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Synthesis, characterization and application of bismuth and boron Co-doped TiO_2: A visible light active photocatalyst

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HIGHLIGHTS

- Bi–B–TiO_2 nanoparticles were prepared by modified sol–gel method.
- Bi and B species have been doped into the crystal lattice of TiO_2 with Bi.
- Bi^{3+} substituted for Ti^{4+} while B exist as both substitutional (O) and interstitial B.
- Bi–B–TiO_2 degraded 2, 4-DCP and AO7 under visible light effectively.
- Bi species enhanced visible light harvesting, e^-/h^+ separation and mobility.

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ABSTRACT

Bismuth and Boron co-doped TiO_2 nanoparticles were successfully prepared by a modified sol–gel method. The products were characterized with various spectroscopic and analytical techniques to determine their structural, morphological, light absorption and photocatalytic properties. The results reveal that all the samples consist of highly crystalline anatase with mesoporous structures. The experimental results further indicate that Bi and B species have been doped into the crystal lattice of TiO_2 with Bi substituting Ti in the form of Bi^{3+} and B doped in the form of substitutional and interstitial B. The presence of Bi species facilitated the incorporation of B into the crystal lattice of TiO_2. XRD and TEM analysis show that all the dopants (B and Bi) have the ability to inhibit particle growth of anatase TiO_2 with more inhibition exhibited by Bi. Compared to pure TiO_2, B and Bi singly doped TiO_2; Bi–B co-doped samples showed better activities for degradation of Acid Orange 7 (AO7) and 2, 4-dichlorophenol under visible light irradiation. The highest activity is observed for 3% Bi–B–TiO_2 calcined at 450 °C. The superior performance of this sample is ascribed to the high surface area, ability to absorb in visible light, efficient charge separation as well as improved e^- transfer associated with the cooperate effects of appropriate amounts of B and Bi in co-doped sample. Bi species are found to play a pivotal role in the co-doped samples. Superoxide radicals are the most reactive species in degradation of AO7 over 3% Bi–B–TiO_2 under visible light irradiation.

1. Introduction

Employing Titania (TiO_2) as a photocatalyst in degradation of organic and inorganic pollutants in air and water offers a viable approach for solving environmental pollution problems. This is due to its unique properties which include high oxidizing capacity, low cost, non-toxicity, chemical robustness and high photostability [1–4]. However, practical application of this great substance is impeded by its high recombination rate of photo induced charge carriers and wide band gap (3.2 eV for anatase polymorph). TiO_2 only shows photo-response to UV light, hence making it more costly to use it because of the need for a UV light source. A more cost effective way will be the use of renewable energy (solar energy) for the purpose of environmental clean up due to its abundance and environmental friendliness. However, its larger portion is comprised of low energy light (visible light ~45%) which cannot be utilized by TiO_2. In order to address the above mentioned drawbacks in the use of TiO_2 in environmental remediation application, numerous attempts in research have been done to induce visible light absorption in TiO_2 for efficient utilization of solar energy as well as improvement in charge carrier separation. These methods include dye sensitization [5,6], metal doping [7,8], non-metal doping [9–12], composites with other semiconductors [13,14] and surface metallization [15–21]. Although dye sensitization and surface metallization of TiO_2 induced visible light absorption in TiO_2, their use

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