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RESEARCH ARTICLE

Visible light-driven photocatalytic degradation of methylene blue dye over bismuth-doped cerium oxide mesoporous nanoparticles

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Abstract

A series of Bi^{3+}-doped ceria nanoparticles (0 to 20 wt% of Bi^{3+}) were synthesized by sol-gel assisted hydrothermal method at a lower temperature of 150 °C. The synthesized nanoparticles were found to be effective photocatalysts for the degradation of methylene blue dye under visible light irradiation. The synthesized photocatalysts were well characterized by crystallographic, microscopic and spectroscopic methods. XRD patterns showed that the developed photocatalysts have cubic fluorite structure, and the absence of any impurity peaks in the XRD patterns of doped samples emphasizes the effective doping in host lattice. All samples exhibited mesoporous nature as evident from the adsorption and desorption pore size measurement. The shift of band gap energy from UV to visible region (2.90–2.77 eV) of the undoped and doped ceria results in the photo degradation of methylene blue dye in the visible light.

Keywords Cerium oxide · Visible light · Photocatalysis · Doping · Sol-gel · Degradation · Hydrothermal method · Mesoporous · Methylene blue

Introduction

Nowadays, an extensive number of research studies are reported in the development of suitable materials for the removal of recalcitrant organic pollutants and effluents from the textile industry, especially the organic dyes, which contribute towards the major source of water contamination (De Lima et al. 2017). About 50% of the dyes used on textile fiber are not fixed on it; instead, they remain as pollutant in water bodies (Yuan et al. 2020). Untreated dye pollutants in water not only affect the appearance of water, it also inhibits the passage of light through them, which decreases the rate of photosynthesis and amount of dissolved oxygen, resulting in an increase in the value of COD and BOD causing undesirable impacts on aquatic life (Katheresan et al. 2018). To resolve such complication, conventional methods namely adsorption, coagulation, ion-exchange, and enzyme degradation are inefficient for the complete mineralization of dye effluents, as these methods bring about secondary pollutants like toxic gases and sludge which require additional processing (Balcha et al. 2016). In this context, alternative techniques such as heterogeneous photocatalysis using nano semiconductor has emerged as promising technology for the removal of dye pollutants from waste water (Tahir et al. 2019; Akerdi and Bahrami 2019).

The heterogeneous photocalysis is an advanced oxidation process capable to completely mineralize recalcitrant organic pollutants present in textile dye effluents non-selectively into CO_2 and H_2O with the in-situ generation of highly oxidizing hydroxyl radicals (·OH) having oxidation potential of $E^{\circ}_{(\bullet OH/H_2O)}$ = 2.8 eV (Babu et al. 2019). Semiconductor metal oxides such as TiO_2 and ZnO are much publicized photocatalyst (Chen et al. 2020; Ong et al. 2018). Even though CeO_2, the most abundant rare earth metal oxide has been noted remarkably as an effective

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