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Original research article

Effective Photodegradation of CR & MO dyes by morphologically controlled Cerium oxide nanocubes under visible light Illumination

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ABSTRACT

Synthesis of novel CeO_2 nanocubes via simple wet chemical method has described in this manuscript. Since the CeO_2 nanoparticles have been admired for their properties and extensive applications in the recent years, the structural properties and morphology of the obtained materials were investigated in detail. The results indicated that formation of CeO_2 nanocubes and it act as very dynamic photocatalyst in visible region. When applied to the photocatalytic degradation of Congo red (CR) and methyl orange (MO) dyes, the best results were obtained when using this catalyst which is due to the formation of more reactive oxygen species owing to the presence of Ce^{4+}/Ce^{3+}. The photodegradation efficiency of CeO_2 nanocubes was 95% within 100 & 90 min for CR and MO respectively. Furthermore, the catalyst can be easily recovered and reused until fifth cycles without significant loss of activity.

1. Introduction

Rare earth metal oxides, a technically significant group of materials, have been investigated for numerous advanced electronic, magnetic, optical and catalytic properties [1]. Among several metal oxides semiconductor nanoparticle, Cerium oxide (CeO_2) show potential catalytic activity because of its unique properties like UV absorbing ability, non-toxicity, high thermal stability, facile electrical conductivity, specific chemical reactivity, rigidity, the swift and expedient transformation of Ce(III) to Ce(IV) and high refractive index [2–7]. As a result of these unique properties, CeO_2 can be used in many applications such as glass polishing material, gas sensor, UV absorbent, UV blockers, automotive exhaust promoter, as an oxidation catalyst, solid electrolytes, catalyst, anti-oxidant, solar cells, free radical scavenger, photocatalytic behaviour in dye degradation, additives in ceramics and removal organic pollutants from waste water [8–15]. CeO_2 is one of the most important semiconductor with a band gap of 3.1 eV [15–17] and exhibit excellent activity to degrade dyes.

The structure and morphologies of CeO_2 exhibited distinctive physico-chemical properties, so it gives the special importance on the fabrication [18–20]. It has been synthesised effectively in various morphologies, such as nano rods [21,22], nano wires [23,24], nano particles [25], nano tubes [26–28], nano cubes [29], nanocrystals [30], nanobelts [31,32], nanobundles [33], and nanoflakes [34]. As mentioned earlier, nano structured CeO_2 possess unique properties and novel functionali-

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ties depend upon their composites and morphologies. Several methods were employed to synthesise these nanostructures, among them wet chemical method is an efficient method to synthesise CeO_2 nanocubes at low temperature and as well as cost effective.

In this paper, a wet chemical synthesis method has been adopted to prepare CeO_2 nanocubes and it was characterised in detail, moreover synthesized CeO_2 nanocubes shows excellent photocatalytic activity to degrade dyes.

2. Experimental

2.1. Materials

Ceric ammonium nitrate, formic acid, acetic acid, glucose, sodium hydroxide, methyl orange and Congo red were purchased from sigma Aldrich and used as such without any further purification.

2.2. Synthesis of cerium oxide nanocubes

Cerium oxide (CeO_2) nanocubes were synthesised by simple wet chemical method. 0.1 M of Ceric ammonium nitrate was prepared in 100 mL distilled water and 2 g of glucose in 10 mL water was added to it under vigorous stirring for 15 min. 1 M of sodium hydroxide solution was added to the above reaction mixture until the brown colour precipitate of cerium hydroxide was obtained. This brown precipitate was washed with water and alcohol for several times to remove impurities. Then it was dried in oven at 80 °C for 12 h and the resulted product was calcinated at 550 °C in muffle furnace for 2 h.

2.3. Photocatalytic test

The photocatalytic efficiency of the CeO_2 nanocubes was evaluated towards the photocatalytic degradation of Congo red (CR) and methyl orange (MO) dye solution under visible light irradiation using 300 w tungsten lamp in self-made Haber reactor. The photodegradation of the dye were monitored by Shimadzu UV–vis spectrophotometer. Prior to irradiation, the dye solution was stirred about 30 min under dark condition to attain equilibrium. The dye solution was collected about 5 mL at regular intervals during the irradiation and dye solutions were separated from the photocatalyst before the analysis. The degradation was monitored by measuring the absorbance using UV–vis spectrophotometer.

3. Results and discussion

3.1. Characterisation of the samples

Fig. 1 shows the XRD pattern of CeO_2 nanocubes. It can be found that all the diffraction peaks of the CeO_2 can be assigned to face-centred cubic face (JCPDS 89–8436). The characteristic 2θ region of 28.51, 47.51 and 56.58 corresponds to the reflection planes (111), (220) and (311) respectively. The sharp and intense diffraction peak indicates that the sample was good crystalline in nature. The average size of CeO_2 nanocubes calculated by Sherrer' formula for the strongest peak (111) is about 36.35 nm.

Fig. 2 shows FT-IR spectra of CeO_2 nanocubes were recorded in the range of 400–4000 cm^{-1}. The appearance of sharp band at 456 cm^{-1} confirms the formation CeO_2 nanocubes which correspond to Ce-O stretching vibrations. Additionally, the broad peak at 3425 cm^{-1} possibly corresponds to the O—H group during synthesis.

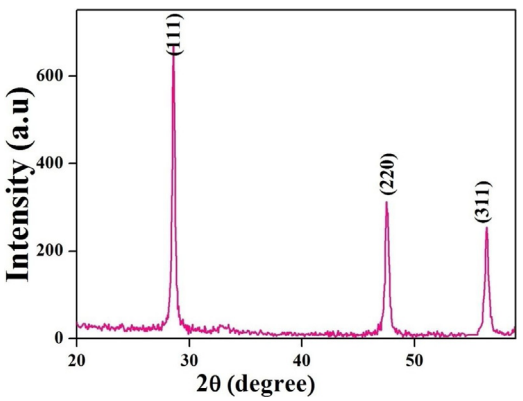

Fig. 1. XRD pattern of CeO_2 nanocubes.