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Synthesis and Characterization of ZnO Nanoparticles

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ABSTRACT

A simple Wet-chemical method has been successfully deployed to synthesis ZnO nanoparticles at room temperature. The estimated band gap from the UV-VIS absorption spectra shows formation of nanoparticles. The photoluminescence spectrum shows presence of defect states. The structural characteristics of the nanoparticles were investigated through X-ray Diffraction .The crystal unit cell of the nanoparticles was found to be hexagonal. The morphology of the nanostructures was studied using transmission electron microscopy (TEM).The nanopartiles are spherical in shape. Selected area electron diffraction (SAED) pattern reveals the single crystalline nature of the nanoparticles.

***Keywords*:** Zinc oxide Nanoparticles, UV-VIS Spectra, Band gap, Photoluminescence, XRD, TEM

1. Introduction

Zinc oxide (ZnO) is a II–IV semiconductor with wide band gap of 3.37 eV and large exciton binding energy of 60 meV at room temperature. Due to excellent tuned luminescence property ZnO nanoparticles can be used in several biomedical and pharmaceutical applications for mankind [1,2]. Due to this large direct band gap it is being used in many optoelectronic devices [3,4]. like short wavelength light-emitting[5], UV lasing[6], and It also exhibits other interesting properties, like piezoelectricity [7], photovoltaic devices and optical solar cells [8], gas sensing[9], These properties depend on the morphology of the nanostructures. Various methods, such as physical and chemical-vapour deposition [10], hydrothermal growth [11,12], pulsed-laser deposition [13] have already appeared in the literature to fabricate various types of ZnO nanostructures. Some of the above-mentioned methods have some drawbacks. Used precursors are unstable causing environmental hazards and require very high temperature, low pressure, control rate of carrier flow and many more. These methods are not cost effective also Hence it is necessary to develop a simple method to synthesis ZnO nanostructures. Wet-chemical method provides a better route for the fabrication of ZnO nanostructures. In this study, a simple chemical method to synthesis ZnO nanoparticle from zinc acetate dehydrate at room temperature without any capping agent was employed. Such nanoparticles shows a strong emission in the violet region of the visible spectrum.

2. Experimental

All the chemicals used in this synthesis process were of analytical grade (99.99% pure) and used as supplied without any further purification. In a typical synthesis process 0.15M of zinc acetate dehydrate was first dissolved in water and kept as stock solution. 0.25M NaOH solution was added drop wise into the stock solution. The mechanical stirring was continued for 2 h. The pH of the solution was 11. At the end of the reaction the white precipitate deposited at the bottom of the flux was collected, filtered, washed several times by de-ionized water and dried at 300C for further characterizations. X-ray diffraction was carried using Rigaku X-ray diffractometer system over $20 < 2\theta < 80$ using Cu-kα radiation of wavelength λ=1.54Å. For further structural characterization transmission electron microscopy images were taken in a JEOL JEM-2100F microscope with the accelerating voltage of 200 kV. For TEM study a very small amount of the powder sample was first dispersed in alcohol by ultra-sonication. A drop of that solution was taken on a carbon coated grid for TEM imaging. The room temperature PL spectrum was recorded in PERKIN ELMER LS- 55 with a Xenon lamp with the excitations of 330nm. The optical absorption spectra of the samples were taken by using Shimadzu-Pharmaspec-1700 UV-VIS, after ultrasonification of the samples in alcohol.

3. Results and discussions

3.1. UV-visible spectroscopy

UV-visible spectroscopy was carried out to study further the optical property of the nanoparticles. The room temperature UV-absorption spectra of the ZnO nanoparticles dispersed in ethanol is shown in figure 1. ZnO NPs shows a prominent exciton band at 374 nm due to excitonic transition at room temperature[14,15]. This absorption in the visible range of wavelength implies that there exist more defect energy levels in the synthesized ZnO nanostructures that are due to the specific experimental synthesis conditions.

