Asian J. of Adv. Basic Sci.: 2(3), 39-49
ISSN (Online): 2347 - 4114
www.ajabs.org

Synthesis and Structural properties of Zinc Oxide Nano Particles (ZnO NPs): A Review

Pankaj Kumar and Yogesh Kumar Walia

Department of Chemistry, School of Basic & Applied Sciences, Career Point University,
Hamirpur, Himachal Pradesh - 176041 (INDIA).
Email ID: pankaj21256@gmail.com

ABSTRACT: ZnO (Zinc Oxide) is generally recognized as safe (GRAS) material by FDA (Food and Drug Administration, USA) that is why it is used as food additive and in various medicine. The FESEM (Field Emission Scanning Electron Microscopy) of hydrothermally synthesize ZnO NPs showed that ZnO NPs are spherical in shape with a diameter of 20-30 nanometer. The XRD (X-rays Diffractometery) and TEM (Tunneling Electron Microscopy) studies of ZnO nanopowder synthesized by ultrasonic Spray pyrolysis (USP) technique showed that the crystalline size increased with an increase in the pyrolysis temperature and also exhibit direct band gap in the range 3.37 – 3.40 eV. Also the band energy gap of bulk ZnO crystals was approximately 3.3 eV. The SEM (Scanning Electron Microscopy) micrographs of ZnO NPS prepared by chemical method using PVP (Polyvinyl Pyrolidine) as capping agent showed spherical shape of nanoparticles, having band gap energy of 3.4 ev and these nanoparticles also showed lattice contraction due to high electrostatic interaction between Zn^{2+} and O^{2-} ions. ZnO is an important member of semiconducting material of II-VI group. Due to unique properties, ZnO is the richest family of nano structures among all semiconducting materials and thus used in the number of application like gas sensor, varistors and low voltage phosphor. ZnO is only semiconductor material extensively investigated after Si/Ge. Also nano cluster of ZnO, which exists as nanoparticles, nanobelts, nanorods, nanotubes, nanowires, nanoflowers as well as colloid and bulk nanoparticles also have shown potential/excellent luminescence properties.

Keywords: ZnO, GRAS, FDA, NPs, XRD, TEM, USP, SEM, PEG, CTAB, MEA, EG.

INTRODUCTION

ZnO is also known as "Lu-Gan Stone" in china and has been used in medical Treatment from number of years ago[14]. In 1966 Damen and Porto studied the Raman Effect study of ZnO, Which leads to the identification of ZnO phonon energies[15]. ZnO NPs has been employed as a powerful Heterogeneous catalyst during several organic transformations[16, 17, 18, 19, 20 & 21] with the increase in concentration of ZnO NPs, there is a decrease in the microstructuralline parameters (such as lattice strain and crystalline size)[22]. ZnO nanocrystals showed potential novel applications including photocatalysis (acts as photo catalyst)[23], transparent conductive oxides[24] , ultraviolet (UV) light absorbers[25], photocatalysis (i.e. highly active free radicals decomposing or dissociates organic molecules) were also useful as organic Pollutant scavenging and antifouling[26]. Which also helps in enhancing the photo catalytic properties of semiconductor nanoparticles (Such as ZnO NPs)[27 28 29 30]. In ZnO NPs when polymeric matrix was added, there was strongly change in physical mechanical, optical, thermal and other properties of a material[31 32]. Due to the weakened intermolecular Vander Waal's forces between the ZnO NPs. Also due to the versatile properties of ZnO NPs as biodegradability and biocompatibility[33], ZnO NPs were used as most efficient catalyst in the knoevenagel condensation and synthesize coumarins in High yield, through the Reaction between various ortho-hydroxy benzaldehydes with 1, 3 dicarbonyl compounds under microwave and thermal conditions[34]. The recent literature survey of nano ZnO [35] as Hetereogeneous catalyst received many versatile features because of its inexpensive, non toxic catalyst and has eco-friendly nature (such as low corrosion, minimum wasting, easy transportable recycling of the catalyst and easily disposal nature). The various organic ligands such as polyethylene glycol (PEG)[36], cetyltrimethyl ammonium bromide

(CTAB)[37], olic acid[38] and gelatin[39] acts a polymerization agents that had been used to control the morphology and size of ZnO NPs and also helps in order undergoing spontaneous growth and aggregation. ZnO synthesized by using Zinc Chloride and sodium hydroxide as precursors of different temperatures revealed that the size of the particles is directly proportional to the reaction temperature as well as ionic strength (i.e. Base concentration). The possible mechanism or reason for these above two observations is that the particles may acquire the shape and size in such a way so as to minimize the Gibb's free energy[40]. In contrast to physicochemical approach, Biological approach of formation of ZnO NPs is a simple and cost effective[41]. The formation of ZnO NPs biologically by using C. Procera (calotropis Procera), which is a desert plant known as madar in Grreco Arab medicine (Latex at Room Temperature) and is widely distributed in Tropical and subtropical Africa and Asia [42, 43]. In addition to this, for the synthesis of spherical shaped ZnO NPs milky latex of calotropis procera had been used as a reducing material as well as surface stabilizing agent[44]. In the recent studies in the field of biology[45, 46 ,& 47], many Researchers reported that ZnO NPs used in the treatment of Cancer [48,. 49, 50, 51 & 52]. Also the antibacterial properties of these ZnO NPs against Escherichia coli and staphylococcus aureus[53] were also studied. Furthermore ZnO NPs have good biocompatibility to human cell [54]. The possible mechanism for ZnO antibacterial activity is the release of Zn^{2+} ions which can damage the cell membrane and interact with interacellular contents[55].

Wide range of nanostructures of ZnO, makes it best suited for nanoscale optoelectronics (M.H. Huang et al, 2001)[56] and piezoelectric nanogenerators (J. Song et al, 2006)[57]. As Nano zinc oxide has antibacterial, antifungal properties it is been considered as efficient material in Medicine and Biotechnology field (Z.L. Wang et al; J.Sawai et al, 2004) [58, 59]. Unique optical, electrical and chemical properties of nano ZnO have increased its importance in electronic sector, solar cells, gas sensors, and photocatalytic degradation of chemicals (J. B. Baxter et al, 2005; Z. Ling et al, 2001; C. Y. Hsu et al, 2008; Y. Wang et al 2008) [60, 61, 62 & 63].

