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Synthesis and Characterization of ZnO Nanoparticles

S. Rajivgandhi[1], A. Dinesh Kumar[2], R. Sundareshwaran[3] & V. Vineeth[3]
[1] Assistant Professor of Physics, Dhanalakshmi Srinivasan Engineering College, Perambalur, India.
[2] Assistant Professor of Mathematics, Dhanalakshmi Srinivasan Engineering College, Perambalur, India.
[34] UG Scholar, Mechanical Engineering, Dhanalakshmi Srinivasan Engineering College, Perambalur, India.
[1]selvarajivgandhi@gmail.com, [2]dineshkumarmat@gmail.com, [3]mathsphd1@gmail.com

***Abstract*— ZnO nanoparticles were synthesized by chemical method which prepared by molar concentrations at different temperature. The morphology and structure of the synthesized nanoparticles were characterized by Scanning electron microscope (SEM), X-ray diffraction (XRD), IR Raman spectroscopy. The optical band gap energy characterized by UV-Visible spectrometer was in the range of 3.2eV to 4.8eV. The electrical, optical and structural properties were studied.**

Keywords: ZnO nano particles, electrical, optical and structural properties.

I. INTRODUCTION

Zinc oxide (ZnO) is no stranger to scientific study. In the past 100 years, it has advantage as subject of thousands of research papers, dating back as early as 1935. Valued for its ultra violet absorbance, wide chemistry, piezoelectricity and luminescence at high temperatures, ZnO has penetrated far into industry, and is one of the critical building blocks in todays modern society [1]. It can be found in paints, cosmetics, plastic and rubber manufacturing, electronics and pharmaceuticals, to name just a few. More recently however, ZnO has again entered the scientific spotlight, this time for its semiconducting properties. Fuelled out of advances in growth technologies and the potential for ZnO to become a suitable substrate for GaN, the fabrication of high quality single crystals and epitaxial layers was achieved [2-4]. Allowing for the realisation of ZnO-based photonic and optoelectronic devices, where, amongst other potential applications it stands with GaN as a prospective candidate for the next generation of light emitters for solid state lighting applications [5]. With a wide band gap of 3.4 eV and a large exciton binding energy of 60 meV at room temperature, ZnO holds excellent promise for blue and ultra-violet optical devices. Although in the past GaN and GaN-based materials have dominated this wavelength range, ZnO enters the arena with several advantages [6,7]. The two most crucial of these are:

1. The larger excition binding energy, which will allow for room temperature devices operating with higher efficiency and lower power threshold for lasing by optical pumping.

2. The ability to grow high quality single crystal substrates with relative cost effectiveness and case - something that still eludes GaN, some of the key properties of ZnO, and provides a comparison with GaN. Other favourable aspects of ZnO include its broad chemistry leading to many opportunities for wet chemical etching, piezoelectric properties, radiation hardness and high ferromagnetic Curie temperature for spintronic applications. Together, these properties make ZnO an ideal candidate for a variety of devices including blue and ultra-violet laser diodes and light emitting diodes [8-10].

Despite the maturity of the field of semiconductors and the wide information base available for ZnO; as a semiconductor, little is actually known about this material. As with all wide band-gap semiconductors, ZnO has presented a number of hurdles to the scientific community which need to be understood and overcome before ZnO based devices can be commercially realised. The thesis comes in what could be described as the 'teenage years' of research into ZnO devices. These would include mainly growth advances, which have seen the development of reproducible high quality epitaxial layers and single crystals [11]. Zinc oxide (ZnO) is of great interest as a suitable material for high temperature, high power electronic devices either as the active material or as a suitable substrate for epitaxial growth of group III-nitride compound UV photoconductivity of ZnO is governed by surface-related and bulk-related processes [12].

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II. EXPERIMENTAL WORK

A. *Synthesis of ZnO nano particles*

To prepare of ZnO nanoparticles in a typical experiment, 0.5 M aqueous solution of zinc acetate $(CH_3COO)_2Zn.2H_2O$ and 1 M aqueous solution of sodium hydroxide (NaOH) were prepared in Millipore water. Then, the beaker containing NaOH solution was heated at the temperature of about 55ºC. The $(CH_3COO)_2$ Zn solution was added drop wise (slowly for 25 min) to the above heated solution under high-speed stirring. The beaker was sealed at this condition for above 2 hours. The precipitated ZnO nanoparticles was cleaned with Millipore water (2X) and ethanol. Then a white colour powder was calcined at 90°C and then grinded for uniformities of the powder. The dry synthetic powders were weighted and the percentage yields were calculated from the expected total amount of ZnO based on the solution concentration and volume and the amount that was actually crystallized.

