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STUDIES ON THE SYNTHESIS AND CHARACTERIZATION OF CTAB STABILISED ZnO NANOPARTICLES

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Abstract

Zinc oxide (ZnO) represents an important semiconductor material due to its wide band gap (3.2 eV at room temperature), large exciton binding energy (60 meV), high optical gain and luminescence as well as piezoelectric properties. Due to its unique properties in electrical and optical characteristics ZnO is considered as a liable material for a variety of visible and near ultraviolet (UV) spectra. ZnO is regarded as a promising semiconductor for fabrication of the various optoelectronic devices with high light emission efficiency and durability. The present study deals with the synthesis and characterization of zinc oxide nanoparticles using CTAB as the stabilizer.

Keywords : ZnO nanoparticles, CTAB, X-ray diffraction, UV-Visible absorption

I. INTRODUCTION

Semiconductor compounds have drawn much attention during the last few years because of their novel optical and transport properties which have great potential for many optoelectronic applications. Zinc oxide is an interesting semiconductor material due to its application on solar cells, gas sensors, ceramics, catalysts, cosmetics and varistors. In materials science, ZnO is often called a II-VI semiconductor because zinc and oxygen belong to the 2^{nd} and 6^{th} groups of the periodic table respectively, which has a direct band gap (3.37 eV at RT) in the ultraviolet (UV) range, is a promising material that possesses various applications, such as transparent electrodes and ultraviolet-emitting devices [1-3]. This semiconductor has several favourable properties like good transparency, high electron mobility, wide band gap, strong room temperature luminescence, etc. The high exciton binding energy of ZnO would allow for excitonic transitions even at room temperature, which could mean high radiative recombination efficiency for spontaneous emission as well as a lower threshold voltage for laser emission [4,5].

Studies have been carried out to fine-tune the properties of ZnO to adopt it for different applications; for example, the band gap of ZnO is modified to use as UV detectors and emitters [6]. Nanoparticles of ZnO attract an increasing interest, due to their possible use in a range of new nanodevices. Applications in optoelectronics, as blue colour light emitting phosphors, as nanorod UV light emitters, as fluorescence labels in medicine and biology, in controlling units as UV photodetectors and as high-flame detectors, as nanosensors of various gases, but also in cosmetic industry, as a component of sun screens, are envisioned [4, 7-9].

In the present work, ZnO nanoparticles are prepared by chemical precipitation method using CTAB as capping agent. The effect of stabilizer on the optical and structural properties of ZnO nanoparticles are studied using UV-visible absorption spectroscopy and X-ray diffraction technique.

II. EXPERIMENTAL

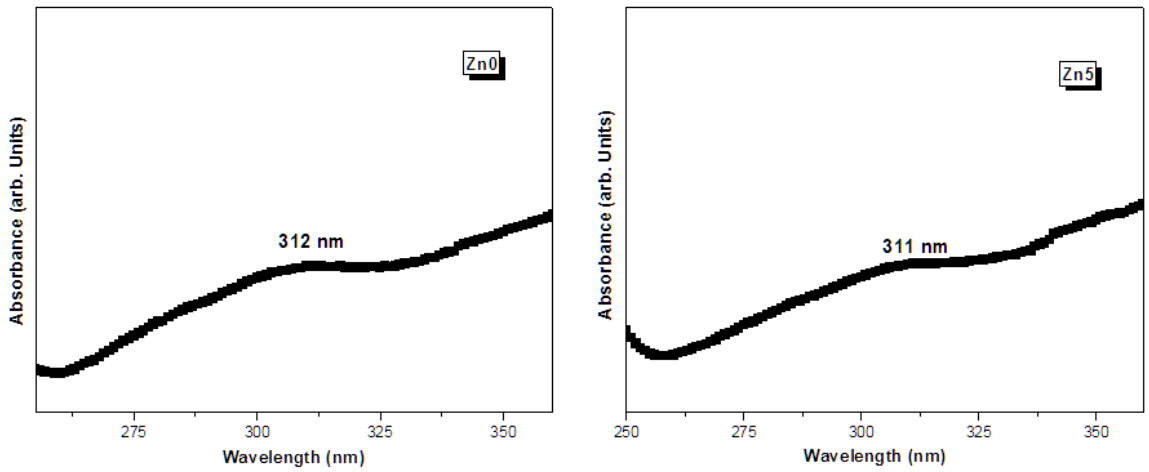
The ZnO nanoparticles were prepared by wet chemical method using zinc nitrate [0.1M Zn $(NO_3)_2.6H_2O$] and sodium hydroxide [1M NaOH] as precursors and CTAB [.01M (CH_3) $(CH_2)_{15}$ N (CH_3) Br] as stabilizing agent [6].