For the past decade, scientists have been involved in the development of new synthetic routes enabling the precise control of the morphology and size of the nanoparticles. In addition, nanoparticle synthesis can be possible *via* liquid (chemical method) [64, 65, 66, 67, 68 & 69], solid, and gaseous media [70 ,71, 72 & 73,], but due to several advantages over the other methods, chemical methods are the most popular methods due to their low cost, reliability, and environmentally friendly synthetic routes, and this method provides rigorous control of the size and shape of the nanoparticles[74, 75 & 76]. In general, nanoparticles with high surface-to-volume ratio are needed, but the agglomeration of small particles precipitated in the solution is the main concern in the absence of any stabilizer. In this regard, preparations of stable colloids are important for nanoparticle growth. In addition, nanoparticles are generally stabilized by steric repulsion between particles due to the presence of surfactant, polymer molecules, or any organic molecules bound to the surface of nanoparticles. Sometimes vander Waals repulsion (electrostatic repulsion) also plays important role in nanoparticles stabilization. With all the issues related to nanoparticle synthesis, there are various types of nanoparticles reported in the literature, e.g., metal nanoparticles, metal oxide nanoparticles, and polymer nanoparticles. Among all these, metal oxide nanoparticles stand out as one of the most versatile Materials, due to their diverse properties and functionalities. Most preferentially, among different metal oxide nanoparticles, zinc oxide (ZnO) nanoparticles have their own importance due to their vast area of applications, e.g., gas sensor, chemical sensor, bio-sensor, cosmetics, storage, optical and electrical devices, window materials for displays, solar cells, and drug-delivery [77, 78, 79, 80 & 81].

Nanostructures are of requisite claim owing to their incomparable dimension dependent properties and promising applications as building blocks in electronics, optoelectronics [82, 83 & 84], sensors & actuators and in bioimaging [85, 86]

Among them all, II–VI direct band gap semiconductors have engrossed substantial consideration due to their applications in light-emitting diodes[87, 88 & 89], photo-detectors, field emitters and full colour displays. [90, 91] The wide band gap and notably large binding energy make them an ideal choice for inorganic passivation shells in a variety of semiconductor core/shell nanocrystals and also an attractive host for the development of doped nanocrystals. [92, 93] In recent years, metal oxides and their nanostructures have emerged as an important class of materials with a rich spectrum of properties and great potential for device applications, e.g., transparent electrodes, high-electron mobility transistors, gas sensors, photovoltaic and photonic devices and hydrogen storage applications.[94] Of their class, wide-band gap oxide semiconductors have occupied the forefront in the past decade because of an increasing need for short wavelength photonic devices, high-power, high-frequency electronic devices. Although research on the wide bandgap oxides has been focused on a plethora of oxides e.g. TiO_2, CuO_2, SnO_2 and ZnO etc. among them, zinc oxide an II–VI semiconductor with a wide gap of 3.37 eV and sufficiently large exciton binding energy of 60 meV at room temperature making it suitable as a material for blue and ultraviolet light-emitting devices, has been of growing interest due to their scientific and technological importance. ZnO has a key of nanotechnology and well-recognized functional material suitable for various applications such as optoelectronic, the solar cell and so on. [95, 96, 97 & 98.] Nano-structured ZnO have been synthesized by various methods, such as chemical vapor deposition, [99] laser ablation,[100] molecular beam epitaxy[101] or a simply just by heating Zn powders with or without catalyst.[102] Because of the ability to produce high yield, easy scalability and low cost, the combination of thermal evaporation and vapor transport method has emerged as a promising route to grow ZnO nanostructures.[102, 103] In addition to the conventional nanowire and nanobelt structures, a diverse group of novel ZnO nanostructures has been discovered recently, such as nanocages,[104] anorings,[105] nanohelixes/nanosprings,[106] nanobows,[107] nanodiscs,[108] nanotetrapods[109] and nanocombs[110] etc. These novel nanostructures indicate that ZnO contains probably the richest family of nanostructures among all materials, in both structure and properties, and also provides valuable models for understanding the nanoscale crystal growth. This is in addition to the high potential ZnO has for fabricating novel nanoelectronics and optical devices with enhanced performance. It is now well known that the doping of nanocrystals can be achieved. [111, 112 & 113]

OBJECTIVE OF THE STUDY

From literature survey it is revealed the main objectives of this study as:

1) Versatile applications in industries at higher level.
2) In biology and medical sciences (in the treatment of cancer).
3) To aware the population about the utility of ZnO nanoparticles.

MATERIAL AND METHODS

ZnO NPs synthesized via sol-gel method in starch media were calcined at different temperatures exhibited a hexagonal (wurtzite) structure, ranging sizes from 30 to 50 nm[134].

The nanofuilds were synthesized by dispersion of ZnO NPs in EG (Ethylene glycol) solution using an ultra sonicator[135].

ZnO – SnO_2 (Zinc oxide-tin dioxide) nanocomposites were prepared from ZnO and SnO_2 NPs by using homogeneous precipitation route, in which Zinc acetate dehydrate [Zn $(CH_3COO)_2$.$2H_2O$] and tin (II) chloride dehydrates ($Sncl_2$, $2H_2O$) have been used as precursor, monoethariolamine (MEA) was used as a sol stabilizer[136].

ZnO flower like and brush pen like nanostructure can be formed on large scale by a hydrothermal decomposition route[137].

Chu et al recently reported a solution based high yield synthesis of co-doped ZnO nanorods with Room Temperature ferromagnetism[138].

Xu et al. reported on the high yield synthesis of single crystalline ZnO Hexagonal Nano plates[139].

Zinc oxides and indium ion doped ZnO Particles with different morphology (flower and prism like structure) were prepared in aqueous medium by the so-called hydrothermal method[140].

Colloid chemical synthesis method opens up ways to prepare nanoparticles with controlled size high specific surface area and phrases with various degree of crystallinity.

