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Characterization and Photoactivity of Cotton Loaded with ZnO NPs

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Abstract

In this work, ZnO NPs were prepared by a simple co-precipitation technique. Cotton fibers loaded with ZnO NPs were prepared also. X-ray diffraction (XRD), scanning electron microscopy (SEM) and UV-Vis spectrophotometer have been used to characterize the prepared samples. The photocatalytic properties of the cotton loaded with ZnO (C-ZnO) and ZnO NPs, were studied under sunlight irradiation and lamp illumination as a function on time. The results showed that X-ray diffraction of ZnO NPs has a single-phase wurtzite structure with an average particle size of 29 nm. The morphology on the surface of ZnO NPs has a spherical shape. The optical band gap of ZnO nanoparticles was 3.37 eV. The photocatalytic confirms that C-ZnO exhibited higher photocatalytic activities than ZnO NPs.

Keywords

ZnO Nanoparticles, Cotton Loaded with Zno, Methylene Blue, Photocatalytic Activity

1. Introduction

ZnO oxide is an important n-type semiconductor material which receives a great interest for various applications due to its unique properties, such as a direct wide band gap (3.37 eV), large exciton binding energy (60 meV) at room temperature [1]. ZnO is one of the most photocatalyst due to low cost, nontoxic, high catalytic activity, thermal stability and environmental friendly [2] [3] [4]. ZnO has received much attention as a very promising photocatalyst for photocatalytic degradation of water pollutants, because it produces H_2O_2 more efficiently, it absorbs high efficiency with solar light and has higher rates of activities [5]. There are some routes used to improve the photocatalytic performance

of ZnO, such as doping metal or non-metal ions likes Mg, C Al and graphite [6] [7] [8] [9], and combining ZnO with another semiconductor materials such as Tio_2 [10] [11] [12]. It is very important to separate traditional catalysts from reaction systems. So we can use cotton fibers as supporting material. Cotton fibers have characterized by good moisture absorptivity, self-cleaning, high catalytic efficiency, low cost, easy recycling, and environmental sustainability [13]. In the present work, ZnO NPs are successfully synthesized by co-precipitation technique. The structural and optical properties of the ZnO NPs were investigated. Also, the photocatalytic activities of ZnO NPs and cotton loaded with ZnO for the degradation of MB under visible light and UV lamp were studied.

2. Experimental Work

2.1. Synthesis

Co-precipitation technique is suitable and a low-cost method for preparing ZnO NPs with a semispherical shape. $ZnSO_4$ and NaOH solution were prepared separately and then mixed together. The solution was maintained at room temperature stirring for 2 h and heating of $Zn(OH)_2$ at 70˚C for 24 h for drying. The dried ingots were heated at 400˚C for 4 h, after that time period, the powder was left to cool down slowly at room temperature to get pure ZnO.

The preparation of C-ZnO as follows, cotton fibers were washed several times with deionized water. Then clean it by acetone and ethanol, and let dried at room temperature for 24 h. Then the cotton fibers were immersed in the ZnO solution on stirrer for 1 h. The solution was filtrated, and dried the cotton fibers at 150˚C for 2 h. During this step, ZnO NPs were loaded on the cotton fiber.

2.2. Photocatalytic

The photocatalytic properties of ZnO NPs and C-ZnO were measured through the photo-degradation of MB dye under the direct sunlight and under the Philips 400 W lamp illumination. The experiments were carried out as follows: Solution of 10 ppm MB dye was prepared, then we have four beakers divided into two categories one for sunlight and the second for lamp illumination. Each beaker contains 100 ml of the dye. For each group, two photocatalytic were used for comparison, 0.1 g of ZnO nanoparticles and 0.4 gram of C-ZnO. UV-vis absorption was used to evaluate the photocatalytic degradation for MB dye.