The UV–visible spectra were recorded on a Jasco V-550 UV–visible spectrophotometer in a 1 cm optical path quartz cuvette. X-ray diffraction pattern was recorded using an X-ray diffractometer (PANalytical) using CuK_α radiation of wavelength λ = 0.15406 nm.

III. RESULTS AND DISCUSSION

UV-VISIBLE ABSORPTION STUDIES

UV-visible absorption spectroscopy is the most widely used method for characterizing the optical properties and electronic structures of nanoparticles. UV-Visible absorption spectroscopy measures the percentage of radiation that is absorbed at each wavelength. Fig 1 shows the UV-visible absorption spectra of ZnO nanoparticles. The excitonic absorption peak is observed due to the ZnO nanoparticles at 312 nm, which lies much below the bandgap wavelength, 388 nm (E_g = 3.2 eV) of bulk ZnO [10]. An attempt has also been made to study the effect of stabilizer on the formation of ZnO nanoparticles. The stabilizer acted as the protection from agglomeration of nanoparticles. By the addition of CTAB as the stabilizer, the absorption peak blue shifts from 312 nm to 311, 301, 307 and 308 nm with increase in concentration of CTAB. The blue shift in the excitonic peak results from the decrease in crystalline size which can be attributed to the quantum confinement effect in the ZnO nanocrystallites



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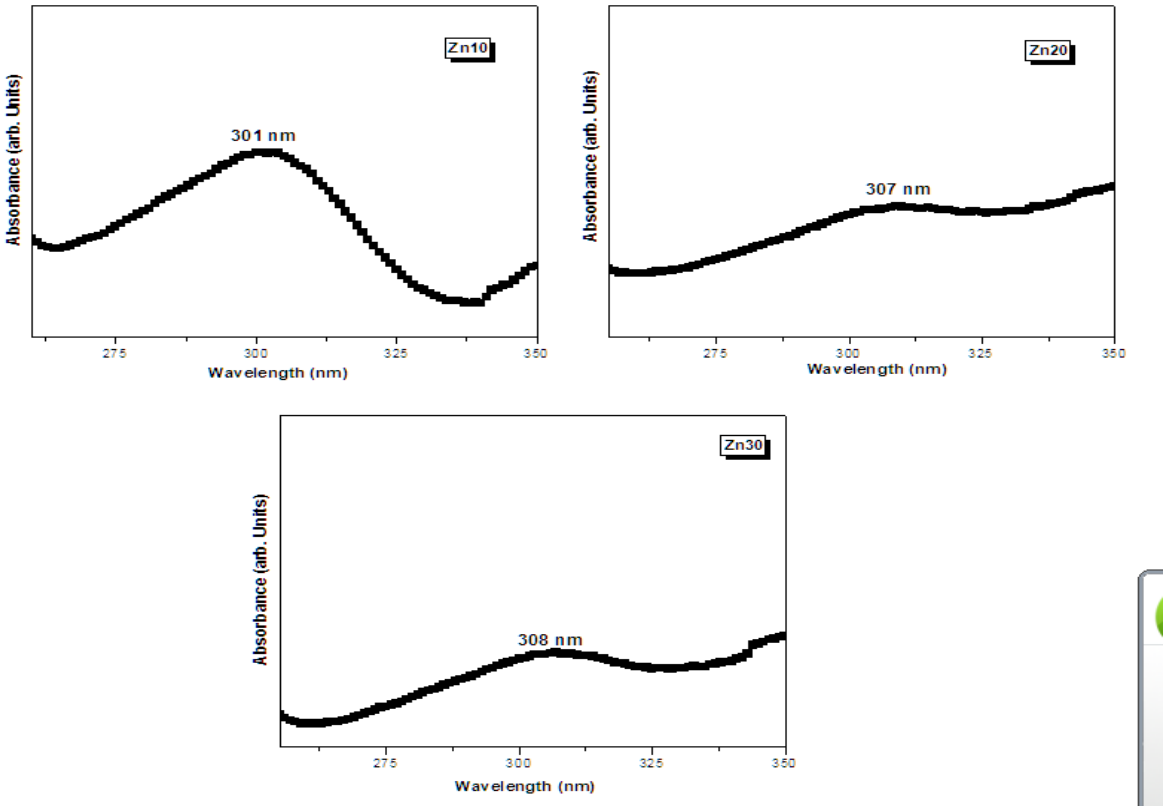

Fig 1. Absorption spectra of ZnO nanoparticles formed with different concentrations of CTAB.