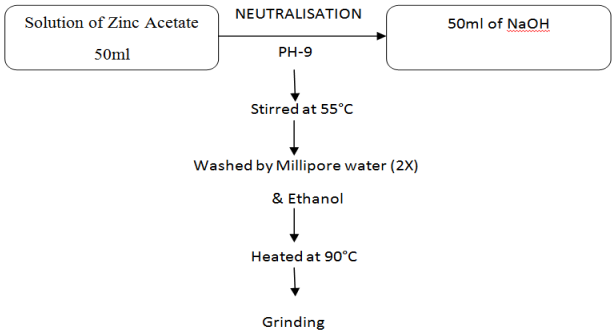

Fig-1 Flowchart showing the synthesis of ZnO nano particles

B. *Characterization analysis*

Compound confirmation of the as synthesized powder was studied by Powder XRD method. The X-ray diffraction patterns of the powdered samples of the ZnO nanoparticles were analysed using an X'Pert-Pro,PANalytical(with λ=1.5405 Å Cu-Kα radiation) operating at room temperature. Microstructural Morphology of the sample was investigated using Scanning Electron Microscopic study. A scanning electron microscope of oxford model Leo 1550 was used for the morphlogical and average particle size study. Linear optical characteristics of the as synthesized samples were studied by UV visible spectrophotometer studies.The UV-visible absorption spectrum was recorded using Lambda 35, Perkin-Elmer double beam UV-visible absorption spectrometer.

III. RESILT AND DISCUSSION

A. *Structural Characterization*

X-ray diffraction (Figure 2) is a well known technique for the structural identification and determination of the crytallite size. X-ray diffraction pattern the narrower and higher intense peaks are obtained in the diffraction pattren samples formed at high evaporation rate. The crystallite/particle size has been calculaed using the Debye-Scherrer equation for all diffraction peaks.The particle size of the sample is found ranging between 50 and 65nm.The intensity peaks of XRD pattren coordinated with JCPDS file number 790206 and its confirmed that the crystalline sample is of ZnO which is hexagonal in structure which lattice parameters a=3.238Å and c=5.177Å.

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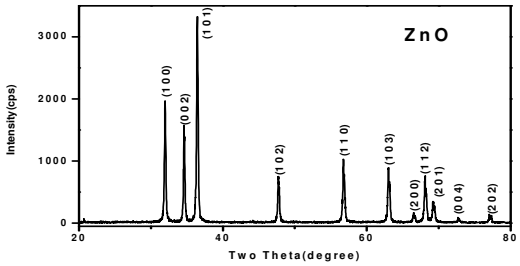
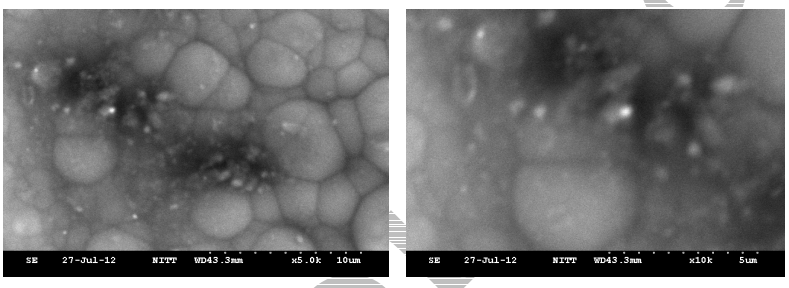


Fig(2).XRD patterens for powder sample of ZnO-3 nanoparticle at high evaporation rate.

B. SEM Analysis

The particle morphologies of the prepared ZnO nanoparticles were observed by SEM. The SEM image of ZnO nanoparticles at different magnifications at difrerent temperature.The SEM image shows random distribution of the ZnO nanoparticles having non-spherical shape and average diameter of 10µm at 90^0c temperature and 5µm at 330^0c temperature figure(3).



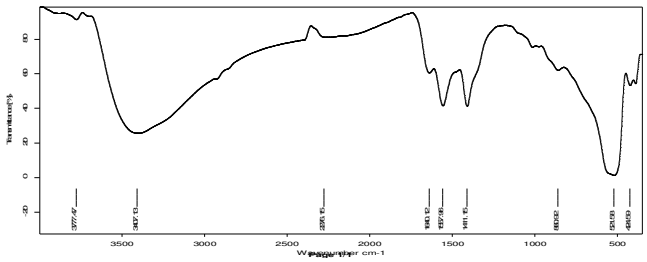
(a) (b)

Fig (3): SEM image of (a) ZnO-3(at 90^0c) (b) ZnO-2(at 330^0c) nano particles using zinc acetate.

C. Fourier Transform Infra Red Spectroscopy

The FTIR spectrum of ZnO-3 is shown fig(4).The spectra of the sample,palletised with KBr, were recorded over 400 to 4000 cm^{-1}. The transmittance spectrum of ZnO-3 nanoparticles shows main absorbtion bands centred at 521 to 3407 cm^{-1} and several features are located at 2276, 1640, 1557, 1411 and 860 cm^{-1}.

