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Studies of Zinc Oxide Nanoparticle Synthesis Methods and Effect on its Structure, Characteristics and Morphology : A Review

Dr. B. S. Surung [*1], Dr. R. M. Lokhande[2], Mrs. M. R. Thokare[3]

[*1]Department of Physics, Lalbahadur Shashtri Sr. College, Partur, Maharashtra, India

[2]Department of Physics, DNCVPS Shirish Madhukarrao Chaudhari College, Jalgaon, Maharashtra, India

[3]Department of Physics, J. E. S. College, Jalna, Maharashtra, India

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ABSTRACT

Now a day's more interesting and attracting point in research area is the synthesis of nanomaterials with specific properties. Nanotechnology allocate with the production and usage of material with nanoscale dimension to provide nanoparticles are large surface area to volume ratio, this is very important properties of the nanoparticles (NPs). So this review done on ZnO nanoparticles because of it recently studies of various authors due to change in its properties at small scale range and unique properties of zinc oxide (NPs) nanoparticles more attention in research areas. Zinc oxide nanoparticles (ZnO NPs) had been in recent studies due to its large bandwidth and high excitation binding energy. Zinc oxide nonmaterial has number of application depending upon the size and shape of produced nonmaterial such as LED, sensors, photo-detector, anti bacterial, anti fungal etc. The chemical synthesis of nanomaterials via Solvothermal, Hydrothermal and Sol-gel method's are effective because of high quality crystalline structure are produced, as a result of this morphology of the synthesized nonomaterials are excellent. We go through the various research papers and discuss the synthesis of ZnO particles with different methods by the various authors.

Keywords : Zinc oxide nanoparticles, Nanostructure nanoparticles, Morphology, Nanomaterials, Hydrothermal, Solvothermal, Sol-gel methods.

I. INTRODUCTION

Nanoparticles are very small sized particles having Nano scale dimension therefore one 1 nm = 10^{-9} m. Nanoparticles enhance the catalytic reactivity, thermal conductivity, optical performance and chemical reactivity due to its large surface area to volume ratio [1]. One example of transition metal oxide is zinc oxide that exhibit specific electric optical and mechanical properties. Due to their unique property they have number of applications in the field like pharmaceutical electronics optical and electrical devices [2-6]. The morphology of zinc oxide nanoparticle has a significant role in their applications [7].

Nanoparticles have been integrated in to various industrial, health's, food, space, chemical and cosmetic industry of consumers which calls for a green and environmental eco-friendly approach to their synthesis [8]. Zinc oxide nanoparticles synthesis by chemical methods root comparative study on hydrothermal, Solvothermal, sol-gel, chemical bath deposition, weight chemical process, spray pyrolysis, microemulnsion and precipitation synthesis methods [9-15].

Zinc oxide nanostructure was successfully synthesized by using sol-gel method and the result of zinc oxide Nano rod like structure obtained and has ability to control the particle size and morphology through systematic monitoring of reaction parameters. Synthesized nanoparticle was characterized by using XRD, EDX and FESEN and analysis. XRD of zinc oxide Nanoparticle shows good purity [16].

In this literature authors studied number of techniques are being developed for a suitable and easy to achieve desire property of synthesized nanostructure. However it was reported that wet chemical techniques of nanoparticles synthesizing metal oxide nanomaterials usually produced impure particles with larger particle size [17]. Therefore new researchers having interest in an efficiency synthesis process for the nonomaterial. This is a key factor for synthesized of nanocrystalline materials and review appropriate three chemical synthesis methods that are Hydrothermal, Solvothermal and Sol-gel synthesis methods, comparatively study on future features of zinc oxide nanoparticles for its specific application.

II. METHODS FOR THE SYNTHESIS OF NANOMATERIAL

We studied how to synthesis the nanomaterials by the various methods in some of them we cannot control the size and shape of nanomaterials when it is synthesized via physical method, but in chemical method we can control the shape and size of nanomaterials. Here we studied the number of research paper and discuss the method used for the synthesis of nonomaterial but we write only three method of them out of these we focus on the Sol-gel method due to its result are better than other studied method.