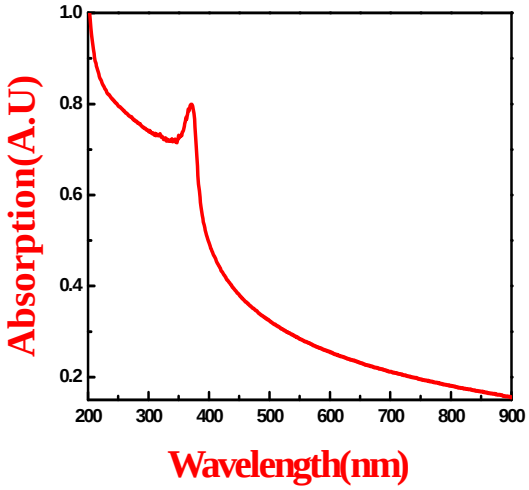

Figure 1:

Optical absorption coefficient has been calculated in the Wavelength region 200–900 nm. The bandgap of the as-prepared nanoparticles are are determined from the relation [16]

$$(\alpha h\nu)^2 = c(h\nu - E_g)$$

where C is a constant. E_g is the band gap of the material and α is the absorption coefficient. Figure 4 shows the plot of $(\alpha h\nu)^2$ vs. energy (hν) and it is used to determine band gap. The bandgap of the sample is found to be 3.61 ev(figure 2), which is greater than the bulk ZnO (3.37 eV) [17].

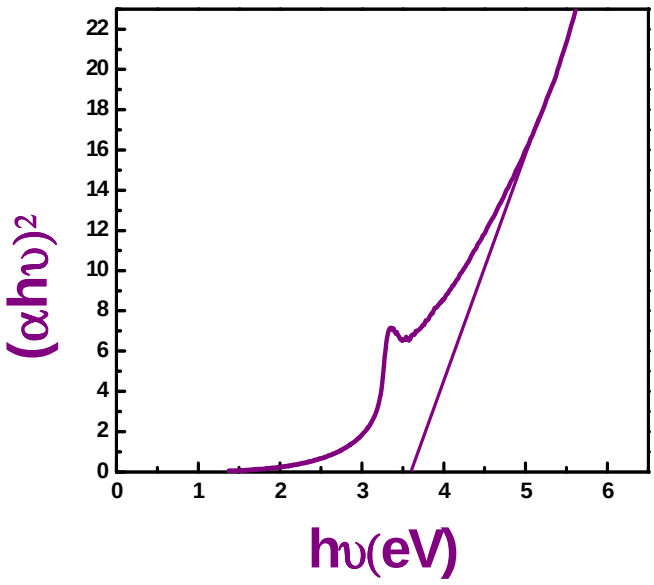

Figure 2:

3.2. Photoluminescence spectroscopy

Room temperature photoluminescence (PL) was recorded with the excitation wavelengths of 330nm (figure 3) shows a strong emission in the violet region of the visible spectrum. Nanoparticles Synthesized emission peak around 377nm can be assigned to the recombination of an electron at zinc interstitial and a hole in the valance band. Some other peaks are also observed at 449nm, 486nm, and 533nm which are attributed to different defect state emissions. The visible luminescence of ZnO mainly originates from different defect states such as oxygen vacancies and Zn interstitials[18]. Oxygen, in general, exhibit three types of charge states of oxygen vacancies such as V_{o0}, V_{o+}, and Vo_{2+}. The oxygen vacancies are located below the bottom of the conduction band (CB) in the sequence of V_{o0}, V_{o+}, and V_{o2+}, from top to bottom. The peak around 533 nm can be related to singly ionised oxygen vacancy.