Amor Sayari in 2013, synthesized the nanocrystalline ZnO flakes via simple reaction process by using zinc acetate dehydrate dimethyl amine and sodium hydroxide under refluxing at 85°C for 4h [141].

A variety of methods such as thermal oxidation of metallic zinc, hydrothermal method, plasma chemical synthesis, laser ablation and vapor condensation[142, 143 & 144] have been used to synthesized uniform nanosized ZnO nanoparticles and control their size and morphology.

Pure nanocrystalline ZnO compound was synthesized by chemical co-precipitation method. The composite of polyaniline with nanosized prepared by in situ chemical oxidation. Polymerization method with ammonium per sulfate as an oxidant in aqueous HCL acid under constant stirring at 0-4°C in the presence of nitrogen atmosphere[145].

Kim Leang Khan et. Al in 2013 studied that ZnO nanoparticles were synthesized in an ethanolic medium and then mixed with chitosan solution prepared in 1% acetic acid. The result composite was used as a seed layer for the fabrication of vertically aligned ZnO nanorods[146].

P.K. Giri et al. synthesis low cost low temperature method with high yield (>90 %) of synthesizing ZnO nanoparticles by using two different catalysts (acetic acid and Trifluoroacetic acid)

Structural studies: The XRD and FTIR studies of synthesized ZnO NPs by sol-gel method revealed that all of the Zinc Oxide nanoparticles calcined at 400°C, 500°C and 600°C exhibited the hexagonal wurtzite structure.

X -ray diffractometer (XRD) study of synthesized ZnO-SnO_2 nanocomposites by homogeneous precipitation route showed that there are preferred crystal orientation and particle size of thin film.

ZnO nanorods with 30-40 nm diameter and 600-800 nm length were synthesized by a hydrothermal route and ZnO nanowires which had a diameter of 20-30 nm and length of 1-2 micro meter were prepared by an electrodeposition method [147].

The XRD, IR, SEM and TEM investigation of Nanocrystalline ZnO sensors prepared by chemical precipitation method showed that nano ZnO having wurtzite hexagonal structure and the average particle size of prepared ZnO sensors increased with increasing the sintering temperature and decreased with CeO_2 addition[148].

The FESEM measurement of ZnO nanoparticles synthesized by novel gas condensation process revealed that all the nano particles are in the structure of a Hexagonal prism and its average particle size is 20 mm. Also ESCA (electronic spectra for chemical analysis) study of this method confirmed the chemical elemental compositions and also confirmed that powder produced by this system is really ZnO [149].

The XRD spectrum of ZnO flakes prepared by a simple solution process indicates that these nanosized ZnO particles are highly crystallized in structure and the entire diffraction peaks matched well with Bragg reflection of the standard wurtzite type ZnO structure [150, 151]. The Uv-visible absorption of this process showed that ZnO nano particles has blue shift compare to that of ZnO bulk (375 nm) and demonstrated that this blue shift depends upon the nano crystal size[152].

The FTIR spectrum shows a characteristic significant spectroscopic band at around 521cm^{-1} [153] and also confirmed the high purity.

The ZnO nanoparticles incorporated HPMC films were prepared by the solution casting method revealed that there are decrease in 30% tensile strength , 37% in young's modulus and 24% in percentage elongation when the ZnO concentration is 0.04% [154].

P.K. Giri et al. confirmed that XRD patterns of ZnO nanoparticles shows excellent crystallinity. SEM and TEM images shows hexagonal cross section of the nanoparticles and nanorods and they also exhibit a strong Uv-absorption peak at ~378 nm and strong Uv-emission peak at ~380nm [155].

REVIEW OF APPLICATIONS

Zinc Oxide nanoparticles (ZnO NPs) have extensively used in cotton and wool fabrics for Uv-shielding as well as to impart sunscreen activity to the treated textiles[114].

Zinc Oxide nanoparticles are commonly applied in Pollutants Removal and disinfectants, because of its high chemical stability, oxidation- reduction capacibility and poison less characteristics.

Zinc Oxide nanoparticles are used as a suitable candidate for Luminescent materials due to its unique properties such as wide band gap (3.37 eV), large binding energy (60 meV) and Radiation hardness nature[115, 116].

Zinc oxide nanoparticles can also be used to increase the wash fastness, by dipping fabrics in a solution containing a specific binder[117].

In the decade of 1970, ZnO NPs was used in the manufacturing of simpler Zinc oxide devices like ceramic varistor and piezoelectric Transducer[118].

In comparison to bulk material, zinc oxide nanoparticles having a large surface area to volume ratio, which significantly helps increasing the effectiveness in blocking Uv-radiation[119].

ZnO has versatile applications including sunscreen food additives, pigments (paint pigment) Rubber manufacture and electronic materials.

Robust ZnO has important applications in the field of biosensors, solar cell window, piezo actuator devices surface acoustic devices and in gas sensors[120, 121].

In the knoevenagel condensation, ZnO NPs used as a most efficient catalyst for the synthesis of coumarins. In addition to this Knoevenagel condensation is one of the most useful and widely employed methods for carbon-carbon formation which helps in the synthesis of the fine chemical [122] hetero Diels Alder reaction[123].

ZnO NPs show high Piezo Electricity because it has melting point 1800°C and symmetrical (Hexagonal wurtzite) as well as not having symmetrical center.

Biological approach for the formation of ZnO NPs has versatile applications in biosensing electronics and photonics[124].

ZnO NPs is a biocompatible material with antiseptic properties.

ZnO NPs also used in the treatment of cancer biologically.

ZnO NPs can be used to produce vulcanisates with high tensile strength, tear resistance and hardness.

For the carboxylated elastomers, apart from the scorch problems, Zinc-oxide is used as a very effective and common cross linking agent[125].

Even DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid) damage has been raising industrial and academic concerns for the safe use of ZnO as effective Uv-shielding agent.

ZnO is used as an additive in the manufacture of concrete and as a coating agent in various paints[126].

ZnO NPs are utilized in electronic and electrical devices, image recorder, attenuation of light, High Temperature lubricant gas turbine engines, and also used as a demilitarization of chemical biological warfare agent[127]. ZnO NPs also exhibits various catalytic antibacterial, anticorrosive, antifungal and Uv-shielding/filtering properties.