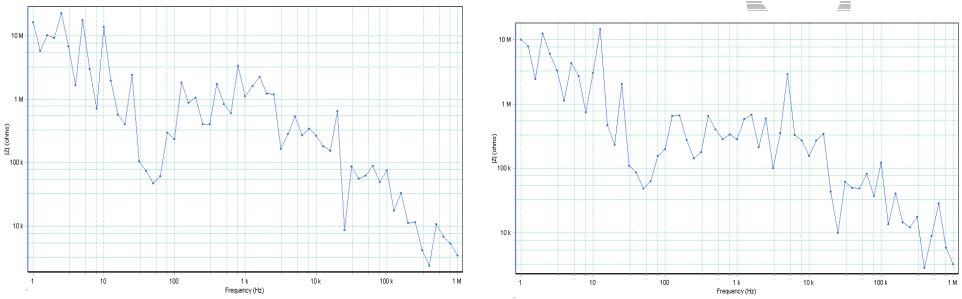
The absorbtion bands centred at 1411 to 424 cm^{-1} can be associated with ZnO bond vibration, comparing with standard IR of ZnO powder. It should be noted the pellet of ZnO-3 has a strong peak at 3777 cm^{-1} is observed which is very sensitive to stretching vibrations of OH bond.The other application bands at 2278, 1640, 1557, 1411 and 860 cm^{-1} can be related to N-H, N-O bond.



Fig(4) FTIR spetrum of ZnO-3 nanoparticles

IV. IMPEDANCE SPECTROSCOPY

Impedance measurements were done using impedance Spectroscopy. In this study we obtained the impedance values for various frequencies. From this study (figure 5), the value of impedance decreases as the frequency increased. So the conductivity increases when the frequency is increased. The dispersion of dielectric constant with frequency was examined.



(a) (b)

Fig(5).Variation of impedance with frequency of (a) ZnO-3 (b) ZnO-2 nanoparticles at 50^{O} C

V. LINEAR OPTICAL STUDIES

A. Absorption spectra of ZnO-3 nanoparticles

The room temperature UV-visible absorption spectrum of the ZnO-3 nanoparticle is recorded in the wavelength range of 220-1100nm. Fig (1) represents the UV-visible absorption spectrum of ZnO-3 nanoparticles. Spectrum has a peak at 229 nm (3.22 eV). The absorption peak for 30 nm ZnO-3 nanoparticles has been reported at 254 nm (3.52 eV). It also shows that the absorption increases exponentially as the wavelength increases and the absorption spectrum in the visible region. In this spectrum the lower cut-off region near to 250 nm for 0.5 Zinc acetate and 1M NaOH. The band gap for normal-sized ZnO is 3.3 eV.

B. Optical band gap

The values of direct band for ZnO nano powders synthesized with molar concentrations were shown in table(1). The band gap energy was calculated from the absorption spectra.(Note: The ZnO synthesized nanoparticles powder kept at different temperature as like ZnO-3 at 90^{o}c temperature and also ZnO-2,ZnO-1 kept at respectively 330^{o}c and 350^{o}c temperature).

Table(1)The values of direct band for ZnO nano powders synthesized with molar molar concentrations.

Sample	ZnO-3	ZnO-2	ZnO-1
Band gap for hν vs $(\alpha h\nu)^2$	3.2eV	3.5eV	4.8 eV

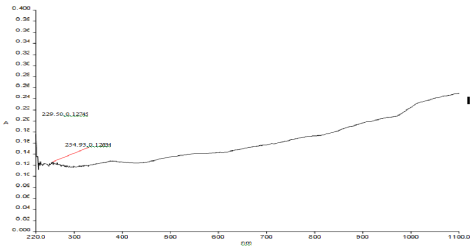
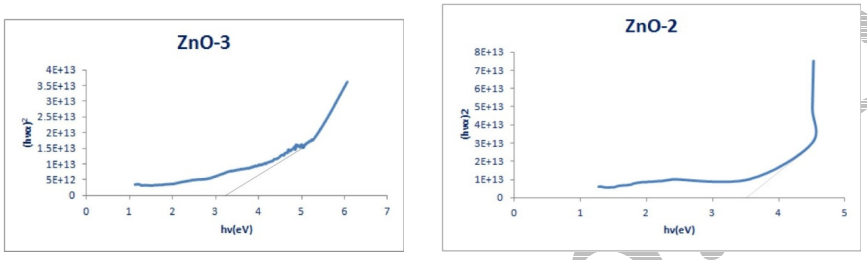


Fig (6).UV-visible absorption spectrum of ZnO-3 nanoparticles



(a) (b)

Fig(7).Optical band gap for (a) ZnO-3 at 90^0c (b) ZnO-2 at 330^0c temperature

It was found that in direct band gap of ZnO nano powder sample deviate between 3.2eV to 4.8eV, which shows the higher direct band gap as compared to the bulk value.The table shows the direct band gap energy for different molar concentrations. The band gap of ZnO nano powders increases with increase in molar concentrations.

VI. CONCLUSION

Synthesis and characterization of ZnO nanoparticles were investigated. ZnO nanoparticles were characterised using UV-visible spectrometer at different concentration and different temperature. The Optical properties of the band gap energy (3.2eV to 4.8 eV) of ZnO nanoparticles increases with increase at temperature in molar concentration. The obtained nanoparticles were investigated using FTIR, SEM, and X-ray analysis. The particle size of ZnO nanoparticles were calculated as 50 to 65 nm, using XRD. The SEM images show the nanoparticles morphology of prepared ZnO sample.

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