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Effect of carbon and nitrogen co-doping on characteristics and sonocatalytic activity of TiO_2 nanotubes catalyst for degradation of Rhodamine B in water

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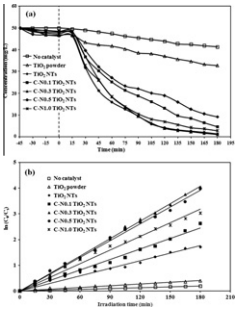
HIGHLIGHTS

- Successful synthesis of carbon and nitrogen co-doped TiO_2 NTs.
- Influences of doping on characteristics and activity of TiO_2 NTs.
- TEM, XRD, FTIR, XPS, UV–Vis DRS and surface analyses.
- Elucidation of sonocatalytic behaviors based on catalyst's properties.
- TiO_2 NTs with N:Ti ratio of 0.3 enhanced activity by 130%.

GRAPHICAL ABSTRACT



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ABSTRACT

Carbon and nitrogen co-doped titanium dioxide nanotubes (C—N co-doped TiO_2 NTs) catalysts were successfully synthesized using a hydrothermal method at N:Ti molar ratios between 0.1 and 1.0. Transmission electron microscope (TEM), X-ray diffraction (XRD), Fourier transform infrared (FTIR), X-ray photoelectron spectroscope (XPS), UV–Vis diffuse reflectance spectroscope (UV–Vis DRS) and surface area analyzer were used to characterize the synthesized catalysts. Urea doping at N:Ti = 0.3 led to the highest sonocatalytic activity with an apparent-first-order rate constant of 0.0226 min^{-1} as compared to 0.0098 min^{-1} for the un-doped TiO_2 NTs. The high performance was associated with the synergistic effects between the doped C and N atoms, higher surface area and lower band gap energy. It was also ascribed to the creation of surface oxygen vacancies due to the formation of Ti^{3+} species and better crystallinity of anatase phase as compared to the un-doped TiO_2 NTs. Most of the nitrogen atoms were bonded to oxygen atoms in the interstitial sites (Ti—O—N and Ti—N—O), but only minority of them could substitute the sites of oxygen atoms (N—Ti—O). C atoms evidently presented in the form of Ti—C and a complex carbonate species on the catalyst surface.

1. Introduction

In recent years, the application of ultrasound technology as an advanced oxidation process to degrade organic pollutant in wastewater has received much attention [1–3]. The chemical effect of ultrasonic arises from acoustic cavitation, namely the formation, growth and implosive collapse of bubbles in a liquid. The collapse of bubbles generates localized hot spot with transient temperature of about 5000 K and a pressure of about 1000 atm [3]. Under such extreme conditions, the dissolved oxygen and water molecules can undergo direct thermal dissociation to produce highly reactive radical species such as hydroxyl (·OH), hydrogen (·H) and oxygen (·O) [1], which can attack and oxidize organic pollutants in water.

TiO_2 is one of the preferred catalysts in environmental application owing to its properties such as non-toxic, inexpensive and possesses high chemical stability, hydrophilicity and catalytic activity without causing the generation of secondary pollutions [4]. In a previous work, we reported that TiO_2 NTs showed a high degradation efficiency under ultrasonic irradiation [5]. However,

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