Co-doped ZnO and Mn-doped ZnO would have a potential to be used as the durable Uv-shielding agents for the protection of plastics, textiles and other organic matters from Uv-rays.

ZnO NPs are used in the various commercial products such as cosmetics, sunscreen and also used in various antibacterial activities[128].

Nano ZnO in future is also used in Auto Industry. Nano ZnO is used in hydrogen fuel engine, in engine oil reduces friction, ZnO LED's used in head light (more efficient less power usage and longer life). Nano ZnO is also acts as an activator and accelerator in vulcanized rubber tyre, having longer working life[129].

Most sunscreen lotions that protects human skin from dangerous Uv-rays of sunlight whereby inorganic NPs (Titania and Zinc Oxide) as photo catalyst perform better than organic photo catalyst.

ZnO has been widely used in various filed and serves applications such as in catalysis[130] Gratzel type solar cells[131] and short wavelength light emitting devices[132, 133].

SCOPE OF FUTURE RESEARCH

Nano ZnO in future widely used in auto industry, due to its low cost ,reduces engine oil friction nature,in headlights of more efficiency, less power usage & longer life. Furthermore also extensively used in textiles industry & in various cosmetics or sunscreen lotions that protects human skin from dangerous Ultraviolet – rays.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my supervisor, Dr.Yogesh Kumar Walia for his constant guidance, support and encouragement throughout my studies. I wish to thank the Vice Chancellor of career point university, Hamirpur (H.P) for providing best internet facility ,& library facility. Lastely I also wish to thank department of chemistry.

REFERENCES

1. Emamifar A., Kadivar M., Shahedi M. and Za S.S. (2010) Evaluation of nanocomposites packing containing Ag and ZnO on shelf life of fresh orange juice, innovation food science and Emerging Technologies, 11, 742-748.
2. Pandey C.A, Sharda S.S. and Raghvendra S.Y. (2010) Application of ZnO nanoparticles in influencing the growth rate of cicer ariethinium, Journal of Experimental nanoscience, 5(6) 488-497.
3. Patil L.A., Bari A.R, Shinde M.D. and Deo. V. (2011) effect of pyrolysis Temperature on structural microstructural and optical properties of nanocrystalline ZnO powder Journal of experimental Nanoscience, 6(3), 311-323.
4. Khan R.Z, Arif M. and Singh A. Development and study of the structural and optical properties of hexagonal ZnO nanocrystals, international nanoletters a springer open journal.
5. Soosen Samuel. M, Bose. L. and George K.C. (2009) optical properties of ZnO nanoparticles, S.B. Academic Review, 16 (1-2), 57-65.
6. D. Beydoun, R.Amal, G.Low and S. McEvoy (1999) Role of Nanoparticles in Photo catalysis, J. Nanopart Res. 1(4), 439-458.
7. Gupta T.K. (1990) J. Am. Ceram Soc. 73, 1817.
8. Dijken A.V., Mulenkamp. E.A., Vanmae Kelbergh D., and meijerink. A (2000) I. Lumin, 90, 123.
9. Singh P.R., Shukla K.V. Yadav S.R., Sharma K.P., Singh K.P. and Pandey C.A. (2011) Adv. Mat. Lett., 2(4) 313-317.
10. J.S. Mossa, J.S. Tariq, M. Mossin, A. Ageel, A.M. AI-Yahya, M.A. AI-Said and M.S. Rafatullah (1991) S. American J. Chin Med. 19, 213.
11. Chopra R.N., Nager S.L. and chopra. I.C. (1956) Glossary of Indian Medicinal plant CSIR New Delhi, India, 46.
12. A Khorsand Zak, W.H. Abd. Majid, M.R. Mahmohdian, Majid Darroudi and Ramin Yousefi (2012) Starch-Stabilized synthesis of ZnO nanopowders of low temperature and optical properties study, Advanced powder technology.
13. Mitra. P., Chattergee A. and Maiti.H (1998) Mater. Lett., 35, 33.
14. Pareek S.S and Pareek. K (2013) An empirical study on structural optical and electronic properties of ZnO nanoparticels, IOSR journal of applied Physics (IOSR-JAP) 3(2), 16-24.
15. Damen T., Porto S.P.S and Tell. B. (1966) Phys. Rev., 142, 2.
16. Beckers J. and Rothenberg G. (2008) Dalton Trans., 6573.
17. Thathagar M.B., Beckers J .and Rothenberg G. (2003) Adv. Synth.Catal., 345,979.
18. Dejene F.B, All,A.G, Swart H.C. , Botha R.J., Liza , Coetsee KR and Biggs MM. (2011) optical properties of ZnO Nanoparticles via synthesized by Varying NaOH concentration, cent . Eur. J. Phys.,95,1321.
19. Hotchandani .S and Kamat . PV. (1991) J. electrochem. , Soc. , 113, 2826.
20. Sakohapa.S., Tickazen L.D., and Anderson M.A. (1992) J.Phys. Chem. , 96, 11086.
21. Harbour . J.R , and Halr ML. (1979) J.Phys.chem.,83,652.
22. Goddard W.A. , Brenner D.W. , Lyshevski S.E and Lafrate G.J. (2003) Handbook of Nanoscience Engineering and Technology (CRC.Press, London).
23. Hosono .H. (2007) Recent progress in transparent oxide semiconductors materials and device application , Thin solid films, 515(15) , 6000-6014.

24. Becheri A. , Durr M. , Nostro P.L and . Baglioni P. (2008) synthesis and characterization of Zinc oxide nanoparticles, application to textiles as Uv- absorbers , J. Nanopart. Res. ,10(4) , 679-689.

25. Deng D. , Martin S.T. and Ramanathan .S.(2010) synthesis and charactrerization of one dimensional flat ZnO Nanotower arrays as high effeciency absorbents for the photocatalytic Remediation of water pollutants, Nanoscale , 2(12), 2685-2691.