1. Hydrothermal Methods: One of the most used methods for synthesis of nanoparticle is hydrothermal method. It is solution reaction based approach and water is used as solvent. In this case mixture of precursor heated in autoclave above the boiling point of water, consequently pressure within the reaction is increases above the atmospheric pressure.

For the synthesis of nanoparticles through hydrothermal method these authors use solution of 0.5 M Zinc Nitrate in 30 ml distilled water for stirring it for 30 min. Meanwhile 5 M Sodium Hydroxide solutions were prepared by mixing weighed pellets of NaOH in 30 ml distilled water under stirring for same duration. NaOH solution is added drop wise to former solution under continuous stirring until Ph of the reactants becomes 12 [18-21].This solution mixture was transferred into Teflon lined sealed stainless-steel autoclaves and kept in hydrothermal oven at a temperature of 100 °C for 2 hour. Then the beaker was taken outside and cools at room temperature. The resultant solution was filtered, then washed with distilled water and kept for drying under lamp. The experimental procedure is repeated for 125 °C and 150 °C by keeping 2 hour duration as constant and for the different samples. Samples were also prepared by varying the reaction time and keeping temperature as constant. Samples synthesized at a temperature of 120 °C for a reaction time of 1 hour, 3 hour and 5 hour for different sample. The method of preparation for the nanoparticles is shown in scheme 1. [18-21]

The synergistic effect of high temperature and pressure provides one stay process to produce highly crystalline material without need post annulling treatment. Novel seat like ZnO nanocrystals were successfully fabricated by using as template unite and ZnO has functional unite through one step hydrothermal process. Formation of CNC ZnO nanohybride with hexagonal seat like structure shows good antimicrobial activity, photo catalytic activity of 95% of methylene blue dye [22]. ZnO Nana particles were synthesized by hydrothermal method under different reaction condition, reaction parameter play a very important role in determining the size and shape of nanoparticle. Nanoparticle grain size was found to be decreases with increasing reaction temperature and reaction time. TEM image shows nano roads, nano flower and nanosphere at different temperature. Material zinc nitrate sodium hydroxide and distilled water was used through experimental [23]. The hexagonal wurtzite ZnO nanocrystals were produced from microwave-assisted hydrothermal technique. This study reported that variation of reaction temperature and time produced diverse morphologies (flower-like, rod-like, and spherical granular) and increase in temperature time decreased the crystallite size (46.19, 41.66, and 34.74 nm), whereas an increase in reaction time increased the size (44.76, 53.51, and 78.21 nm). Ming et al. [24].

2. Sol-gel Methods: Sol -gel means the combination of Sol that a colloidal form of suspended solid particles and gel that is solid macromolecules dissolved in solvent. This method completed through three steps as Hydrolysis, Polycondensation and Drying. Sol is the formation of stable solution of the metal oxide with distilled water or non aqueous solvent such as ethanol, alcohol, ketoses etc. Which were stirred for some time depending upon the precursor, after well mixing of solution, titrated with ethanol drop wise after the condensation reaction precipitation formed. Calcinations of the gel get nanomaterials ZnO nanoparticles was successfully synthesizing using Zinc acetate dehydrate having purity about 99%, and it acts as precursor, Sodium hydroxide having purity 98% acts as solvent, ethanol acts as reagent and distilled water. This author obtained the ZnO rod like structure and having size of 84.98 nm in powder crystalline form [16].

A small quantity of ZnO Nano powder watch what's continuously dispersed in a mixture of ethanol, dematerialized water and ammonium hydroxide solution in a ultrasonication bath for one hour and three types of metallic substrates aluminum, copper and zinc are use to test corrosion with ZnO NPs [25]. Preparation of ZnO nanoparticle by Zn (No_3), $6H_2O$, zinc nitrate and $C_6H_8O_7$ were as starting materials. Polythene glycol, ethylene glycol and polyvinyl alcohol where used as surfactant by Sol-gel method. [26]. In this research the use of materials are zinc acetate dihydrate sodium hydroxide methanol's and distilled water. Zinc acetate the hydrate is precursors, ethanol acts as agent and distilled water used as solvent. [27].

