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Research paper

Synthesis and characterization of TiO_2–Montmorillonite/Polythiophene-SDS nanocomposites: Application in the sonophotocatalytic degradation of rhodamine 6G

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ABSTRACT

Titanium dioxide–montmorillonite/Polythiophene–sodium dodecyl sulphate (TiO_2–Mt/PTP–SDS) nanocomposites were synthesized via the in situ intercalative oxidative polymerization of thiophene (TP) in TiO_2–Mt clay and $CHCl_3$ solvent using anhydrous ferric chloride ($FeCl_3$) at ambient temperature for 24 h in the presence of anionic surfactant SDS at a ratio by mass of 20% of TP/TiO_2–Mt. The TiO_2–Mt was obtained by the modification of sodium montmorillonite (Na-Mt) with titanium isopropoxide (Ti (OPr^i) $_4$) at 50 °C for 3 h. The products obtained were characterized using different techniques, such as Fourier Transform Infrared Spectroscopy (FTIR), X-ray Fluorescence Analysis (XRF), X-ray diffraction (XRD), and Environmental Scanning Electron Microscopy (ESEM), which proved the successful intercalation of polythiophene in the TiO_2–MT in the presence of anionic surfactants. The degradation of rhodamine 6G (R6G) in aqueous solutions was investigated kinetically in the presence of catalysts under Sun-test simulator at 400 W/m^2, sonocatalysis at 500 kHz (30 W), and sonophotocatalysis. The findings revealed that the TiO_2–Mt/PTP20%-SDS catalyst exhibited good levels of photocatalytic, sonocatalytic, and sonophotocatalytic degradability for R6G. The synergistic effect between the two techniques was observed using TiO_2–Mt/PTP20%-SDS (w %) as a catalyst, and the kinetic results indicated that enhanced degradation rate constants were achieved particularly with sonophotocatalytic processes.

1. Introduction

Among the various processes employed in water treatment, heterogeneous semiconductor photocatalysis has often been reported to offer a number of key advantages, including the possible use of solar irradiation, operation at ambient conditions, and reuse of the catalyst. Heterogeneous photocatalysis is a process wherein the irradiation of a wide-band gap semiconductor, such as TiO_2, with light result in excited electron-hole pairs that can be conveniently applied to produce electricity in solar cells, initiate photoinduced superhydrophilicity that involves surface bound redox reactions (Cap et al., 2004), generate specific catalytic reactions and chemical processes, such as organic synthesis, or to promote the degradation of pollutants.

In this context, the degradation of industrial dyes has triggered extensive research aiming to search for viable alternative methods for industrial dye waste removal that can compensate for the inadequacies associated with the conventional procedures used for the purification of industrial water wastes. Industrial dye wastes can pose serious challenges to human health, aquatic life and the environment. Of particular relevance to this issue, TiO_2 nanoparticles have often been reported to constitute good photoactive materials for application in the removal of organic pollutants (Hoffmann et al., 1995; Pan et al., 2006). They can be suitably employed in complementary processes for the detoxification of drinking water and decontamination of industrial wastewaters (Erdemoglu et al., 2008; Kangwansupamonkon et al., 2010; Lathasree et al., 2004; Song et al., 2007; Tang et al., 2007; Vohra and Tanaka, 2003).

Commercial products of TiO_2 photocatalysts are, however, usually small sized particles that can agglomerate in aqueous solutions, which often lead to decreased photocatalytic activities and impede their after-use recovery. The use of those particles in wide scale industrial applications has also been limited because of their tendency to accumulate, which often creates troublesome problems, such as instrument blockage and malfunction. Moreover, as TiO_2 can absorb and be activated by UV light of $\lambda < 395$ nm, it can make use of only about 4% of the solar energy that reaches the earth. Considerable efforts have, therefore, been made to overcome these shortcomings. Several proposals have been made to overcome the first limitation, including the use of support materials for TiO2 photocatalysis. In fact, various materials, such as activated carbon (Kumar et al., 2010; Ping-Feng et al., 2008), silica (Chmielarz et al., 2009), and Mt (Damardji et al., 2009a, 2009b; Kun et al., 2006; Mogyorosi et al., 2002; Shirini et al., 2012), were proposed as TiO_2 supports to condense pollutants in bulk solution for degradation. Likewise, several attempts have been made to address the second problem,

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