Journal of Environmental Chemical Engineering 4 (2016) 1148–1155

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Carbon quantum dots decorated N-doped ZnO: Synthesis and enhanced photocatalytic activity on UV, visible and daylight sources with suppressed photocorrosion

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ARTICLE INFO

Article history:
Received 30 April 2015
Accepted 27 June 2015
Available online 2 July 2015

Keywords:
Carbon quantum dots
Zinc oxide
Malachite green
Photocatalyst
Photocorrosion

ABSTRACT

Carbon quantum dots decorated N-doped ZnO (CQD/N-ZnO) composites were prepared by a simple one step method. The existence of CQD and ZnO phases in the CQD/N-ZnO composite was confirmed by XRD, Raman, XPS and HRTEM techniques. The CQD/N-ZnO composite exhibited an enhanced photocatalytic performance on aqueous malachite green dye, irrespective to the light sources of UV, visible and daylight. The dye degradation of ~38% and 99% was noticed for N-doped ZnO and CQD/N-ZnO photocatalyst, respectively after 15 min of daylight irradiation and it required just 30 min to degrade an entire dye. Repeated photocatalytic experiment was carried out to investigate the reusing capability of CQD/N-ZnO photocatalyst and it was found that the suppressed photocorrosion offered by CQDs coverage on the ZnO crystals.

Introduction

The progress towards the development of efficient photocatalyst is a critical issue for an environmental remediation due to major organic contaminants originated from the textile and food industries. The malachite green (MG) dye is largely used to color in silk, wool and leather industries and it is extremely toxic to fish [1,2]. The MG dye is easily entering into the environment from municipal wastewater treatment plants and it is suspected of being capable of causing gene damage and causing cancer [2]. Now a days, it becomes one of the challenging tasks to eradicate the MG dye in the wastewater. Hence, various inorganic semiconductors are recommended to use as a photocatalyst to decrease the environmental impacts due to its efficiency and broad applicability. Amongst, zinc oxide (ZnO) is blooming nowadays as of being its high catalytic activity, low cost, and environmental friendliness over other photocatalysts [3]. However, a quick recombination and the narrow absorption band of the ZnO photocatalyst are the major concerns that affect their photocatalytic efficiency. To overwhelm these issues, a suitable modification is obligatory for developing new types of ZnO nanostructures.

Carbon quantum dots (CQDs) have received greater attention because of their advantages in non-toxic, photostability, low cost, heavy metal-free and eco-friendly over traditional toxic heavy-metals based quantum dots creating serious health and environmental issues [4]. There are many reports related to carbon related materials were found in the literature [5–7]. However, it was rare work involved to prepare ZnO photocatalyst covered with carbon dots [3]. The usage of CQDs are being acknowledged due to the characteristic photo-induced electron transfer [7] and up-conversion of photoluminescence properties [3]. Hence, a new type of photocatalyst, CQD decorated N-doped ZnO (CQD/N-ZnO) was prepared for higher photocatalytic performance due to the combinational effect of N-doping [8] together with the carbon nanoparticle [5–13]. The combination of N-doped ZnO and CQDs seems to be an ideal tactic for endorsing the improvement in charge separation by hindering charge recombination to enhance the photocatalytic efficiency and anti-photocorrosion.

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http://dx.doi.org/10.1016/j.jece.2015.06.029
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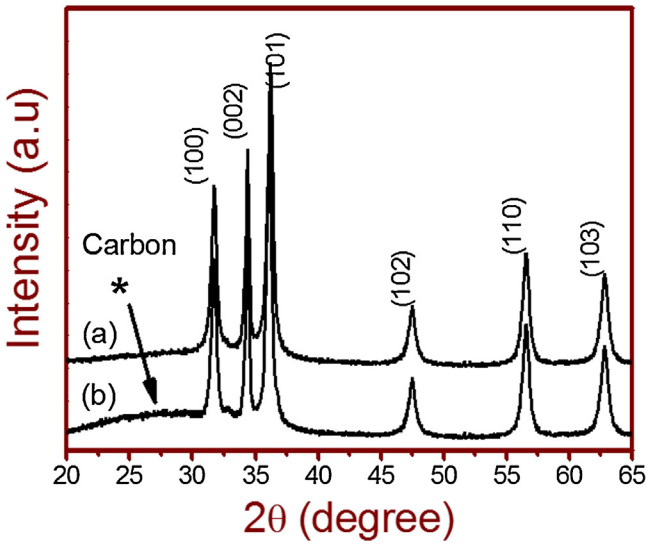

Fig. 1. XRD patterns of (a) N-doped ZnO and (b) CQD/N-ZnO composites.

In addition, the new type of photocatalysts should enable us to use under different light sources of UV, visible and daylight. Herein, we report an easy methodology for preparing N-doped ZnO, CQDs, and CQD/N-ZnO composites, exhibiting an enhanced photocatalytic activity on degrading MG dye under UV, visible and daylight irradiation.