Table 1: Some of studied the ZnO nanoparticle synthesized via Hydrothermal Methods are listed in the below table

Sr. No.	Precursor or Reactant	Condition for Synthesis	Structures/Properties	Applications	References
1	Zn(Ac)$_2$-2H$_2$O, NaOH and Solvent Water/Ethanol	Reaction temp. 100^{0}C for 45 min. & 140^{0}C for 60 min. MWP = 800 W Drying temp. 80^{0}C for 24 hrs. pH = 10	Flower like, plate like and brush like/ Band Gap 3.17/3.24 eV	Photocatalyst agents	*[29]*
2	Zn(No$_3$)$_2$, NaOH	pH = 8.3 Microwave irradiation 1-5 min. Drying temp. 70^{0}C	Flower like, plate like/ Particle size 100-200 nm	Boi-imaging	*[30]*
3	ZnCl$_2$,NaOH, CTAB, Pluronic:F127	MWP = 2.45 GHz, 130W for 5 min. Reaction temp. 50^{0}C for 90 min. Drying temp. 60^{0}C overnight	Plate like and Cone like/Particle size 92.8 nm; 58.1 nm for CTAB 80.2 nm for Pluronic F127, Band Gap 3.36 eV for CTAB 3.34 eV for pluronic F127	Photocatalyst	*[31]*
4	Zn(Ac)2·2H2O, TEOA,BTCA, KOH	Microwave power: 2.45 GHz, 800 W, 150°C, 30 min; Drying temp: 100 °C; pH = 12/13	Dumb-bell (pH 8), Spherical (pH 9) Hexagonal bi-pyramidal (pH 10); Surface area: 35, 15, 25 m2 /g (Dumb-bell, spherical, hexagonal bi-pyramidal); Particle size: 195, 430, 60 nm (Dumbbell, spherical, hexagonal bi-pyramidal)	Photoelectrode	*[32]*
5	Zn(NO3)2·6H2O, NaOH (4, 5 & 6 mol of NaOH	Microwave power: 110 ºC for 1 h; Drying temp: 80 ºC for 24 hours.	Star-like , flower-like structures; Energy band gap: 3.21, 3.22 & 3.24 eV; Crystallite size: 26, 24, 21 nm respectively.	Photocatalyst for reduction of chromium(VI)	*[33]*
6	Zn(NO3)2·6H2O, NaOH	Microwave power: 2.45 GHz, 1000 W, 10 min; Drying temp: 60 ºC 24 hours pH = 10	Spindle-like; Crystallite size: 21 nm; Surface area: 11.06 m2 /g (ZnO)	Antibacterial inhibitor &Antdiabetic	*[34]*
7	Zn(NO3)2, NaOH	Irradiation time: 15 min; Drying temp: 60 ºC for 24 h; pH = 10	Spherical shape; Crystallite size: 15.5 nm (ZnO)	Antdiabetic activity	*[35]*
8	Zn(Ac)2·2H2O, TRIS (20%)	Microwave power: 300 W for 3 min; Drying temp: 80 °C overnight	Spherical; Energy band gap: 3.49 eV	Antifungal agent	*[36]*
9	Seed layer preparation: Glass substrate,	Reaction temp: 60 ^{0}C for 1 h; Drying temp: 300 ^{0}C for 10	Rod-like; Crystallite size: 9-25 nm (seed layer), 38-56 nm (nanorods); Particle size: 180-	UV Sensor	*[37]*