Fig 2 shows the variation of absorption peak with concentration of CTAB. The decrease in absorption wavelength with concentration of CTAB is an indication of decrease in particle size with concentration of CTAB.

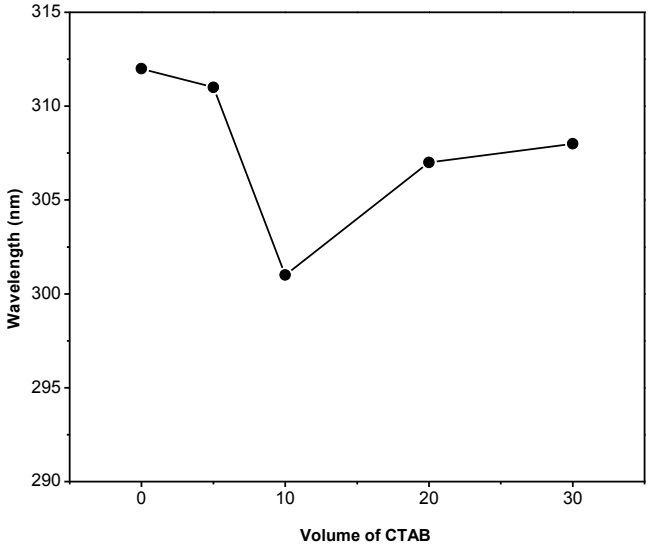

Fig.2. Variation of absorption wavelength with concentration of CTAB

According to Tauc relation, the absorption coefficient, α, for direct band gap material is $\alpha h\nu = A\,(h\nu - Eg)^n$ where *Eg* is the energy gap, hν is the energy of photon, A is a constant and n is an index which assumes the values depending on the nature of the electronic transition responsible for the reflection. For ZnO, n=1/2 which is responsible to the allowed direct transition [8]. The band gap of the ZnO nanoparticles was calculated by extrapolating the curve drawn between (h ν) and $(\alpha\ h\nu)^2$ where ν is the frequency and α is the optical absorption coefficient. The estimated band gap energy was found to be 3.08, 3.10, 3.36, 3.24 and 3.21 eV for the samples prepared with different CTAB concentrations. The results show that the band gap energy increases with increasing the surface to volume ratio or the reduction of the particle size.