26. Obata. K, Irie. H. and Hashimoto K. (2007) enhanced Photo catalytic activities of Ta, N-Co-doped TiO_2 thin films under visible light chem. phys. 339, 124-132.

27. Xu C., Cao L.X., Su. G., Liu. W., Qu X.F. and Yu .Y.Q., Preparation characterization and photocatalytic activity of co-doped ZnO powders, J. Alloy Comp. 497 (1-2), 373-376.

28. Xang J.H, Zhao L.X., Zhang Y.J. wang, Y.X. and Liu H.C. (2009) X-ray study of the structure and magnetic properties of ZnO: (Co, Mn) Powders, J. Alloy, Compd., 473 (1-2), 543-545.

29. Lin D.D., Wu. H, Zhang R. and Pan W. (2009) enhanced photo catalysis of electrospum Ag-ZnO hetero structured Nano fibres, chem. Mater. 21(15), 3479-3484.

30. Kumar V.B, Halehatty, Naik B.S, Girija D. and Kumar V.B. (2011) ZnO nao particles as catalyst for efficient green one pot synthesis of coumarins through knoevenagel condensation, J. Chem. Sci., 123(5) 615-621.

31. V. Agabekov, N. Ivanova, V. Dlugunovich and I. Vostchula (2012) optical properties of polyvinyl alcohol films modified with silver nanoparticles, jounal of nanomaterials, 2012, 1-5.

32. Kumar R.T.R., McGlynn E., McLoughlin C, Chakrabarti S. Smith, R.C. Carely J.D. Mosnier J.P. and Henry M.O.(2007) control of ZnO nanorod array density by Zn supersaturation variation and effect on field emission, Nanotechnology.

33. Zhau J., Xu. N., and Wang Z.L (2006) Dissloving behaviour and stability of ZnO wires in biofluids : a study of biodegradability and biocompatibility of ZnO nanostructures, Advanced materials, 18, 2432-2435.

34. Moghaddam F.M., Saeidian H., Mirjafary Z. and Sadehi A. (2009) J. Iran Chem. Soc. 6, 317.

35. Shanti Kumar N., Abhilash S., Divya Rani VV., Deepthy M., Seema N, Manzoor K and Satish R (2009) J. Mater. Sci.: Mater. Med., 20, 235.

36. Cheng.B and Samulski.ET (2004) Hydrothermal synthesis of one dimensional ZnO nanostructures with different aspects ratio., Chemical communications, 8, 986-987.

37. Zhai H.J., Wu W.H., Lu F, Wang H.S and Wang C (2008) Effect of NH3 and cetyltrimethyl ammonium bromide (CTAB) on the morphologies of ZnO nano and micromaterials under solvothermal process, material chemistry and physics, 112, 1024-1028.

38. Xuan-Q, Hein S. and Misra R.D.K. (2010) New generation of chitosan encapsulated ZnO quantum dots loaded with drug: synthesis, characterization and in vitro drug delivery response Acta Biomaterialia, 6 (7), 2732-2739.

39. Zak A.K., Majid W.H.A., Darroudi M. and yousefi R. (2011) Synthesis and characterization of ZnO nanoparticles prepared in gelatin media, Materials letters, 65 (1) 70-73.

40. Mayekar J, Dhar. V. and Srinivassan. R. (2013) To study the rate of temeperature and sodium hydroxide conc. in the synthesis of ZnO nanoparticles, International Journal of scientific and research publications, 3 (11).

41. Shukla V.K., Singh R.P and Pandey A.C. (2010) J. Alloy Compd. 507, 113.

42. J.S. Mossa, J.S. Tariq, M. Mohsin, A. Ageel, A.M. AI-Yahya, M.A. A.I- Said and M.S. Rafatullah S. (1991) American J. Chin Med., 19,223.

43. Chopra R.N., Nagar S.L., and Chopra I.C. (1956) Glossary of Indian medicinal plants CSIR New Delhi India, 46.

44. Ravindra P.Singh, Vineet K. Shukla, Raghvendra S.Yadav, Parshant K.Sharma, Parshant K.Singh and Avinash C. Pandey (2011) Biological approach of ZnO Nps formation and its characterization advanced material letters, 2(4), 313-317.

45. Shanti Kumar N., Abhilash S., Divya Rani V.V., Deepthy M., Seema N., Manzoor K. and Satish R. (2009) J. Mater. Sci. mater. Med., 20 , 235.