Experimental details

Preparation of N-ZnO photocatalyst

All the chemicals were of analytical grade and used as received without further purification. Typically for synthesizing N-doped ZnO, about 1.25 g of zinc acetate dihydrate was dissolved completely in 125 ml of double distilled water. The aqueous ammonia solution was added slowly to keep the solution pH to be around 10. The resultant clear solution was filtered and it was further mixed with 50 ml of double distilled water and kept at 60 °C on a constant temperature bath for 26 h. White crystals of N-ZnO photocatalyst were collected, washed with distilled water and ethanol several times and dried [14].

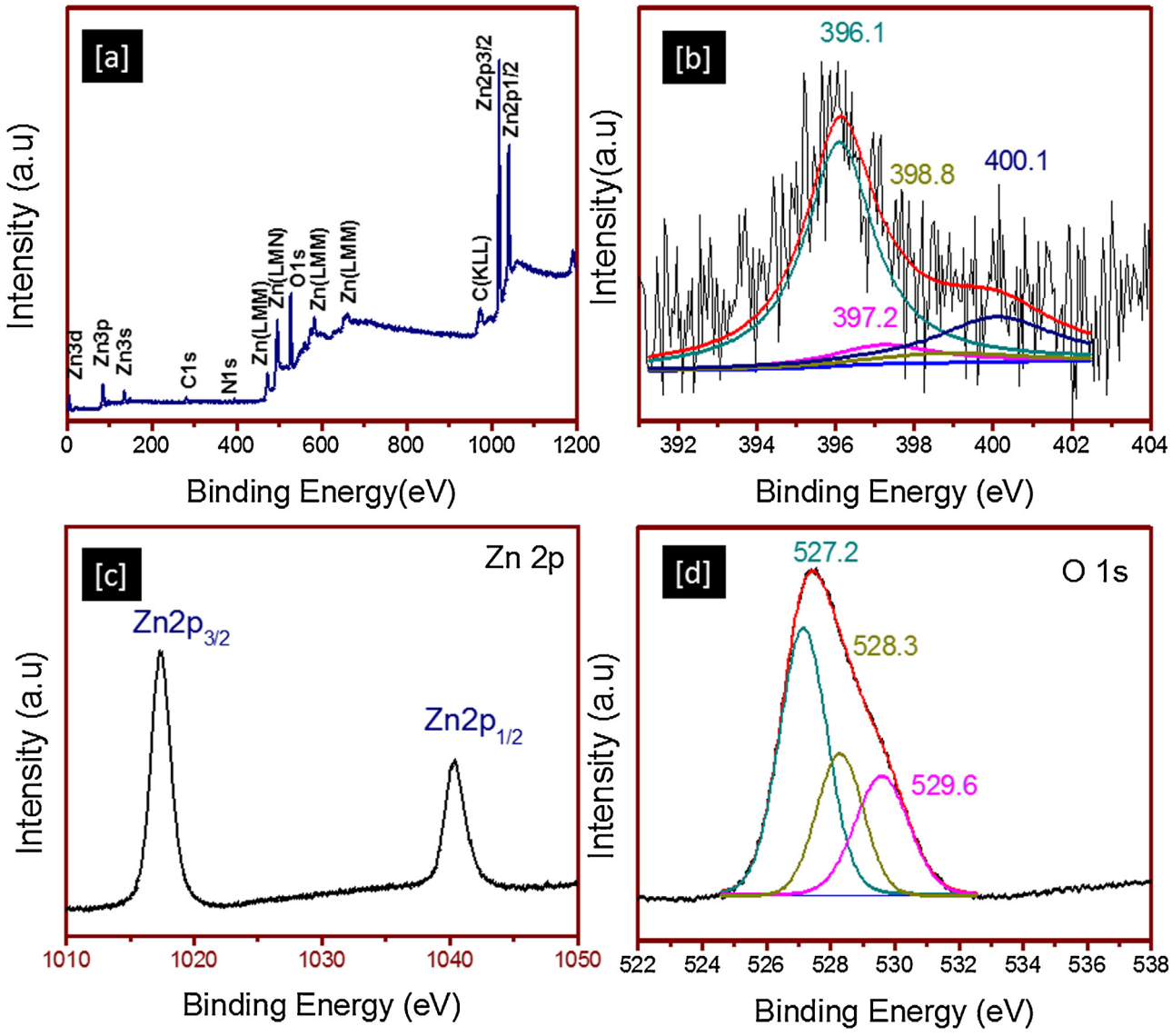

Fig. 2. The XPS spectra of CQD/N-ZnO composites with (a) full survey scan and high resolution core (b) N 1s, (c) Zn 2p, and (d) O 1s scans.