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ORIGINAL PAPER

A highly photoresponsive and efficient molybdenum-modified titanium dioxide photocatalyst for the degradation of methyl orange

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Abstract

The degradation of azo dyes in aquatic environments is still challenging due to their stability and perpetual effect. This work demonstrates the application of highly ultraviolet-responsive titanium dioxide/molybdenum photocatalyst to degrade methyl orange. A series of titanium dioxide/molybdenum photocatalyst with different molybdenum concentrations (1–10 wt%) were synthesized by a facile wet impregnation method. The introduction of molybdenum has favorably induced changes in surface morphology, crystallite size, optical absorption, and specific surface area, which have collectively enhanced the photocatalytic performance of titanium dioxide/molybdenum photocatalyst on the removal of methyl orange. A systematic investigation on the influencing parameters such as photocatalyst dosage, initial methyl orange concentration, and initial pH was investigated, and the optimum conditions were achieved. The best-performing titanium dioxide/molybdenum (3 wt%) photocatalyst yielded a 94.5% methyl orange photodegradation efficiency within 120 min of irradiation. The dopant concentration, photocatalyst dosage, and pH were investigated to validate the optimized conditions for titanium dioxide/molybdenum on methyl orange removal using response surface methodology via the Box–Behnken design. The present results demonstrated that both the superoxide radical and hydroxyl radical play a primary role in the degradation mechanism. This study provides fresh insight that the successful structural modification of titanium dioxide by molybdenum could enhance the photocatalytic removal of dye wastewater.

Keywords Doping · Metals · Photocatalysis · Wastewater · Wet impregnation

Introduction

Access to the clean drinking water supply is a basic human right. However, contamination of water supplies with recalcitrant organic pollutants, dyes, and toxic industrial chemicals has become a major global issue that could potentially risk human health and the living environment. Therefore, eliminating contaminants is vital, and heterogeneous photocatalysis has been commonly recognized as an efficient method of degrading organic pollutants in wastewater and air (Umar and Aziz 2013). Titanium dioxide (TiO_2) has been extensively applied as a photocatalyst due to its excellent properties, such as non-toxic, low cost, resistance against photochemical corrosion, and high oxidizing power (Jalali and Mozammel 2017). However, the application of TiO_2 photocatalysis is limited due to a high degree of recombination between the photoexcited electron–hole pairs, resulting in lower quantum efficiency (Moma and Baloyi 2018). Therefore, various strategies have been developed to prolong the lifetime of photoexcited electron–hole pairs, such as depositing noble metal on the TiO_2 surface, coupling with narrow bandgap semiconductors (Bumajdad and Madkour 2014), dye sensitization (Fan et al. 2017), and metal doping (Zhu et al. 2016).

Among these strategies, metal doping in the TiO_2 matrix is an effective approach to improve the photocatalytic activity of TiO_2 (Khairy and Zakaria 2014; Sreedhar et al. 2018;

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