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Synthesis of ZnO Nanoparticles and Its Photocatalytic Application

[1]Nitiya, [2]Deepanshi Agarwal, [3]Prapti Agarwal, and [4]Gandharve Kumar*

Author's Affiliations:
[1-4]Department of Chemistry, Faculty of Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh 244001, India.

***Corresponding Author: Dr. Gandharve Kumar**, Assistant Professor, Department of Chemistry, Faculty of Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh 244001, India.
E-mail: gandharv.tmu@gmail.com

ABSTRACT
ZnO nanoparticles as photocatalyst were synthesized by a simple synthetic route involving hydrothermal method at 150°C, and it is efficiently characterized by number of techniques, such as XRD, FESEM, and UV-vis DRS. UV-vis DRS and showed a reflection edge with corresponding energy at 3.5 eV. The photocatalytic removal activity of the ZnO nanoparticles was tested against the removal of MB dye under natural sunlight irradiation. About 75% degradation of methylene blue is observed in 150 min.
Keywords: ZnO, Photocatalyst, Methylene Blue, Nanoparticles

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INTRODUCTION

Extensive usage of organic dyes in textile and other fabric industries leads to the contamination of water bodies [1]. Many water sources are polluted by residual dyes, which enter directly into the aquatic environment through number of means like dye industries, textile industries, etc. [2]. As a cationic dye methylene blue found its wide application in coloring fabrics. Due to its water-soluble nature, methylene blue is highly stable in an aquatic environment, non-biodegradable, and cancer-causing in nature, which makes it harmful to humans and living species of aquatic ecosystems [3].

However, because of their highly stable nature in water, these extracted dyes are not quickly metabolized, because of which they can randomly pollute groundwater and surface water, causing harmful diseases in animals and humans [4]. To date, number of methods have been used for wastewater remediation, but they have certain drawbacks such as excessive sludge formation, and other harmful byproducts generation. In order to overcome these limitations, semiconductor-based photocatalysts are widely utilized for the photocatalytic removal of various water pollutants [4]. To date, ZnO and TiO_2 nanoparticles are the most widely used nanomaterials for degrading organic dyes, but they require ultraviolet light for photoexcitation as their band gap is large [5-7]. Recently, over the last few decades, tin-based photocatalysts have been utilized as the most promising and new class of photocatalysts for wastewater treatment. The tin-based photocatalyst found applications in various areas such as the production of ammonia from nitrogen, water-splitting, reduction of CO_2, and degradation of water pollutants through heterogeneous photocatalysis. The band structure of these nanomaterials makes them a sunlight-active photocatalyst and a well-distributed valence band in favor of recombination charge, enabling them to act as potential photocatalytic materials for wastewater treatment over metal oxides [8-9]. Another class of heterogeneous semiconductors photocatalysts is metal sulfides, which mostly utilize the light in the visible region and work in the small wavelength region i.e., (NIR) near-infrared regions. This light harvesting property make them a suitable visible light driven photocatalysts [10-11]. The band gap of Zinc oxide ranges between 3.1-3.3 eV, beside this is considered to be non-toxic, less costly, and has phenomenal chemical stability in neutral and acidic medium [12]. Because of all these properties zinc oxide is considered an efficient visible and UV light-active photocatalyst. For an effective photocatalytic reaction in visible light, a semiconductor photocatalyst must possess a wide bandgap, with a low charge recombination rate, with conduction band on more negative potential side and valence band on positive potential side [13].

METHODOLOGY

Preparation of ZnO nanoparticles

$Zn(CH_3COOH)_2$. $2H_2O$ (0.4M) was added in 30 mL 0.5 M sodium hydroxide of deionized water. After stirring both the solutions for 30 min separately, with continuous magnetic stirring. After 1 hr constant stirring, the mixture was poured into a Teflon-lined stainless-steel autoclave and heated under a controlled temperature of 150°C for 12 h. The finally synthesized material was washed with H_2O and C_2H_5OH and was dried in an oven at about 50°C. The synthesized nanomaterial is further tested for the removal of dyes. The synthesis route is shown in Figure 1.

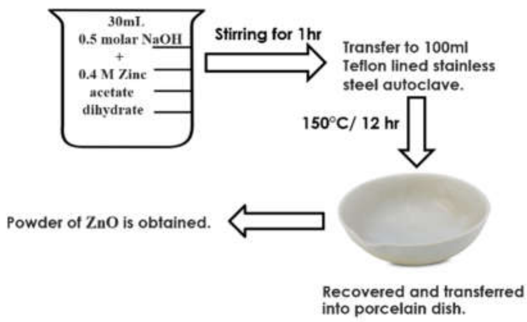

Figure 1: Synthesis route of Zinc Oxide nanoparticles

RESULTS AND DISCUSSIONS

XRD analysis

The XRD plot of ZnO was recorded on X-ray diffractometer. The XRD peaks for Zinc Oxide were detected at 2θ = 2θ=15.5°, 23.4°, 25.2°, 30.6°, 36.3°, 37.7° and 39.7° which are matched to (1 0 1), (1 1 0), (1 0 2), (1 0 1), (1 0 3), (1 1 0) and (1 1 1) monoclinic planes of zinc Oxide (Card No.- 79-1868) (Figure.2).

