

Electrochemical synthesis, photodegradation and antibacterial properties of PEG capped zinc oxide nanoparticles

Ajay Jose^a, K.R. Sunaja Devi^{a,*}, Dephan Pinheiro^a, S. Lakshmi Narayana^b

^a Department of Chemistry, Christ University, Hosur Road, Bengaluru 560029, Karnataka, India

^b Department of LifeScience, Christ University, Bengaluru 560074, Karnataka, India

ARTICLE INFO

Keywords:

ZnO
PEG capped ZnO
Electrochemical synthesis
Photodegradation
Antibacterial studies

ABSTRACT

The effect of surfactant and dopant on the properties of zinc oxide nanoparticles were studied by preparing polyethylene glycol (PEG) capped ZnO and tungsten doped PEG capped ZnO nanoparticles via the electrochemical method. These nanoparticles were characterized using X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Ultraviolet Diffuse Reflection Spectroscopy (UV-DRS), Scanning Electron Microscopy (SEM) and Electron Dispersive Analysis of X Rays (EDAX). The photocatalytic degradation of malachite green dye using these nanoparticles was studied under visible light. The effects of various reaction parameters like dye concentration, catalyst concentration, pH and time were studied to optimize the photodegradation reaction. Reusability of these nanoparticles was studied and no significant change was observed in the degradation efficiency of PEG capped ZnO till the fourth cycle, while there was a gradual decrease in the degradation efficiency of tungsten doped PEG capped ZnO. Langmuir-Hinshelwood kinetic model well describes the photodegradation capacity and the degradation of malachite green follows pseudo-first order kinetics. Photocatalytic studies reveal that PEG capping increases the degradation properties of ZnO while tungsten doping decreases the extent of PEG capping and has a detrimental effect on the degradation properties of ZnO. The prepared nanoparticles exhibit significant antibacterial properties against gram-positive *Bacillus cereus* and gram-negative *Escherichia coli* bacterial strains by agar well diffusion method.

1. Introduction

In recent years, nanotechnology has gained considerable attention because of its applications in biomedicine, electronics, agricultural field and industries [1]. It has been the constant endeavor of scientists to increase the efficiency and expand the application of nanoparticles to different fields by modifying their chemical and physical properties. Among various metal oxide nanoparticles, zinc oxide (ZnO) is an important material used in short wavelength optoelectronic devices, room temperature UV lasers, and as a distinctive n-type semiconductor. ZnO can also act as a photocatalyst in short wavelength region [2]. It can promote electrons from valence band to conduction band via photoirradiation. An ideal photocatalyst is one which has band gap energy comparable to visible light, can absorb maximum quanta of light, photostable and cheap. ZnO is an environment-friendly semiconductor photocatalyst with band gap energy of 3.37 eV. Similarities in band gap between ZnO and TiO₂ has attracted researchers to replace the comparatively expensive photocatalyst TiO₂ with ZnO. But it has been reported that ZnO has very low activity under visible light compared to

TiO₂ and suffers from photo instability in aqueous solutions [3]. Many attempts have been made to improve the properties of ZnO. Recently it was reported that ZnO band gap energy can be engineered by dopant materials [4]. Ananda et al. reported that transition metal ions can be used as dopants in ZnO lattice to enhance its photocatalytic properties [3]. These doped ZnO semiconductor nanoparticles can be used in deactivating harmful microorganisms, solar energy conversions and waste water purification. UV light of wavelength 254 nm expels the oxygen from ZnO lattice sites and enables their participation in the degradation reaction. The visible light radiation (400-800 nm) can only create electron-hole pairs [5].

In order to overcome this limitation, ZnO was doped with suitable transition metal ions. Thus, certain lattice sites in ZnO modifies as Zn-O-M instead of Zn-O-Zn in the wurtzite framework. This leads to the incorporation of new energy levels by lowering band gap and shifting absorbance to longer wavelengths [5]. Residual color due to the dyes in effluents from the related industries is a major environmental challenge and Mo-doped ZnO can serve as a photocatalyst in the degradation of such dyes [3]. Various approaches like sol-gel, microemulsion,

* Corresponding author.