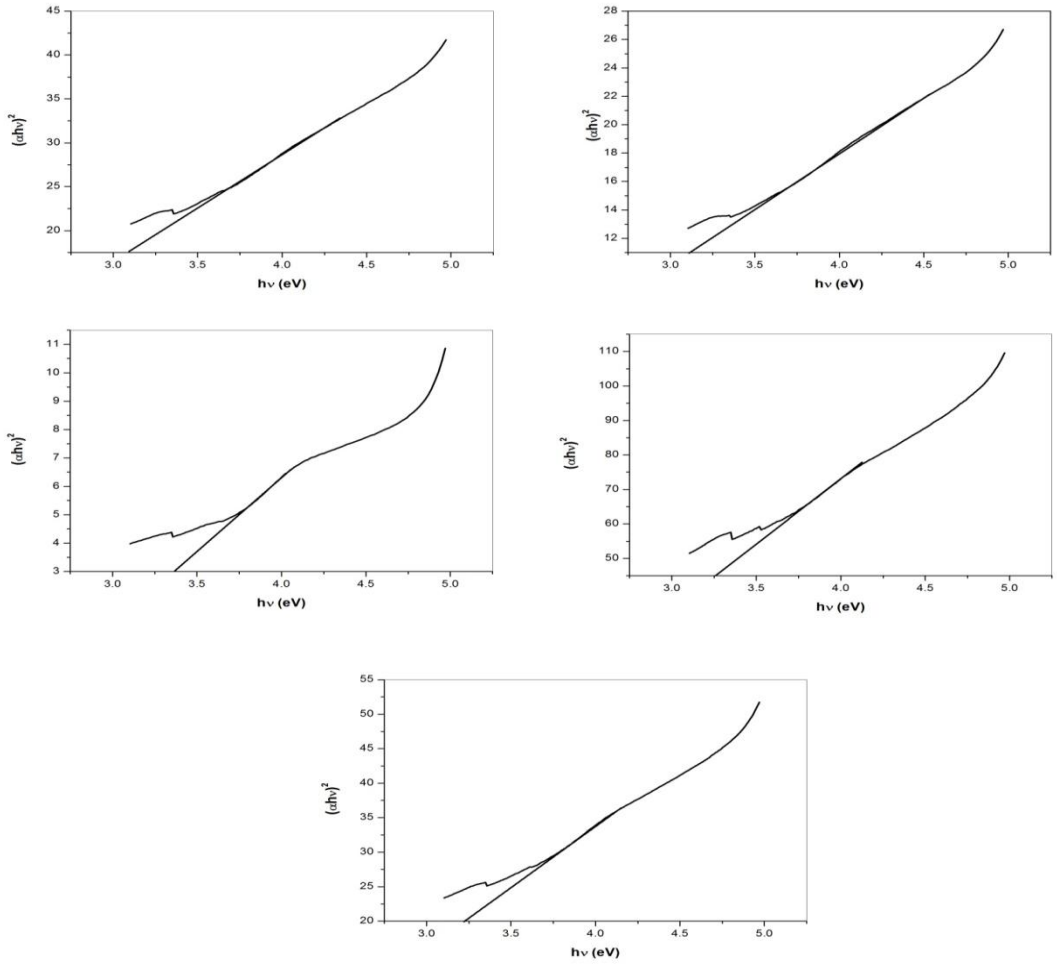

Figure 3Band gap determination from h ν - $(\alpha\ h\nu)^2$ graph

Fig 3 Bandgap determination of ZnO nanoparticles using hν and $(\alpha h\nu)^2$ graph

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X-RAY DIFFRACTION STUDIES

Fig.4 shows the X-ray diffraction pattern of ZnO nanoparticles prepared with different concentrations of CTAB. The diffraction peaks were indexed as (100), (002), (101), (102), (110), (103), (112) and (201) reflections of wurtzite (hexagonal) structured ZnO (JCPDS card No. 36-1451, lattice parameters of a = b = 3.25 Aº and c = 5.207 Aº) [11]. The products are well crystallized and no peaks associated with other crystalline forms are detected.

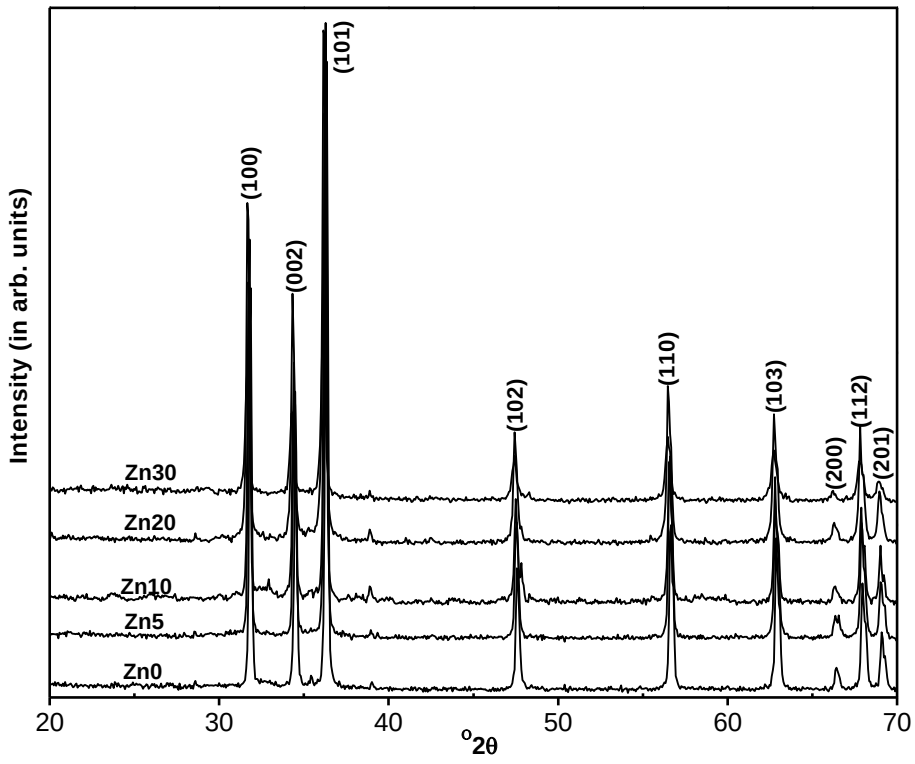

Fig.4. X-Ray diffraction pattern of ZnO nanoparticles formed with different concentrations of CTAB

CONCLUSIONS

In the present study, ZnO nanoparticles are prepared with CTAB as the stabilizing agent via chemical method. The excitonic absorption peak observed due to the ZnO nanoparticles is found to be blue-shifted with concentration of CTAB, indicating a decrease in particle size with CTAB concentration. XRD analysis shows that the ZnO nanoparticles are highly crystalline in nature.

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