	Zn(Ac)2·2H2O, C2H7NO, C3H8O2 deposit by spin coating Precursor growth: Seeded substrate, Zn(NO3)2·6H2O,HMTA	min; Calcination temp: 100-500 ^{0}C, Microwave power: 90 oC, for 1 hours.	350 nm (nanorod length); Energy band gap: 3.22-3.30 eV (seed layer), 3.17-3.98 eV (nanorods)		
10	Zn(NO3)2·6H2O, C6H12N4 (mole ratio of 3:20, 5:20, 12:20, 20:20 and 30:20)	Microwave power: 750 W, ~120 °C for10 min; Drying temp: 80 °C for 24 h; Calcination temp: 400 °C for 1 hours	Spherical to hexagonal rod-like structures; Crystallite size: 16.7-57.9 nm; Particle size: 25 nm to micro/sub micro sizes	Antimicrobial agent	*[38]*
11	Zn(NO3)2·6H2O, NaOH (1:15 molar ratio), PEG	Microwave power: 2.45 GHz, 320 & 480 W for 5 s & 15 s; Drying temp: 80 °C for 24 h; Calcination temp: 450 °C for 1 hours	Needle-like (320 W), Rod-like (480 W); Particle size (PEG free/PEG): < 500 nm/ 300 nm length (320 W), 2 µm/3 µm length (480 W); Energy band gap: 3.24 Ev (PEG free), 3.10-3.23 eV (PEG)	Photocatalyst in the degradation of methyl blue (MB)	*[39]*

Table 2: Some of studied the ZnO nanoparticle synthesized via Sol-gel Methods are listed in the below table

Sr. No.	Precursor or Reactant	Condition for Synthesis	Structures/Properties	Applications	references
1	Zn(CH3COO) 2 , oxalic acid, etha-nol and methano	reaction temperature: 60 °C; drying: keep solution 24 h, 80 °C; calcination: 500 °C	Zincite structure; aggregate particles: ~100 nm; shape of rod; particles L: ~500 nm, D: ~100 nm; BET: 53 m2	--	*[46]*
2	ZnCl2, NaOH	Reaction temp: 50-90 °C; Dripping time: 20-60 min; Drying temp: 70 °C	Crystallite size: 21-37 nm	Photocatalyst in the degradation of dyes	*[47]*
3	ZnSO4·7H2O, NaOH (1:1, 1:2, & 1:3 mole ratio)	Reaction time: 8, 10 & 12 h; Drying temp: 100 ^{0}C; Calcination temp: 300, 500, & 700 ^{0}C for 2 h	Nanoplatelets (1:1, 10 h, 300 ^{0}C), nanospheres (1:2, 8 h, 700 oC), nanoplatelets and nanorod (1:3, 12 h, 500 ^{0}C); Particle size: 164-197 nm (300 oC), 1.73-167 nm (500 ^{0}C), 85-157 nm (700 ^{0}C); Crystallite size: 40.57 nm	Reinforcement agent for polymers	*[48]*
4	Zn(NO3)2·6H2O, PVA	Reaction temp: 80 ^{0}C for 60 h; Drying temp: 100 ^{0}C for 24 h; Calcination temp: 400-700 ^{0}C	Spherical; Crystallite size: 15-51 nm (400-550 ^{0}C); Particle size (TEM): 15 nm (400 ^{0}C), 25 nm (500 ^{0}C)	Photocatalyst in the degradation of phenol	*[49]*

III. CONCLUSION

The zinc oxide nanoparticle was successfully synthesized by Hydrothermal, Solvothermal and Sol-gel methods for the given sample. This shows that synthesized nanomaterials having nano rod, flower and disc plate like structure. Author suggested that hydrothermal technique become useful for the precursor which is difficult to dissolve at low temperature or room temperature. In hydrothermal synthesis nanomaterials can takes place in wide temperature range from room temperature to high temperature. Nanomaterials synthesized by hydrothermal are large size and high quality crystals but this is costly method.

In Solvothermal techniques author used as non aqueous organic solvent such as ethanol, ammonia, methanol etc. depend upon the precursor used for the synthesis of nanomaterials. In this method used non aqueous solution are evaporated at specific temperature. Sol-gel method is better than the above state method for the synthesis of nanomaterials because it control over the shape and growth of synthesized nanoparticle and also avoids the reaggregation. In this method synthesized high purity, homogenous nanomaterials. The best of this method is that it processing at low temperature, minimizing the evaporation loss.

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