E-mail address: SUNAJADEVI.KR@CHRISTUNIVERSITY.IN (K.R. Sunaja Devi).

<https://doi.org/10.1016/j.jphotobiol.2018.07.022>

Received 9 March 2018; Received in revised form 7 June 2018; Accepted 24 July 2018

Available online 02 August 2018

1011-1344/ © 2018 Elsevier B.V. All rights reserved.

ultrasonic, microwave assisted techniques, chemical vapour deposition, solvothermal [6] hydrothermal [7] microemulsion [8] organometallic precursor [9] electrodeposition [10] sonochemical and microwave assisted [11], chemical vapour deposition [12] and spray pyrolysis [13] techniques have been developed for the preparation of ZnO nanoparticles.

The ZnO nanoparticles in 10% H₂O₂ is found to be an effective photocatalyst for the decomposition of Rhodamine B dye under the solar light/visible-light irradiation [14]. It was reported that the ZnO NPs showed appreciable antibacterial activity against *E.coli* and *S.aureus* as compared to the standard pharmaceutical formulation. Almost complete degradation of methylene blue dye was achieved with these ZnO NPs [15]. The well-constructed ZnO hybrid composite was utilized as a photocatalyst for the degradation of MB and exhibits an efficiency of 95% in a neutral medium under UV-light irradiation for 60 min [16]. CA-PS-ZnO appears to be a potential membrane for the degradation of dyes [17]. Heterogeneous ZnO nanostructures were found to show phenomenal performance than ZnO nanoparticles. Pt-decorated ZnO nanorods supported on g-C₃N₄ nano sheets were reported to be remarkable gas sensors for ethanol and NO₂ [18]. g-C₃N₄/ZnO nanosheets coated on the surface of fluorine doped tin oxide showed upgrade insensitivity and high linearity range towards H₂O₂ [19]. Heterostructural nanofibres like ZnO-SnO₂ showed enhanced photocatalytic activity towards rhodamine B dye [20]. All these studies showed that ZnO nanoparticles, when combined with other semiconductors, achieved distinctive properties than pure ZnO nanoparticles.

It has also been reported that PEG capped ZnO nanoparticles can enhance the properties of pure ZnO nanoparticles [4, 21, 22]. The repulsive electrostatic forces formed between the polymeric chains of PEG prevent the ZnO nanoparticles from adhering together and aggregating. Use of surfactants during the synthesis of ZnO nanoparticles can give divergent morphologies and such surface modification can scale up the extent to which quanta of light is absorbed [5]. Low molecular weight polymers exhibit high adsorption rate. Further, studies showed that by adsorbing PEG and PVA, a relatively large electrostatic repulsive force between nanoparticles occurs and size of aggregated nanoparticles decreases [21]. PEG makes ZnO less water soluble, exhibit excellent antioxidant properties and is used widely in various biomedical applications [23]. PEG 400 is known to be less toxic substance than its high molecular weight counterparts as it is used in eye drops. The presence of PEG restricts the concentration of oxygen vacancies on the surface [22]. In most of the reported procedures, the capping has been done by the traditional methods which come with limitations.

The present study focuses on the electrochemical synthesis of PEG capped ZnO (PZn) and tungsten (W) doped PEG capped ZnO (W-PZn) nanoparticles. Further, we have made attempts to compare the effect of capping and doping tungsten on ZnO. Photocatalytic efficacy of the prepared nanoparticles on the photodegradation of Malachite green (MG) dye, a common industrial dye and toxic water pollutant has also been studied and compared with that of commercial ZnO. The synthesized ZnO nanoparticles were evaluated for its antibacterial properties against gram-positive *Bacillus cereus* and gram-negative *Escherichia coli* bacterial strains by agar well diffusion method.