2.3. Characterization Techniques

The obtained ZnO powder was characterized by X-ray diffraction (XRD), analysis of the samples was performed using a Rigaku miniflex diffractometer with CuKα radiation (λ = 1.5406 Å). Scanning electron microscopy (SEM; Inspect S, FEI, Holland) was used to determine the particle size and morphology of the prepared sample. Optical characterization was carried out using a Shimadzu UV-3600 UV-VIS-NIR spectrophotometer in the wavelength range 200 - 850 nm.

3. Results and Discussions

3.1. Characterization

XRD pattern of the pure ZnO exhibits a hexagonal wurtzite structure with a preferred (101) orientation as shown in Figure 1. The diffraction peaks corresponding to (100) and (002) planes of ZnO a hexagonal phase were also observed. Average crystalline size (D) is found to be ~29 nm by using Debye-Scherrer's equation $\left(D = 0.94\lambda/\beta\cos\theta\right)$ [14] [15], where λ is wavelength of X-rays, β is full width at half maximum (FWHM) and θ is the diffraction angle.

The morphology of ZnO NPs, cotton fibers and C-ZnO were studied from SEM. Figure 2(a) shows the presence of ZnO sample in a spherical shape with average particle size ~29 nm. A smooth surface for the cotton fibers with no particles on its surface is shown in Figure 2(b), while C-ZnO is shown in Figure 2(c), its obvious differences, which were covered with a large quantity of ZnO NPs with a good dispersed. The stability of ZnO NPs on the surface of cotton fibers may be related to electrostatic bonding interactions between the negatively charged hydroxyl groups on cotton fiber and positively charged from the ZnO Nps.

The optical properties of the ZnO NPs were studied by UV-visible spectroscopy. The absorption spectra of ZnO NPs were shown in Figure 3. The sharp absorption edge is observed for the wavelength of about 376 nm in the absorption spectra which is characteristic of ZnO NPs. The optical band gap (E_g) for ZnO NPs was evaluated using the Tauc's relation $\left(\alpha h\nu = B\left(h\nu - E_g\right)^{1/2}\right)$ [16]

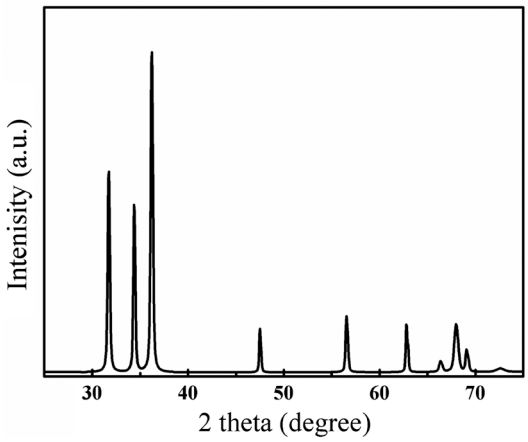

Figure 1. XRD diffraction patterns of ZnO.

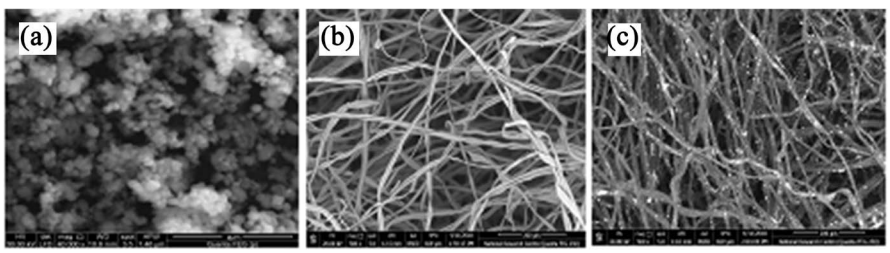

Figure 2. SEM image of (a) ZnO NPs, (b) cotton fibers and (c) C-ZnO.

