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Solution-combustion synthesis of anion (iodine) doped TiO_2 nanoparticles for photocatalytic degradation of Direct Blue 199 dye and regeneration of used photocatalyst

Sudhakar Saroj[a], Laxman Singh[b], Satya Vir Singh[a,*]

[a] Department of Chemical Engineering, Indian Institute of Technology (BHU), Varanasi, U.P. 221005, India
[b] Department of Chemistry, R.R.S. College (Patliputra University), Mokama, Patna, Bihar 803302, India

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Citric acid assisted undoped and I doped TiO_2, $Ti_{1-x}I_xO_2$ (x = 0.00, 0.01, 0.03, 0.05, 0.07 and 0.09) have been synthesized successfully by solution-combustion technique. The characterization of synthesized photocatalysts was done using different characterization techniques such as XRD, DRS, FT-IR, XPS, TEM, and EDX. The XRD diffraction patterns revealed that synthesized photocatalysts have only the anatase phase of TiO_2. The DRS analysis indicates that with increasing the doping concentration of I in TiO_2, a continuous shifting in absorbance was observed towards the visible light region. The FT-IR spectra determine the various functional groups which are present in the synthesized photocatalysts. The XPS spectra confirm the existence of all expected elements (Ti, O, and I) in the synthesized photocatalysts and determine their binding energies and chemical state. The shape and crystallite size of undoped and I doped TiO_2 ($Ti_{0.97}I_{0.03}O_2$) photocatalysts were determined by TEM analysis. The chemical composition of the synthesized photocatalysts was examined by EDX analysis. Simulated solutions of dye (Direct Blue 199) of different concentrations were photodegraded by the synthesized photocatalysts to determine photocatalytic activities of the synthesized photocatalysts in the UV photochemical reactor (UV-PCR) and open pan reactor (OPR). The $Ti_{0.97}I_{0.03}O_2$ photocatalyst shows the highest photocatalytic activity among all the synthesized undoped, and I doped TiO_2 photocatalysts. The synthesized photocatalyst ($Ti_{0.97}I_{0.03}O_2$) was also found better than commercially available Aeroxide P-25 photocatalyst in respect of the dye photodegradation. The used I doped TiO_2 photocatalyst ($Ti_{0.97}I_{0.03}O_2$) was regenerated five times and investigated its photocatalytic activity again.

1. Introduction

The material TiO_2 has received great attention in recent years due to its strong redox ability, high photostability, non-toxicity, biocompatibility, and low-cost [1–3]. TiO_2 as a photocatalyst has a wide field of application in air and wastewater purification [4], photovoltaic cells [5], Li-ion batteries [6], electrochromic devices [7], solar cells [8] and gas sensing [9], etc. Nowadays, TiO_2 is frequently used as a photocatalyst in advance oxidation processes (AOPs). The photocatalytic process requires the photo-excitation, transfer of charge carriers, and bulk diffusion that depend on the electronic and surface structure of the photocatalyst. Unfortunately, TiO_2 requires only UV light to generate photo-electron for photocatalysis due to its wide bandgap energy (3.18 eV) which affect its photocatalytic efficiency because solar radiation only has 4–5 % UV rays [10]. Another factor which is also responsible for lower photocatalytic efficiency of TiO_2 is higher recombination rate of photo-generated e^-/h^+ pair. To solve the above mentioned problems, many researchers have tried to modify the characteristics of TiO_2 by the doping of metals (Fe [11], Ag [12], Mo [13], Au [14], Cu [15] and non-metal C [16–18], N [19–21], S [22], I [23–26]. Moreover, modification of TiO_2 with metals doping gives better result in charge separation but show the limited contribution to extending the photo-response from UV to visible light region [27]. On the other hand, the doping or co-doping of TiO_2 with non-metals shows

List of abbreviations: DB-199, Direct Blue 199; DDW, Double Distilled Water; UV, Ultraviolet; UV–vis, Ultraviolet-Visible; IR, Infrared; UV-PCR, Ultra Violet-Photochemical Reactor; OPR, Open Pan Reactor; GT, Glass Tube; QT, Quartz Tube; XRD, X-Ray Diffraction; DRS, Diffuse Reflectance Spectroscopy; FT-IR, Fourier Transform Infrared; XPS, X-Ray Photoelectron Spectroscopy; EDX, Energy Dispersive X-Ray Spectroscopy; TEM, Transmission Electron Microscopy; SAED, Selected Area Electron Diffraction; DSR-1, Direct Solar Radiation; DSR-2, Diffuse Solar Radiation; AT, Air temperature; AS, Wind speed; WD, Wind direction

* Corresponding author.
E-mail addresses: satyavirsingh59@rediffmail.com, svsinghche@iitbhu.ac.in (S.V. Singh).

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