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A Review on the Synthesis Methods for Producing Nanostructured Black TiO_2

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Structured Abstract

Background: Advanced oxidation process (AOP) employing nanostructured TiO_2 is extensively used in environmental remediation because of its photosensitivity, non-toxicity, long-term stability, and low cost. However, nanostructured TiO_2 suffers from quick charge recombination and poor quantum efficiency. By introducing defects and generating Ti^{3+}, black TiO_2 can be produced. Black TiO_2's crystal structure, morphology, and optical characteristics are affected by its synthesis method, which affects its photocatalytic activity.

Methods: Characterized by its black appearance, black TiO_2 exhibits enhanced charge separation and photocatalytic activity compared to conventional TiO_2. Various characterization methods such as X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), and UV-Vis spectroscopy are employed. XRD reveals the crystal phase, while XPS provides insight into its chemical states. UV-Vis spectroscopy aids in understanding its optical absorption behavior. Understanding these properties and characterization methods can pave the way for harnessing the full potential of black TiO_2 in environmental and energy-related applications.

Results: Various synthesis methods have been explored to produce black TiO_2, including metal reduction, CaH_2 reduction, hydrogenation, and electrochemical reduction. In the metal reduction approach, metal precursors like magnesium or aluminium are used to reduce TiO_2, leading to defect formation and the creation of Ti^{3+} states responsible for its black appearance. The CaH_2 reduction method involves the reaction of CaH_2 with TiO_2 at 300-500 ºC to produce black TiO_2. Hydrogenation utilizes H_2 gas at 350 ºC to introduce defects. In electrochemical reduction technique, an applied voltage facilitates the reduction process in Na_2SO_4 solution. Each method influences the final properties of black TiO_2, affecting its crystal structure, optical properties (a reduction in bandgap from 3.2 to 2.8), and photocatalytic performance. Black TiO_2 outperforms white TiO_2 in dye removal, decolorization, and hydrogen generation

Conclusion: The different synthesis approaches have demonstrated their ability to generate black TiO_2 with unique properties compared to traditional TiO_2. A comprehensive understanding of these synthesis routes is crucial in designing novel materials for various applications.

Keywords: Black titanium dioxide, reduction, synthesis, defect, morphology

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