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Short Communication

Visible light responsive ruthenium-doped titanium dioxide for the removal of metsulfuron-methyl herbcide in aqueous phase

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ABSTRACT

Titanium dioxide (TiO_2) under UV light irradiation is one of the effective treatment methods to reduce the concentration of synthetic organic compounds in water. Nevertheless, only a small amount of UV light is absorbed in the solar light. This makes the less use of TiO_2 for environmental applications. In this study, we prepared Ru-doped visible light responsive (VLR) TiO_2 to improve visible light absorption and characterized it in terms of physical and chemical properties. The photocatalytic activity of VLR Ru-doped TiO_2 was investigated to remove metsulfuron-methyl (MSM) in aqueous phase. The Ru-doped TiO_2 at different Ru concentrations was found to have the anatase phase. The undoped and Ru-doped TiO_2 consisted of regular round shape. The photocatalytic activity of VLR photocatalyst was significantly improved on the addition of Ru from 40% for undoped TiO_2 to 80% for Ru-doped TiO_2. The removal efficiency of MSM was proportional to the increasing Ru-doped TiO_2 under visible light. As the calcined temperature increased from 300 to 900 °C, the degradation efficiencies moderately changed from 65 to 90%. However, the effect of calcination duration was marginal on the photodegradation of MSM.

1. Introduction

Synthetic organic contaminants (SOCs) in water, which include most of herbicides and pesticides, are a major source of health risks in water supply systems. Different conventional and advanced methods have been employed in treating SOCs such as adsorption, nanofiltration and chemical oxidation [1–3]. However, adsorption by activated carbon is restricted in adsorbent capacity and membrane fouling is a major obstacle in nanofiltration application. Advanced oxidation processes (AOPs) is one of the effective treatment methods.

AOPs are found to be effective in organic breakdown and detoxification of contaminated water [3–6]. For example, a high degradation (>90%) of atrazine and benazolin was achieved by ozone oxidation in conjunction with hydrogen peroxide [3]. The photocatalytic oxidation also gives a complete degradation of organic pollutants into small and harmless species without large chemical requirement, the subsequent large sludge production and associated disposal problems [7,8]. Titanium dioxide (TiO_2) is one of the most widely studied semi-conducting photocatalysts for the destruction of organic pollutants from water and air, because of its physical and chemical stability, high photocatalytic activity, high oxidative power, low cost and ease of production [9]. However, the photocatalysis with TiO_2 only reacts under UV light due to its wide band gap (3.2 eV), which in turn restricts its use as solar or room-light activated photocatalyst.

Recent studies have been focused on modifying the TiO_2 surface by doping with metal (Fe, Cr, Co, Cu, Ru, Ag) and non-metal (S, C, N) ions to improve its visible light activity [10–16]. For example, Chao et al. [11] studied the effect of silver (Ag) doping on TiO_2 and reported an increase in specific surface area of TiO_2 particles to improve its photocatalytic activity to the visible region. In the other studies, Ohno et al. [15] and Housekova et al. [16] extended the effective wavelength of TiO_2 between 365 and 400 nm by ruthenium (Ru) doping. As Ru ions are doped into TiO_2, impurity energy levels in the band gap are formed. This leads to the alteration of electron hole recombination. Ohno et al. [15] found that the Ru-doped photocatalyst occurred by irradiation of visible light at wavelengths longer than 440 nm using iron(III) ions as the electron acceptor. Housekova et al. [16] reported that ruthenium oxide caused the anatase to rutile transformation to occur at lower temperatures and decreasing of band gap energy of Ru-doped photocatalyst.

In this study, the objectives were to prepare Ru-doped TiO_2 to respond visible light and characterize it in terms of X-ray diffraction (XRD), surface area and scanning electron microscope/energy dispersive X-ray (SEM/EDX). The photocatalytic activity of visible light responsive (VLR) Ru-doped TiO_2 was investigated using photodegradation of metsulfuron-methyl (MSM) which is a widely used herbicide in Australia.

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