



## Heterojunction p-n type $\alpha\text{-Fe}_2\text{O}_3/\text{CeO}_2$ composite for photocatalytic dye degradation

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### ABSTRACT

Composite p-n type heterojunction photocatalysis offers an environmentally friendly and energy-efficient solution for wastewater treatment, leveraging visible light to degrade pollutants effectively. Herein, firstly  $\text{CeO}_2$  and  $\text{Fe}_2\text{O}_3$  were synthesized using chemical reaction methods, followed by the preparation of a p-n type  $\alpha\text{-Fe}_2\text{O}_3/\text{CeO}_2$  composite catalyst via ball milling and calcination at 500 °C. The synthesized composite was characterized using XRD, FTIR, SEM, Raman spectroscopy, PL and UV-visible spectroscopy to investigate their structural and optical properties. The successful integration of  $\text{CeO}_2$  and  $\text{Fe}_2\text{O}_3$  into the composite was confirmed by the combined features in XRD and Raman analyses, as well as characteristic FTIR peaks at 1143  $\text{cm}^{-1}$  and 1084  $\text{cm}^{-1}$ , corresponding to Ce–O–Ce and Fe–O–Fe bridging vibrations. SEM analysis revealed roughly spherical nanoparticles with an average size of 357 nm. UV-visible spectroscopy measurements indicated a reduced band gap of 1.15 eV for the composite, enhancing its visible light absorption. The formation of a stable p-n heterojunction between  $\text{CeO}_2$  and  $\text{Fe}_2\text{O}_3$  improved charge separation and photocatalytic efficiency. The photocatalytic activity of the  $\alpha\text{-Fe}_2\text{O}_3/\text{CeO}_2$  composite was evaluated for the degradation of methylene green dye under visible light irradiation, achieving a maximum degradation efficiency of 95.45 % at an optimal pH of 6 and a catalyst mass of 0.15 g. The relatively low PL intensity observed at 636 nm in the  $\alpha\text{-Fe}_2\text{O}_3/\text{CeO}_2$  nanocomposite suggests that the formation of the heterojunction between  $\alpha\text{-Fe}_2\text{O}_3$  and  $\text{CeO}_2$  facilitates efficient charge carrier separation. This study demonstrates that the  $\alpha\text{-Fe}_2\text{O}_3/\text{CeO}_2$  composite is an effective and stable photocatalyst, with potential applications in environmental remediation, particularly in the treatment of dye-contaminated wastewater.

### 1. Introduction

Photocatalysts play a crucial role in addressing global environmental and energy challenges. These materials harness solar energy to drive chemical reactions, offering a sustainable approach to environmental remediation and renewable energy production [1]. One of the most pressing environmental issues today is pollution, which arises from industrial and domestic activities, leading to the contamination of water bodies, air, and soil. Among these, organic pollutants, including dyes, pesticides, and pharmaceutical residues, are particularly problematic due to their toxicity, persistence, and resistance to conventional

treatment methods [2]. Dye pollutants, such as methylene green, methylene blue, and rhodamine B, are widely used in textile, paper, and cosmetic industries, where they are discharged into water bodies without adequate treatment. These dyes not only degrade water quality but also pose severe ecological and health risks due to their carcinogenic and mutagenic properties. The removal of these pollutants is essential for ensuring environmental sustainability and public health protection [3]. Traditional wastewater treatment methods, including chemical precipitation, adsorption, and biological degradation, often fail to completely eliminate organic contaminants or require high operational costs. As a result, photocatalytic degradation has emerged as a

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