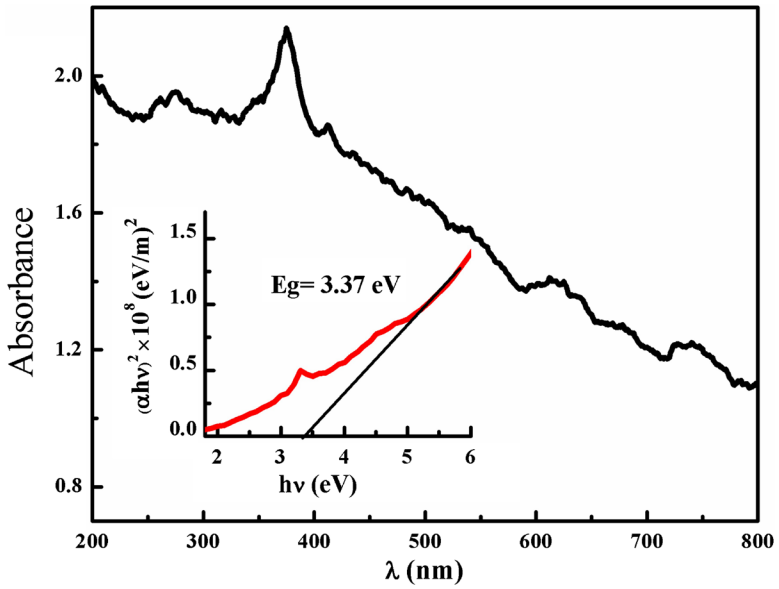

Figure 3. UV-Vis spectra of ZnO nanoparticles, and in the inset the bandgap calculation.

[17], where α is the absorption coefficient, B is a constant and $h\nu$ is the photon energy. The optical band gap could be obtained by extrapolating the linear portion of the $(\alpha h\nu)^2$ versus $h\nu$ plot to $h\nu$ axis, as shown in the inset of **Figure 3**. The optical band gap was found to be 3.37 eV for the ZnO NPs, which is very close to the intrinsic band gap of ZnO.

3.2. Photocatalytic Activity

The percentage photocatalytic degradation was calculated by using the following equation:

$$\text{Percent of degradation} = \left[\left(C_0 - C\right)/C_0\right] \times 100$$
$$= \left[\left(A_0 - A\right)/A_0\right] \times 100$$

where, C_0 represents the initial concentration of the dyes, C is the final concentration after illumination by UV light, A_0 is the initial absorbance, and A is the variable absorbance [18].

In order to illustrate the potential application of ZnO NPs in wastewater treatment, we have investigated their photocatalytic activities for the degradation of MB under sunlight and 400 W UV lamp. **Figures 4(a)-(d)** show the absorbance spectra of the four systems at different degradation time. We show that with increasing degradation time, the intensity of the peaks decreases gradually, which indicates that MB is gradually photodegraded.

Under the UV-lamp irradiation for 2 h, the photocatalytic efficiencies of ZnO NPs and C-ZnO for MB are 62.2% and 73.8% respectively. In addition, the photocatalytic efficiencies of ZnO NPs and C-ZnO for MB under sunlight are 92.2% and 95.2% respectively. The results exhibit C-ZnO can provide high performance of photocatalytic activity for the degradation of MB than ZnO NPs. Also, the photocatalytic for the degradation of MB was very efficient in the presence of