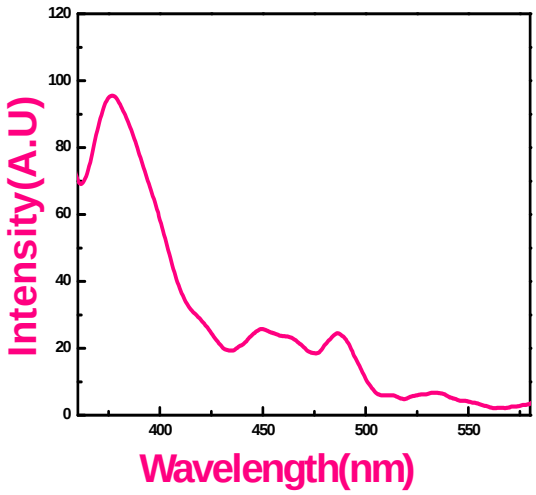

Figure 3:

3.3. X-ray diffraction (XRD)

A typical XRD pattern of the ZnO nanoparticles is shown in figure 4. The unit cell of the crystal was found to be hexagonal with the presence of the peaks (100), (002), (101), (102), (110), (103),(200),(112), and (201). Furthermore, the intensities of different diffraction peaks are different, which indicates that the growth of various planes (direction) is different and that the growth is anisotropic. Also no impurity peaks were detected.

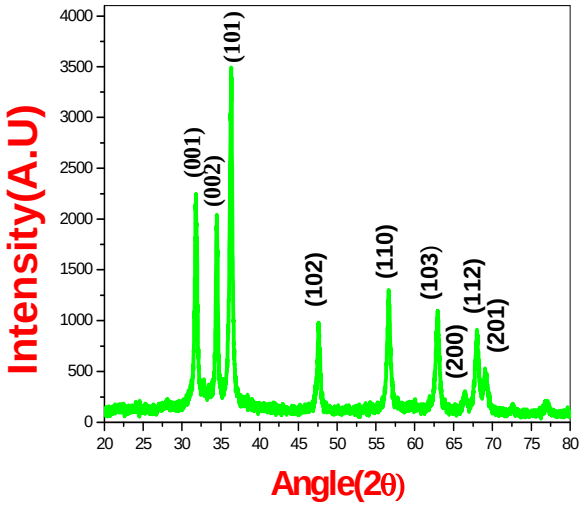

Figure 4:

3.4. Transmission electron microscopy study

Further studies on the structure of the ZnO nanoparticles were done using transmission electron microscopy. Figure 5 shows the TEM image of the fabricated nanoparticles. The diameters of the nanoparticles varies between 20-40 nm. The corresponding selected area electron diffraction (SAED) pattern is also shown in figure 6, which reveals the single crystalline nature of the nanoparticles

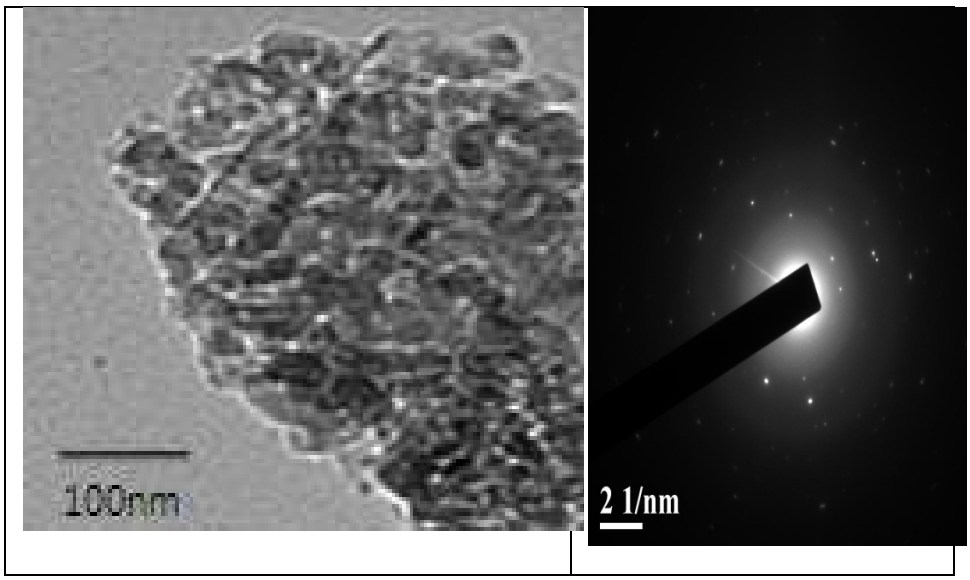

Figure 5: **Figure 6:**

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