Development of visible-light active $TiO_{2-x}C_x$ photocatalysts

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Introduction

Considerable interest has been devoted in recent years to develop materials, which can provide sufficient photosensitivity in the visible light spectral region. Titanium dioxide (TiO_2) is well known[1] as an efficient photocatalyst. However, it is activated only under UV light irradiation due to its relatively large energy band gap (3.23 eV for anatase and 3.06 eV for rutile). The modification of TiO_2 for absorbing longer wavelength visible light is one of the current topics in the field of photocatalysis[2,3]. One approach for achieving this goal is to substitute metals like Fe, Cr, or Ni etc., for Ti^{4+} and another to form Ti^{3+} sites by introducing oxygen vacancies in TiO_2. Recently, doping TiO_2 with non metal atoms has received lot of attention. For example Asahi et al.[4], Khan et al.[5], and Sakthivel and Kish reported[6] that doping TiO_2 with nitrogen or carbon can sufficiently shift its optical response to the visible light region. Here we report a simple method to mass produce high surface area carbon doped TiO_2 catalyst, using melamine borate as a complexing agent for titanium tetrachloride. The carbon doped TiO_2 catalyst produced in this manner has been effectively employed to degrade Orange II dye under visible light irradiation.

Experimental section

Preparation of C-doped TiO_2 Nanoparticles

In a typical synthesis, a known amount of $TiCl_4$ was dissolved in distilled water at 0ºC. In parallel, a known amount of melamine borate was dissolved in deionised water under constant stirring at room temperature. To the clear $TiCl_4$ solution, aqueous melamine borate solution was added and stirred continuously for about 30 min. To this mixture, aqueous NH_4OH was added drop wise until the pH of the resulting solution reached 5. The precipitate obtained was allowed to settle overnight before filtering and washing repeatedly with warm water. It is then dried at 110 ºC for 3 hrs. The white material was milled into fine powder and heated in air at different temperatures and time intervals. The resulting powder appeared light to dark yellow in color.

Results and Discussion

The physical properties of the synthesized materials were systematically characterized by using XPS, diffuse reflectance spectroscopy (DRS), incident photon to current conversion efficiency (IPCE), BET surface area and particle size measurements. The shift in the absorption spectral region has been confirmed using both DRS and IPCE measurements. The C1s core levels in the XPS spectra revealed peaks at 286.5 eV and 288.8 eV, apart from the adventitious elemental carbon at 285.0 eV. The doping of carbon into the TiO_2 lattice has been confirmed from the former two peaks. The percentage of carbon in the oxide lattice varied with the sample treatment conditions.

Photocatalytic oxidation of Orange II dye using C-doped TiO_2

Figure 1 shows the photocatalytic oxidation of orange II under visible light radiation. The activity was evaluated under a Xenon Suntest lamp with an optical filter, which cuts the entire wavelength below 410 nm.

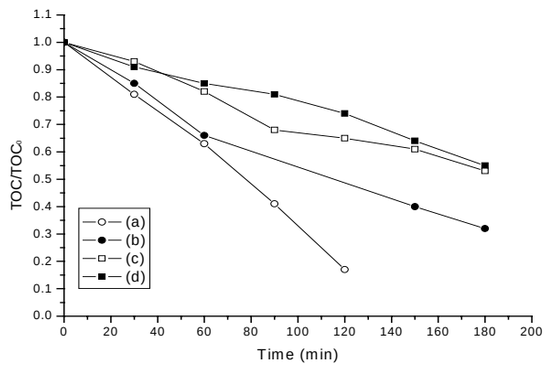

Figure 1 Photocatalytic oxidation of Orange II using $TiO_{2-x}Cx$, a) x=0.0060; b) x=0.0045; c) x=0.0027 and d) x=0 (Degussa P25 commercial TiO_2); wavelength of excitation > 410 nm..

It is evident from Fig. 1 that the carbon doped catalyst exhibited excellent photocatalytic activity for the visible light photodegradation of Orange II, compared to the commercial P25 catalyst. In fact, the catalyst with 0.6% doped carbon degraded more than 80% of the dye within a short reaction time, when compared to Degussa P25. The surface area and the particle size for this particular catalyst were found to be 160 m^2/g and 9.0 nm, respectively. Under the present experimental conditions, boron ion could not be used as a dopant despite starting from melamine borate. Currently we are investigating the possibility of boron doping and its effect on the photocatalytic activity of TiO_2 under visible light[7].

References

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