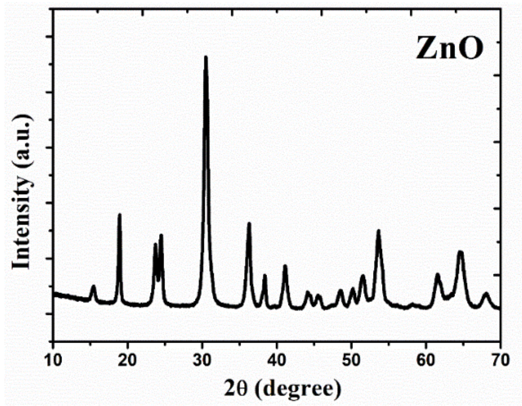

Figure 2: XRD Zinc Oxide nanoparticles

FE-SEM analysis of Zinc Oxide

The FE-SEM image of ZnO nanoparticles was scanned by scanning electron microscope, shows nanoplate-like structures with a diameter in the range of 80-90 nm (Figure. 3). The FESEM indicates the presence of agglomerated nanoparticles of zinc oxide, which confirm the high adsorption of dye molecules which result in the good removal of dye molecule from the waste water.

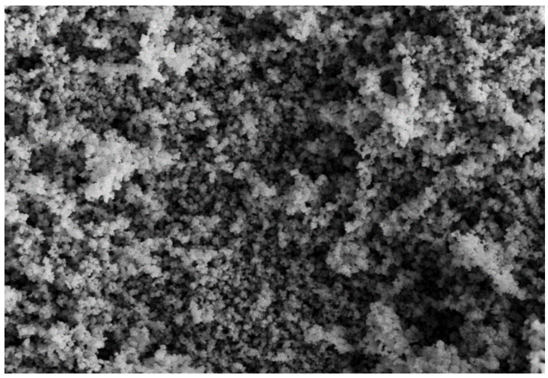

Figure 3: FE-SEM image of ZnO nanoparticles

Optical analysis

The pure zinc oxide nanoparticles absorb in the UV-visible light region (Figure.4). The UV-vis DRS spectra were changed into absorption spectra by using (K-M function) Kubelka-Munk [13], and the band gap was determined from the Taucs plots [12], Figure. Shows Tauc's plots of ZnO photocatalyst. The optical band gap of ZnO was determined to be 3.5 eV.

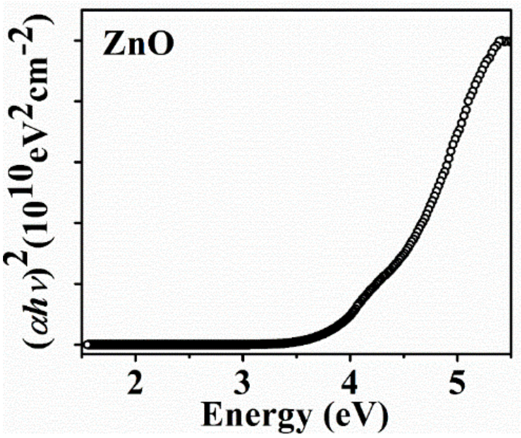

Figure 4: Tauc's plot of pure ZnO

Photocatalytic activity

The sunlight-mediated photocatalytic removal of MB dye (10 mg/L) by the zinc oxide nanoparticles is displayed in Figure. 5. The zinc oxide nanoparticles show the removal performance of about 75 % MB dye removal after 150 min of sunlight exposure. Figure.5 shows the UV-vis absorption spectra, which shows the change in concentration of MB dye during the photocatalytic removal. The decrease in the absorption peak of MB dye (664 nm) was observed over 150 min period of sunlight irradiation.

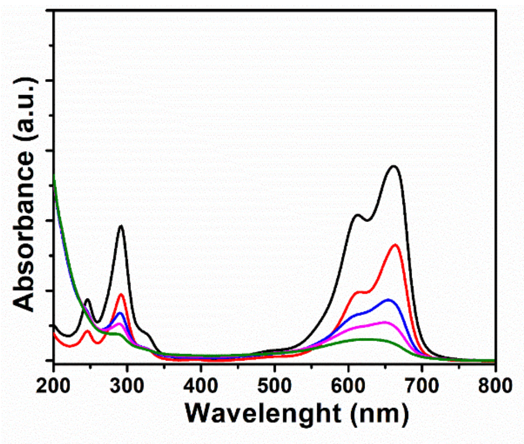

Figure 5: UV-is absorbance spectra of MB dye solution

CONCLUSIONS

A simple synthetic route of hydrothermal has been used for the fabrication of ZnO nanoparticles photocatalyst. The zinc oxide photocatalyst shows photocatalytic performance towards the degradation of 75 % of methylene (MB) under sunlight irradiation. zinc oxide is an effective UV-visible light photocatalyst option for removing various organic dyes in aqueous media due to its strong photocatalytic activity.

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