46. Premanathan M., Karthikeyan K., Jeyasubramanian K and Govindasamy M (2001) Nanomedicine nanotechnology, Biology and Medicine, 7, 184.
47. Sharghi H. and Hsseini M. (2002) Synthesis, 1057.
48. Sarvari H. and Sharghi H. (2004) J. org. chem., 69, 6953.
49. Gupta M., Paul S., Gupta R. and Loupy A. (2005) Tetrahedron Lett., 46, 4957.
50. Hosseine, M. Sarvari (2005) Synthesis 787.
51. Kim Y.J and Varma R.S (2004) Tetrahedron Lett., 45, 7205, Hosseini Sarvari M. and Shaghi H. (2005) Tetrahedron, 61, 10903.
52. Tamaddon F., Amrollahi M. A. and Shrafat L. (2005) Tetrahedron Lett. 46, 7841.
53. Aswathi Sreenivasanev, Justi Javitta. C and S. Suja (2012) Synthesis of ZnO Nanoparticles from Alpinia parpurata and their anti microbial properties, Research Journal of Pharmaceutical, Biological and chemical sciences, 3(2), 1206-1213.
54. Podmawathy N. and Vijayaraghavan R. (2008) Enhanced Bioactivity of ZnO NPs antimicrobial study, science and technology advanced materials 9, 1-7.
55. Ravishankar Rai V. and Jamuna Bai, Nanoparticles and their potential applications as antimicrobial agents against microbial pathogens : Communicating current research and technological advances, A. Mendezvilas (Ed.)
56. M.H. Huang, S.Mao, H. Feick, H.Q. Yan, Y. Wu, H. Kind, E. Weber, R Russo, and P. Yang (2001), Room-Temperature Ultraviolet Nanowire, Nanolasers, In Sers. Science, 292(5523),1897.
57. J. Song, J. Zhou, and Z.L. Wang (2006), Piezoelectric and Semi conducting Coupled Power Generating Process of a Single ZnO Belt/Wire. A Technology for Harvesting Electricity from the Environment, Nano, Lett. , 6(8), 1656-1662.
58. Z.L. Wang (2004), Functional Oxides Nanobelts Materials, Properties and Potential Applications in Nanosystems and Biotechnology, Annu. Rev. Phys. Chem., 55, 159-196.
59. J. Sawai, and T.Yoshikawa (2004), Quantitative Evaluation of Antifungal Activity of Metallic Oxide Powders (MgO, CaO and ZnO) By an Indirect Conductimetric Assay, J. Appl. Microbiol. 96(4), 803.
60. J. B. Baxter, and E.S .Aydil (2005), Nanowire Based Dye Sensitized Solar Cells, *Appl. Phys. Lett.* 86, 53114.
61. Z. Ling, C. Leoch, and R. Freer (2001). Heterojunction gas sensors for environmental NO_2 and CO_2 monitoring. J *Eur Ceram Soc.,* 21, (10-11), pp.1977.
62. C. Y. Hsu, T. F. Ko, and Y. M. Huang (2008), Influence of ZnO buffer layer on AZO film properties by radio frequency magnetron sputtering, Journal Eur. Ceram. Soc, 28(16), 3065-3070.
63. Y. Wang, Li X, Wang N, Quan, Y. Chen (2008). Controllable synthesis of ZnO nanoflowers and their morphology-dependent photocatalytic activities, *Sep. Purif. Technol.*, 62(3), 727-732
64. D. C. Reynolds, D. C. Look, B. Jogai, J. E. Hoelscher, R. E. Sheriff, M. T. Harris, and M. J. Callahan, (2000) *J. Appl. Phys.* 88, 2152 .
65. J. H. Lim, C. K. Kong, K. K. Kim, I. K. Park, D. K. Hwang, and S. J. Park,(2006) *Adv. Mater.* 18, 2720 .
66. M. T. Mohammad, A. A. Hashim, and M. H., and Al-Maamory, (2006) *Mater. Chem. Phys.* 99, 382 .
67. A. B. G. Lansdown and A. Taylor, (1997) *Int. J. Cosmet. Sci.* 19, 167 .
68. J. H. Kim, Y. C. Hong, and H. S. Uhm, (2007) *Surf. Coat. Technol.* 201, 5114 .
69. M. S. Tokumoto, V. Briois, and C. V. Santilli, (2003) *J. Sol–Gel Sci. Technol.* 26, 547.
70. J. Zhang, L. D. Sun, J. L. Yin, H. L. Su, C. S. Liao, and C. H. Yan,(2002) *Chem. Mater.* 14, 4172.
71. M. M. Demir, R. Munoz-Espi, I. Lieberwirth, and G. Wegner, (2006) *J. Mater. Chem.* 16, 2940 .
72. S. Park, K. R. Lee, C. H. Jung, S. J. Kim, and H. C. Shin, (1996) *Jpn. J. Appl. Phys.* 35, 996 .
73. L. C. Damonte, L. A. M. Zelis, B. M. Soucase, and M. A. H. Fenollosa,(2004) *Powder Technol.* 148, 15 .
74. R. Radoi, P. Fernandez, J. Piqueras, M. S. Wiggins, and J. Solis, (2003) *Nanotechnology* 14, 794.
75. X. Zhao, B. Zheng, and C. Li, (1998) *Powder Technol.* 100, 20.

