Preparation, characterization and enhanced photocatalytic activity of Ni$^{2+}$ doped titania under solar light

L. Gomathi Devi*, Nagaraju Kottam, S. Girish Kumar, K. Eraiah Rajashekar
Department of Post Graduate Studies in Chemistry, Central College City Campus, Bangalore University, Bangalore 560001, INDIA

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Abstract: Anatase TiO$_2$ was prepared by sol-gel method through the hydrolysis of TiCl$_4$. Ni$^{2+}$ was doped into the TiO$_2$ matrix in the concentration range of 0.02 to 0.1 at.% and characterized by various analytical techniques. Powder X-ray diffraction revealed only anatase phase for all the samples, while diffuse reflectance spectral studies indicated a red shift in the band gap absorption to the visible region. The photocatalytic activities of these photocatalysts were probed for the degradation of methyl orange under natural solar light. The photocatalyst with optimum doping of 0.08 at.% Ni$^{2+}$, showed enhanced activity, which is attributed to: (i) effective separation of charge carrier trapping - recombination dynamics is investigated.

Keywords: Ni$^{2+}$ doping • Crystallite size • Solar light photocatalysis • Charge carrier trapping-recombination dynamics

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1. Introduction

Wastewater from dyeing processes contains a wide variety of water soluble chemical products that are unsuitable to treat by traditional methods like filtration, carbon adsorption and hypochlorite oxidation. Most of the dyes used in textile industry are highly stable, soluble in water, resistant to chemical oxidation and will have low bio-degradability. Over 100 000 different types of dyes are commercially available [1] and 700 000 tons are produced annually over the world [2]. Nearly 50% of these dyes belong to the azo-category. Azo dyes resist biodegradation by aerobic treatment. However, they can be decolorized by anaerobic treatment leads to the reduction of azo bonds to amines, which are much more carcinogenic than the parent molecule [3-4]. Advanced oxidation processes (AOPs) is widely used, which is based on in situ generation of hydroxyl radicals, a strong oxidizing agent and can oxidize almost all the organic pollutants and mineralize them to CO$_2$, H$_2$O and simple mineral acids. Among various AOPs, TiO$_2$ based photocatalysis is promising technique and extensively used for the degradation of these recalcitrant organic contaminants [5-10]. However, the large band gap of TiO$_2$ (~3.2eV) limits its efficiency under solar light. Further, the high degree of recombination between photogenerated charge carriers limits its overall photocatalytic efficiency. Doping with various transition metal ions is one of the most effective approaches for synthesizing visible light active photocatalysts [11-16]. It has been considered that the metal ions incorporated into TiO$_2$ crystal lattice can modify the electronic properties of TiO$_2$ and extending its light absorption ability to the visible light region. In this regard, the present research focuses on the doping of Ni$^{2+}$ ion into the TiO$_2$ crystal lattice (Ni$^{2+}$-TiO$_2$) and its photocatalytic activity was investigated by the degradation of methyl orange (MO) an azo dye under solar light. The photocatalytic mechanisms for Ni$^{2+}$-TiO$_2$ under solar light were discussed in detail.

* E-mail: gomatidevi_naik@yahoo.co.in