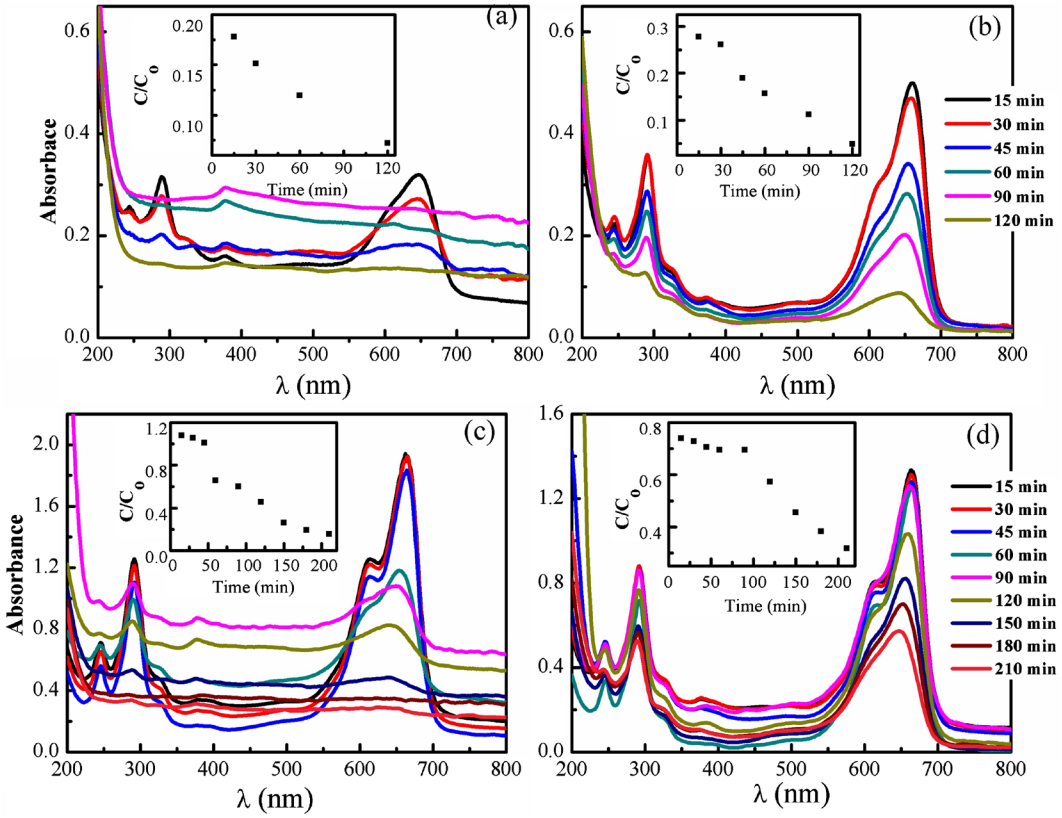

Figure 4. ((a), (b)) ZnO NPs and C-ZnO under sunlight, ((c), (d)) ZnO NPs and C-ZnO under UV, respectively.

sunlight more than the UV lamp.

The mechanism of photocatalytic activity of C-ZnO as fellow: When the light energy is greater than or equal to the band gap energy, a high concentration of conduction band electrons (e^-) and valence band holes (h^+) are created in the density of ZnO NPs attached on cotton. Positive hole (h^+) interacts with hydroxyl group (–OH) on the cotton surface to produces hydroxyl radicals (•OH), which act as strong oxidants through the photocatalytic reaction. Moreover, photo generated electrons (e^-) react with an electron acceptor, such as O_2 and are adsorbed on the surface of the catalyst or dissolved in water to produce superoxide radical anions O_2• and •HO_2. Free radicals react with each other, is major to formation of hydrogen peroxide and increasing gaseous oxygen in the photocatalytic reaction [19] [20] [21] [22]. All these react with methylene blue molecules for their full degradation.

4. Conclusion

Summarizing, we have prepared ZnO NPs and C-ZnO by a simple process co-precipitation method. ZnO NPs were characterized by XRD, SEM and UV-visible. SEM images showed that spherical like ZnO NPs of average diameter 29 nm were successfully prepared. ZnO NPs were loaded on the cotton in a homogeneous manner. ZnO NPs and C-ZnO were used as photocatalytics for the re-

moval of methylene blue dye from aqueous solutions under sunlight and a philips 400 W lamp. The results showed that ZnO nanoparticles decomposed MB by 92.22% in the sunlight and 62.22% in the lamp illumination, and C-ZnO decomposes 95.27% of MB dye in the sunlight and 73.88% in the lamp illumination. In addition, C-ZnO was high performance of photocatalytic activity for the degradation of MB than ZnO NPs.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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