76. J. S. Lee, K. Park, S. Nahm, M. IL. Kang, I. L. W. Park, S. W. Kim, W. K. Cho, H. S. Han, and S. Kim, (2003) *Cryst. Growth*, 254, 423 .
77. J. B. Baxter and E. S. Aydil, (2005) *Appl. Phys. Lett.* 86, 53114 .
78. M. H. Huang, S. Mao, H. Feick, H. Q. Yan, Y. Wu, H. Kind, E. Weber, R. Russo, and P. Yang, (2001) *Science*, 292,1897 .
79. J. Song, J. Zhou, and Z. L. Wang, (2006) *Nano Lett.* 6, 1656 .
80. Z. L. Wang, (2004) *Annu. Rev. Phys. Chem.* 55, 159.
81. J. Sawai, H. Igarashi, A. Hashimoto, T. Kokugan, and M. Shimizu, (1996) *J. Chem. Eng. Japan* 29, 556 .
82. J. F. Wang, M. S. Gudiksen, X. F. Duan, Y. Cui and C. M. Lieber, (2001) Science, , 293, 1455.
83. J. Hu, L. Li, W. Yang, L. Manna, L. Wang and A. P. Alivisatos, (2001) Science, , 292, 2060.
84. R. S. Friedman, M. C. McAlpine, D. S. Ricketts, D. Ham and C. M. Lieber, (2005) Nature, 434, 1085.
85. W. C. W. Chan and S. Nie, (1998) Science, 281, 2016.
86. M. Bruchez, M. Moronne, P. Gin, S. Weiss and A. P. Alivisatos, (1998) Science, 281, 2013.
87. T. Matasuoka, (1996) Adv. Mater., 8, 469.
88. J. Wang, D. C. Hutchings, A. Miller, E. W. Van Stryland, K. R. Welford, I. T. Muirhead and K. L. Lewis, (1993) J. Appl. Phys., 73, 4746.
89. J. Singh, S. S. Patil, M. A. More, D. S. Joag, R. S. Tiwari and O. N. Srivastava, (2010) Appl. Surf. Sci., 256, 6157.
90. H. Jeon, J. Ding, W. Patterson, A. V. Nurmikko, W. Xie, D. C. Grillo, M. Kobayashi and R. L. Gunshor, (1991) Appl. Phys. Lett., 59, 3619.
91. D. J. Norris, N. Yao, F. T. Charnock and T. A. Kennedy, (2001) Nano Lett., 1, 3.
92. M. A. Malik, P. O'Brien and N. Revaprasadu, (2001) J. Mater. Chem., 11, 2382.
93. T. J. Jr. Norman, D. Magana, T. Wilson, C. Burns, J. Z. Zhang, D. Cao and F. Bridges, (2003) J. Phys. Chem. B, 107, 6309.
94. Z. L. Wang (ed.) (2003) Nanowires and Nanobelts - materials, properties and devices;Vol. II: Nanowires and Nanobelts of Functional Materials, Kluwer Academic Publisher.
95. S. Singh, P. Thiyagarajan, K. M. Kant, D. Anita, S. Thirupathiah, N. Rama, B. Tiwari, M. Kottaisamy and M. S. R. Rao, (2007) J. Phys. D: Appl. Phys., 40, 6312.
96. Y. B. Li, Y. Bando and D. Golberg, (2004) Appl. Phys. Lett., 84, 3603.
97. U. Ozgur, Y. I. Alivov, C. Liu, A. Teke, M. A. Reshchikov, S. Dogan, V. Aurutin, S. J. Cho and H. Morkoc, (2005) J. Appl. Phys., 98, 043101.
98. C. Jagdish and S. Pearton, (2006) Zinc Oxide Bulk, Thin Films and Nano Structures Processing, Properties and Applications, Elsevier, Oxford IX51GB UK,.
99. D. C. Kim, B. H. Kong and H. K. Cho, (2008) J. Mater. Sci.: Mater. Electron., 19, 760.
100. Z. W. Liu and C. K. Ong, (2007) Mater. Lett., 61, 3329.
101. W. I. Park, D. H. Kim, S. W. Jung and G. C. Yi, (2002) Appl. Phys. Lett., 80, 4232.
102. J. Singh, R. S. Tiwari and O. N. Srivastava, (2007) J. Nanosci. Nanotechnol., 7, 1783.
103. U. Manzoor and D. K. Kim, (2006) Scr. Mater., 54, 807.
104. P. X. Gao and Z. L. Wang, (2003) J. Am. Chem. Soc., 125, 11299.
105. X. Y. Kong, Y. Ding, R. Yang and Z. L. Wang, (2004) Science, 303, 1348.
106. X. Y. Kong and Z. L. Wang, (2003) Nano Lett., 3, 1625.
107. W. L. Hughes and Z. L. Wang, (2004)J. Am. Chem. Soc., 126, 6703.
108. P. X. Gao, C. S. Lao, Y. Ding and Z. L. Wang, (2006) Adv. Funct. Mater., 16, 53.
109. J. Singh, A. Srivastava, R. S. Tiwari and O. N. Srivastava, (2005) J. Nanosci. Nanotechnol., 2093.
110. C. S. Lao, P. X. Gao, R. S. Yang, Y. Zhang, Y. Dai and Z. L. Wang, (2005) Chem. Phys. Lett., 417, 359.
111. P. Kumar and K. Singh, (2011) J. Am. Chem. Soc., DOI: 10.1021/ ja2088426.
112. P. Kumar and K. Singh, (2011) Nanopart. Res., 13, 1613.
113. P. Srivastava, P. Kumar and K. Singh, (2011) Nanopart. Res., 13, 5077.

114. Alessio Bacheri, Maximilian Durr, Pierandrea Lo Nostro and Piero Baylioni (2008) Synthesis and characterization of ZnO Nanoparticles J. Nanopast Res., 10, 679-689.

115. Nakanishi Y., Miyake A., Kaminami H., Aoki T, Hatanaka X., and Shimaoka G. (1999) Preparation of ZnO thin films for high resolution field emission display by electron beam evaporation, Applied Surface Science, 142, 233-236.

116. Fujihara S., Ogawa Ya and Kasai A. (2004) Tunable Visible Photoluminescence from ZnO thin film through Mg-doping and annealing, Chemistry of materials, 16(15), 2965-2968.

117. Vigneshwaran N., Kumar S., Kathe A.A., Varadarajan P.V. and Prasad V. (2006) Function finishing of cotton fabrics using ZnO- soluble starch nanocomposites, Nanotechnology, 17, 5087-5095.

118. Shyam Sundar Pareek and Kapil Pareek (2013). An empirical study on structural, optical and electronic properties of ZnO nanoparticles, IOSR jounal of applied physics (IOSR-JAP), 3 (2), 16-24.

119. Yadav A., Prasad V., Kathe A.A., Raj. S., Yadav D., Sundar Moorthy C. and Vigneshwaram. N (2006) Functional finishing in cotton fabrics using zinc oxide nanoparticles, Bull Mater. Sci, 29, 641-645.

120. Shi J.H., Huang S.M., Chu J.B., Zhu H.B., Wang Z.A, Li X.D., Zhang D.W., Sun Z., Cheng W.J., and Huang FQ. (2010) Effect of ZnO buffer layer on AzO film properties and photovoltaic application, J. Mater. Sci., 21,1005.

121. Chivukula V., Clplys D., Shur. M. and Dutta P. (2010) ZnO nanoparticle surface acoustic wave UV-sensor, Appl. Phys. Lett., 96, 233-512.

122. Freeman. F. (1981) Chem. Rev., 80. 329.

123. Tietze LF. and Saling PM. (1992) Synlett., 281.

124. Ravindra P. Singh Vineet K. Shukla, Raghvendra S. yadav Prashant K. Sharma Parshant K. Singh and Avinash C. Pandey (2011) Biological approach of ZnO NPs formation and its characterization Adv. Mat. Lett. 2(4), 313-317.

125. M. Przybyszewska and M. Zaborski (2009) The effect of ZnO nanoparticles morphology on activity in cross linking of carboxylates Nitriles elastomer , eXPRESS Polymer Letters, 3(9), 542-552.

126. Juan Xie, Hu Wang, Ming Duan and Liehai Zhang (2011) Synthesis and Photo catalysis properties of ZnO structures with different morphologies via Hydrothermal method applied surface science, 257, 6358-6363.

127. ZnO nanoparticles/Nanopowders (ZnO, 99+%, 10-30 nm, www.us-nano.com/inc/&detail/355)

128. Mingsheng Xu, Daisuke Fujita, Shoko Kajiwara, Takashi Minowa, Xianglan Li, Taro Takemura, Hidlo Lwai and Nobutaku Hanagata (2010) Biomaterials.

