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Nano-sized Fe-metal catalyst on $ZnO–SiO_2$: (photo-assisted deposition and impregnation) Synthesis routes and nanostructure characterization

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ABSTRACT

A nano-sized Fe metal on $ZnO–SiO_2$ was synthesized using the photo-assisted deposition (PAD) and impregnation routes. The obtained samples were characterized by a series of techniques including X-ray diffraction (XRD), UV–vis diffuse reflectance spectroscopy, N_2 adsorption, extended X-ray absorption fine structure (EXAFS), and transmission electron microscopy (TEM). Photocatalytic reactivity using $Fe–ZnO–SiO_2$ catalysts under visible-light condition on the degradation of methylene blue dye was evaluated. The results of characterization reveal, a notable photocatalytic activity of PAD:$Fe–ZnO–SiO_2$ which was about 9 and 12 times higher than that of Img:$Fe–ZnO–SiO_2$ and $ZnO–SiO_2$, respectively.
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1. Introduction

There has been a lot of attention recently on advanced oxidation processes for water and wastewater decontamination, and heterogeneous photocatalysis is a popular technique in these processes that has been applied to produce reactive species (often the hydroxyl radical) with the purpose of controlling aqueous organic pollutants [1]. One way of generating hydroxyl radicals in aqueous solution is the application of semiconductor photocatalysts which is considered a promising technology in solving environmental pollution problems.

Several semiconductors have band gap energies sufficient for catalyzing a wide range of chemical reactions of environmental interest [2,3]. Among various semiconductors studied, ZnO has been identified as a promising host material and proved to be the most suitable catalyst for widespread environmental applications because of its high photosensitivity, excellent mechanical characteristics, low cost and environmentally safe nature [4,5].

However, a major drawback of ZnO is the large band gap of 3.37 eV, so wavelengths below 400 nm are necessary for excitation. Another disadvantage of ZnO is that charge carrier recombination of photo-generated electron/hole pairs occurs within nanoseconds and the photocatalytic activity is low [4,6–8]. Therefore, it is necessary to improve its visible-light activities by extending its absorption threshold from the UV light region to the visible light region and also reduce the recombination of photo-generated electron/hole. The most promising method to increase the photocatalytic efficiency is the surface modification of ZnO. The surface modification of ZnO can be achieved by metal doping into ZnO. A wide range of metal ions, in particular transition metal ions, have been used as dopants for ZnO because the recombination of photogenerated electrons and holes can be hindered by increasing the charge separation [9–12]. Among various transition metal ions, ferric ion (Fe^{3+}) is considered an interesting doping element due to its half-filled electronic configuration. A proper concentration of Fe^{3+} ions is not only to favor electron–hole separation, but also to narrow its band gap [6]. Also the surface modification of ZnO nanoparticles by preparing charge-transfer catalysts with mixing multi-component oxides can enhance the surface chemical and physical properties and considered as the key for the successful photocatalytic applications of such nanoparticles. Silicon dioxide, SiO_2, has been coupled with semiconductor photocatalyst to enhance the photocatalytic process. SiO_2 has high thermal stability, excellent mechanical strength and helps to create new catalytic active sites due to interaction between semiconductor photocatalyst and SiO_2. Also, at the same time SiO_2 acts as the carrier of semiconductor photocatalyst and helps to obtain a large surface area as well as a suitable porous structure [13–17].

In order to develop the efficient and practical catalysts, a novel strategy is desired to provide nano-sized metal with well-controlled size and dispersability on solid support [18]. Together with such strategy, it is also desired to manipulate the single-site photocatalyst band gap to acquire single-site photocatalyst ability to work under UV and/or visible light radiation. Under UV and/or

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