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One-pot synthesis of ZnO–Ag and ZnO–Co nanohybrid materials for photocatalytic applications

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ABSTRACT

ZnO–Ag and ZnO–Co nanohybrid materials with different Ag and Co contents were successfully prepared through a simple one-pot method at room temperature in the absence of surfactants. This synthesis route is effective and environmentally friendly and can produce spherical nanoparticles with sizes between 7 and 20 nm. The nanohybrid materials were characterized by UV–vis spectroscopy, fluorescence spectroscopy, scanning electron microscopy–energy-dispersive X-ray analysis, X-ray diffraction, Fourier transform IR spectroscopy, and high-resolution transmission electron microscopy. Their photocatalytic activity was evidenced by discoloration of the synthetic diazo dye Bismarck brown Y; ZnO–Ag nanohybrid materials had greater efficiency for decolorization of the dye compared with ZnO–Co, ZnO, and TiO_2. The enhanced photocatalytic activity of the ZnO–Ag nanohybrid material is due to three important aspects: (1) the oxygen vacancies present on the ZnO surface, (2) the efficient absorption of visible light due to the interaction of the semiconductor and the surface plasmon resonance of Ag, and (3) the effective separation of charges due to the formation of the Schottky barrier between ZnO and Ag, where Ag acts as an electron trap, and thereby reduces recombination. When the ZnO–Co nanohybrid is used, the addition of Co introduces intermediate energy levels between the valence and conduction bands on the semiconductor surface, which results in a recombination that reduces the photocatalytic activity, making the azo dye decolorization less efficient.

1. Introduction

Synthetic dyes constitute a group of pollutants commonly discharged in wastewaters of the textile, pharmaceutical, food, and tannery industries, among others. Particularly, the textile and tannery industries discharge large volumes of wastewater with a high concentration of synthetic dyes. These pollutants are very stable and are very persistent in the aquatic environment. The discharge of colored wastewater into water bodies can have an environmental impact, such as the production of aesthetic water color problems and the blocking of light penetration, which can lead to oxygen depletion and eutrophication [1,2]. Several wastewater treatment technologies have been tested to remediate effluents from the textile and tannery industries; however, adsorption, biological treatments, and physicochemical processes are all inefficient methods for the remediation of wastewaters. To avoid the environmental effects of discharging these wastes, potent oxidation methods are required for the effective degradation of these dyes and their by-products in wastewaters [3–5]. Photocatalysis can achieve the complete removal of persistent contaminants at room temperature and pressure, without one having to worry about the generation of dangerous intermediates. The most commonly used photocatalysts are oxides, such as titanium dioxide (TiO_2) and zinc oxide (ZnO), the advantages of these oxides being very good photosensitivity, chemical stability, low cost, and nontoxicity. As is normal in photocatalysis, these materials have some disadvantages; the main one is that the photoactivity of these materials is restricted to the UV–visible spectrum [6–8]. Recently, in the photocatalysis field, ZnO has gained attention because of its high electron mobility [7,9–12]. However, ZnO exhibits

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