129. A thesis on synthesis and characterization of ZnO nanostructures → Shahrom Bin Mahmud, University Sains Malaysia (2008).

130. King D.S. and Nix R.M. (1996) Thermal stability and Reductibility of ZnO and Cu/ZnO catalysts J. Catal/60, 76-83.

131. Zhang J., Kitai A.H., Mascher P. and Puff W.J. (1993) The influence of processing conditions on point defect and luminescence centres in ZnO, Electrochem. Soc., 140, 3644-3649.

132. Cao H., Xu J.X., Zhang D.Z., Chang S.H., Ho. S.T., Seeling E.W., Liu X. and Chang R.P.H. (2000) Spatial confinement of laser light in active random media, Phys. Rev. Lett., 84, 5584-5587.

133. Baynall D.M., Chen Y.F., Zhu Z., Yao. T., Kagama. S., Shen M. Y. and Goto T. (1997) Optically pumped lasing of ZnO at Room Temperature , Appl. Phys. Lett. 70, 2230-2232.

134. A khorsand Zak, W.H. Abd Majid, M.R. Mahmoddian, Majid Darroudi and Ramin Yousefi ,Starch Stabilized synthesis of ZnO nano powder at low temperature and optical properties study, Advanced powder technology Journal Homepage. (www.elsevier.com/locateopt).

135. D.K. Singh, D.K. Pandey, R.R. Yadav and Devraj Singh (2013) A study of ZnO NPs and ZnO-EG nanofluid, Journal of experimental nano science, 8(5), 731-741.

136. Gultekin, Deniz, Alaf, Mirac, Guler, Mehmet Qguz Aubulut and Hatem (2012) Synthesis of Zn, SnO_2 nanoparticles and Preparation of ZnO-SnO_2 Nano composites, Journal of Nanoscience and Nanotechnology, 12(12), 9175-9182.
137. W.Bai, K.Yu, Q Zhang, F.Xu., D. Deng and Z. Zhu (2007) Mater. Lett., 61, 3469.
138. D. Chu, Y. Zeng and D. Jiang (2007) J. Am. Ceramic Soc., 90, 2269.
139. F.Xu, Z-Y Yuan, G-H. Du, M. Halasa and B-L. Su (2007) Appl. Phys. A. 86, 181.
140. Optical structural and photoelectric properties of ZnO NPs and hybrid Thin layers. Kunne Pal Edit Supervisor => Dr. Dekang Imre. Professor member of the Hungarian Academy of science, chemistry doctoral school Unv. of Szeged, Depart. of colloid chemistry (2009).
141. Amor Sayari (2013) Characterization of Nanocrystalline ZnO flakes synthesized by a simple Reaction process, KONA powder and particle journal, 30, 119-124.
142. Jang J., Kim C., Ryu. H., Razeghi M. and Jung W.(2008) ZnO 3D flower like nano structure synthesized by GaN epitaxial layer by simpler rate hydrothermal process, J. Alloy comp., 463, 503-510.
143. Huang M.H., Mao S., Feick.H ., Yan H.Q., Wu Y.Y. , Kind. H., Weber E. , Russo R. and Yang P. (2001) Room Temperature ultraviolet Nanowire nanolaser, Science No. 292, 1897-1899.
144. Fan H.J., Scholz.R., Kolb F.M. and Zarcharias M. (2004) Two dimensional dendritic ZnO nanowires from oxidation of ZnO microcrystals, Appl. Phys. Lett., 85, 4142-4144.
145. http:// derpharmachemica.com/archive.html).
146. Kimleng Khan, Zafar Hussain, Ibupoto, Mohomad S., Alsathi Muhammad Atif, Anees A. Ansari and Magnus Willander (2013) Fabrication of well aligned ZnO nanorods using a composite seed layer of ZnO nano Paritcles and chitosan polymer materials journal, 6, 4361-4374.
147. A thesis on Synthesis of ZnO Nanowires and application as gas sensor → By Mintang Liu (university of Saskatchewan Saskatoon), (2010) Canada, 110 science place, Saskatoon, S7N5C9.
148. A.M. El-Sayed, F.M. Ismail, M.H. Khder, M.E.M. Hassouna and S.M Yakoot (2012) Effect of CeO_2 doping on the structure electrical conductivity and ethanol gas sensing properties of nanocrystalline ZnO sensors, International Journal on Smart sensing and intelligent system, 5(8), 606-623.
149. Ho Chang and Ming Hsun Tsai (2008) Synthesis and characterization of ZnO nanoparticles having prism shape by a novel gas condensation process, Mater. Sci., 18, 734-743.
150. Liu B and Zeng H.C. (2003) Hydrothermal synthesis of ZnO nanorods in region of 50 nm, J. Am. Chem. Soc., 125, 4430-4431.
151. Shen G.Z., Cho J.H., Xoo J.K., Xi G.C. and Lee C.J. (2005) Synthesis and optical properties of S-doped nanostructure: Nano nails and Nano wires, J. Phys chem. B, 109 5491-5496.
152. Ashtaputre S.S., Dephpande A., Marathe S., Wankhede M.E., Chimanpure J., Parischa R., Urban J., Huram S.K., Gosavi S.W. and Kullkarni S.K.(2005) Synthesis and analysis of ZnO and CdSe nanoparticles, Pramonna J. Phys., 65, 615-620.
153. Gupta T.K. (1992): Micro structural engineering through donar and acceptor doping in the grain and grain boundary of a polycrystalline semiconducting, Ceramic J. Mater. Res., 7, 3280-3295.
154. B.Lakshmeesha Rao, Songappa S. Asha, Mahadeviah and R. Somashekar, Microstrutural and mechanical properties of ZnO nanoparrticles incorporated HPMC films, International journal of science research 1(4).
155. P.K. Giri, S. Bhattacharyya, B.Chetia, Satchi kumari, Dilip K. Singh and P.K. Layer (2011) High yield chemical synthesis of Hexagonal ZnO Nanoparticles and nanorods with excellent optical properties, Journal of Nanoscience and Nanotechnology, 11, 1-6.