2. Experimental

2.1. Materials

Zn electrodes were used for the electrochemical synthesis of ZnO nanoparticles. Sodium bicarbonate and sodium tungstate were purchased from Nice Chemicals, Cochin. Commercial ZnO from Research-lab fine chem. Industries, Mumbai, Malachite green from Thomas Baker, Mumbai and PEG 400 from Loba Chemie, Mumbai were used in this work.

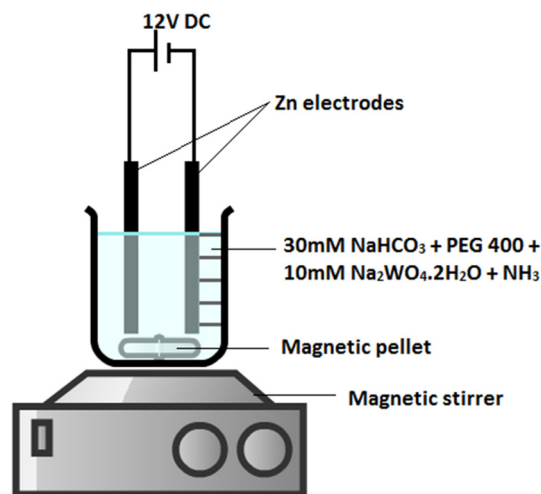
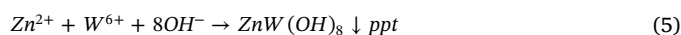
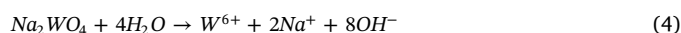
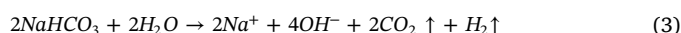


Fig. 1. Experimental setup for electrochemical synthesis of W-PZn nanoparticles.

2.2. Preparation of PZn and W-PZn Nanoparticles

PEG capped ZnO nanoparticles were synthesized in aqueous medium under pH 10 at room temperature. The electrolyte solution consists of 30 mM NaHCO₃ dissolved in 400 mL deionized water. 10 mL ammonia buffer of pH 10 was added followed by 10 mL of the surfactant PEG 400.

A pair of Zn electrodes were taken and dipped in 10% HCl for 30 s. They were dried and polished thoroughly using sandpaper. The electrodes were dipped in the electrolyte solution such that both were immersed equally. The solution was stirred during electrolysis using a magnetic stirrer set at 600 rpm. A potential of 12 V and current of 0.5A was supplied for 1 h. The overall experimental setup is shown in Fig. 1. The resultant solution was decanted and dried in hot air oven at 90 °C overnight. The dried powder was ground and calcined at 600 °C for 1 h and designated as PZn. Tungsten doped PEG capped ZnO nanoparticles (W-PZn) were also synthesized under similar conditions with the addition of 10 mM of sodium tungstate into the electrolyte solution. The reaction occurring during the electrolysis can be as follows.



2.3. Structural Characterization of the Prepared Nanoparticles

Crystal structures were analyzed using PANalytical - Empyrean X-Ray diffractometer with Cu K alpha source. The UV-Vis absorption spectra of the samples were measured on a Shimadzu UV1800 UV-Vis spectrophotometer. The surface structures and elemental composition were studied using Scanning Electron Microscopy and Energy Dispersive Analysis (Quanta LV/ESEM). Using Fourier transforms infrared spectrometer (Bruker Alpha-T ATR-FTIR) the stretching frequencies of the functional groups of PZn and W-PZn nanoparticles were studied. UV-Diffuse reflectance spectra of the samples were recorded in

Download English Version:

<https://daneshyari.com/en/article/6493164>

Download Persian Version:

<https://daneshyari.com/article/6493164>

[Daneshyari.com](https://daneshyari.com)