-made nanoparticles is explained in detail in our previous studies [4]. These materials are characterized with BET surface area, pore size distribution, X-ray diffraction (XRD), ultraviolet–visible light (UV–vis) spectra, and temperature-programmed reduction (TPR).

Results and Discussion

The surface areas of Cr modified TiO2-SiO2 samples decreased with increasing amount of Cr incorporated. Temperature programmed reduction (TPR) and UV–vis spectra profiles clearly indicated that only Cr6+ phase is present in the FSP made material, whereas sol-gel and co-precipitation synthesized catalysts have Cr3+ species along with Cr6+ species. The photodegradation ability of TiO2/Cr catalyst with Ti/Cr atomic ratio of 40 was highly related to the existence of Cr6+ species which strongly interacted with TiO2. The reduction peaks in Cr modified TiO2-SiO2 shifted to much lower temperatures, due to the increase in the reduction potential of titania and chromium species. The developed catalysts also demonstrated an advantage of low metal leaching during the catalytic reaction, avoiding secondary metal contamination to the treated wastewater. The optimal catalyst has also showed stability with time for the photocatalytic degradation of the phenol under visible light irradiation. The surface area and Cr content was stable for the fresh and used samples. The photocatalytic performance, characterizations and the effect of the SiO2 incorporated Cr/TiO2 material synthesized by the three different methods will be presented in the presentation. For the given 40 M/Cr ratio (M = Si+Ti), the Si/Ti atomic ratios in the synthesized materials are 1, 1.2, 1.4, 1.5 and 1.6. We found the optimal Si/Ti ratio of 1.5 has demonstrated better visible light photocatalytic activity. With the optimal ratio of Si/Ti, we have synthesized M/Cr ratio (M = Si+Ti) ratios of 50, 40, 30, 25 and 20.

Figure 1. The time course of total carbon concentration during 500 ppm of phenol isible light photocatalytic degradation over FSP made catalyst with M(Si+Ti)/Cr =40.

Significance

Authors should briefly highlight industrial and/or fundamental significance of the work.

References