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Structural, microstructural and photocatalytic degradation of methylene blue of zinc oxide and Fe-doped ZnO nanoparticles prepared by simple coprecipitation method

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ABSTRACT

Nanoparticles of ZnO doped with Fe (0.00, 0.02, 0.05 and 0.10) were prepared by chemical co-precipitation method. The effect of iron doping on the structural, morphological and optical properties of ZnO nanoparticles was examined by X-ray diffraction (XRD), Scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) and UV–Visible spectroscopy. The XRD analysis revealed the single-phase of the as-made and Fe-doped ZnO nanoparticles. SEM images showed the formation of aggregates of small individual nanoparticles of various sizes. FTIR analysis indicated the existence of distinct characteristic absorption peaks at 447 cm^{-1} for Zn–O stretching mode with some changes in the intensities. UV–Visible measurement revealed a reduction in the energy gap with increasing Fe concentration, which is generally due to increasing mesh parameters. The photocatalytic activity of $Zn_{1-x}Fe_xO$ was evaluated by analyzing the degradation of methylene blue (MB). The presence of iron from 2% to 10 at% in the ZnO nanopowder was found to decelerate the photocatalytic process.

1. Introduction

Zinc oxide nanoparticles (ZnO NPs) have been adopted in a variety of fields and applications such as semiconductors, catalysts and paints [1]. ZnO is a transparent semiconductor with direct gap and wide band gap (3.37 eV) with a fairly high exciton bonding energy of 60 meV [2,3]. This diversity means that ZnO could find many applications in different fields such as optoelectronics, acousto-optics, piezoelectric and as a gas detector photocatalysts and light emitting diodes (LEDs) [4,5]. In addition, ZnO has attracted a lot of interest as a semiconductor photocatalyst, as a powder [6,7], nanoparticle [8–11] or thin film [12–14]. It should be noted that the photocatalytic properties of ZnO are directly linked to its structure, morphology and crystallite size, which in turn depend on the ZnO preparation method. In addition, doping ZnO with metallic elements can also improve its photo-catalytic properties.

To this end, there are several studies in literature showing that it is possible to dope the ZnO matrix with the generally metallic elements according to the desired physical properties (Al, Mn, Ni, Fe, Co, Ga, In, Cl, etc.) [15–21]. Indeed, in order to allow a systematic study of the structural transformation related to the dopant concentration, it is important to know what are the values of the solubility limit of the transition metal (e.g. Fe in this paper) doped in ZnO and to specify the role of the dopant in the generation of additional phases, as these factors directly influence the development of the structural transformation as well as the optical, spintronic, etc. uses [22–24]. The thermodynamic limit solid solubility of Fe in ZnO is reported around 30% [23]. On the other hand, in another paper on iron-doped ZnO structures obtained by various techniques, the solubility of iron is in the range of 0.4–1% [24]. In view of the variation in the reported values of the solubility limit of iron, it might be interesting to determine the solubility of iron in ZnO nanostructures. Moreover, it was reported that doping of ZnO with Fe can improve its optical characteristics and accelerate the rate for its practical applications of near band edge ultraviolet, PL is found as per the deep level emission [24].

ZnO nanoparticles have been synthesized by different methods, such as chemical/physical [25], or hydrothermal method [26], sol-gel [27], vapour phase transport [28], combustion [29] and co-precipitation [30]. Among these techniques, the co-precipitation method has high potential and energy-saving. Moreover, some reports are available in the literature on the Co-doped ZnO nanoparticles [31–34]. In addition, this

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