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# Optimization of α-$Fe_2O_3$@$Fe_3O_4$ Incorporated N-$TiO_2$ as Super Effective Photocatalysts Under Visible Light Irradiation

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## Graphical abstract

## Highlights

The α-$Fe_2O_3$/$Fe_3O_4$ doped n-$TiO_2$ was synthesized via deposition-self assembly technique.

The photocatalyst 1% α-$Fe_2O_3$/$Fe_3O_4$/n-$TiO_2$ show a remarkable performance while MB degradation.

The strong interaction between α-$Fe_2O_3$/$Fe_3O_4$ and n-$TiO_2$ plays an important role.

It exhibits a unique textural, optical and charge transfer properties.

## Abstract

Well dispersed α-$Fe_2O_3$@$Fe_3O_4$ nanoparticles (7 nm) supported on mesoporous nitrogen doped titanium dioxide (N-$TiO_2$) are synthesized by deposition self-assembly route and their performances as photocatalysts toward methylene blue (MB) degradation are evaluated. The results illustrate that the spherical yolk-shell structure of α-$Fe_2O_3$@$Fe_3O_4$@N-$TiO_2$ at the loading of 1%; of excellent $S_{BET}$ (187 $m^2/g$) and pore volume (0.50 $cm^3/g$), achieved high photocatalytic performance for the MB degradation (20 ppm, λ>420 nm, lamp power= 160 W) under visible light illumination (k= 0.059 $min^{-1}$). The influence of the interface formation between α-$Fe_2O_3$@$Fe_3O_4$ and n-$TiO_2$ affects severely the charges separation efficiency and enhances the electron transfer to keep on the existence of $Fe^{3+}$/$Fe^{2+}$ moieties; those take significant role in the reaction mechanism. The existence of the latter junction is affirmed via XRD, TEM-SAED, Raman and FTIR techniques whereas, the photogenerated charges, their separation together with their transport and recombination rates are depicted via photoluminescence, electrical conductivity, incident photon to current efficiency (IPCE), cyclic voltammetry (CV) and impedance (EIS) measurements. The catalyst loading, zero point charge, pH variation, total organic carbon (TOC%) and the effect of lamps power are thoroughly investigated. The 1%α-$Fe_2O_3$@$Fe_3O_4$@N-$TiO_2$ photocatalyst also indicated high activity as a Fenton-like reagent accomplishing the MB degradation (100% removal) in 35 min with a rate of 0.07 $min^{-1}$ at $H_2O_2$ concentration of 0.4 mM. The obtained results demonstrate that the heterojunction nanoscaled materials possess superior visible-light driven photocatalytic activity with appreciable recyclability and promising utilization as a supercapcitor (426 F $g^{-1}$ at scan rate of 5 mV $s^{-1}$) device.