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Synthesis, characterization and evaluation of efficiency of new hybrid Pc/Fe-TiO_2 nanocomposite as photocatalyst for decolorization of methyl orange using visible light irradiation

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ABSTRACT

Novel hybrid nanocomposite based on the Fe-doped TiO_2 and phthalocyanine, (Pc/Fe-TiO_2), has been synthesized and characterized. Also, the efficiency of the nanocomposite as a photocatalyst for the decolorization of methyl orange using visible light irradiation has been evaluated. For the preparation of the nanocomposite, at first Fe-doped TiO_2 nanoparticles have been prepared by a sol–gel method. Then the nanocomposite was synthesized by anchoring the Pc complex on the Fe-TiO_2 nanoparticles calcined at 400 °C. Prepared nanoparticles and the nanocomposite have been characterized by XRD, FT-IR, EDX, BET, DRS, STA (TG–DTA) and TEM techniques. Results revealed that the nanocomposite possesses the anatase structure with the specific surface area of 7.16 m^2/g. The TEM micrograph demonstrated that the average particle size of the nanocomposite was about 15–20 nm. Phthalocyanine and Fe^{3+} ions in the TiO_2 structure caused significant shift of absorption edge into the visible region. The band gap energy of the nanocomposite was calculated as 2.48 eV. Results of decolorization revealed that the nanocomposite has shown much more photocatalytic activity than the pure TiO_2 under the visible light. It was found that about 87% of the methyl orange solution was decolored over the nanocomposite after 450 min under visible light irradiation. Therefore, the synthesized nanocomposite is a suitable photocatalyst to use under the visible light which makes the applicability of TiO_2 photocatalysts even more versatile.

1. Introduction

Industrial wastewaters containing toxic organic dyes have serious problems to the environment [1]. About 1–20% of the total world production of dyes is lost during the dyeing process and is released into the environment as textile effluents [2,3]. It must be noted that organic dyes can produce toxic substances through oxidation, hydrolysis or other chemical reactions occurring in the wastewater phase [4–6]. The decolorization of dyes in the industrial wastewater has received increasing attention. Therefore, several methods for treating various wastewaters have been developed. One of new technologies for treating wastewaters is advanced oxidation processes (AOPs). AOPs are based on the generation of hydroxyl radicals ($^{\bullet}OH$) that degrade a broad range of organic pollutants [7]. AOPs such as Fenton and photo-Fenton catalytic reactions, H_2O_2/UV processes and TiO_2 photocatalysis have been broadly considered [8–10].

Titanium dioxide is widely utilized as a photocatalyst because of its photochemical stability, non-toxic nature and low cost. However, the efficiency of the use of TiO_2 is limited by its relatively large band gap energy (3.2 eV), corresponding to the wavelength of 370 nm where only 3–5% of the solar energy is effective and also by the high recombination rate of electron–hole pairs formed in photocatalytic processes [11–13]. Various methods have been developed for the increment of the photocatalytic activity of TiO_2 particles such as increasing its surface to volume ratio, optimization of particle sizes, coupling of TiO_2 with other semiconductor particles, dispersion of TiO_2 species in zeolite cavities, doping with metal or non-metal ions and dye photosensitization of TiO_2 [14,15].

The introduction of transition metal ions can result in the formation of a doping energy level between conduction and valence bands of TiO_2 and shift the band gap of TiO_2 into the visible region. Also a dopant ion may act as a trap for electrons or holes and increases the catalytic activity of TiO_2 under the visible light irradiation [16,17]. However, the photoactivity of the doped TiO_2

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