A Review of ZnO Nanoparticles Synthesized by Hydrothermal Method

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ABSTRACT

In Nanotechnology, Metal Oxide Nanoparticles have gained a particular interest in the researcher due to their tuneable properties like optical, electronic, magnetic, catalytic, antimicrobial, etc. Nanostructured ZnO materials have attracted a lot of attention from researchers due to their remarkable performance in Electronics, Optics and Pharmaceutical industries. This paper presents studies of the Hydrothermal Technique of preparation of Nanostructured Zinc Oxide. In the next part of this review properties of synthesized Zinc Oxide are described.

Keywords: *Zinc Oxide, Particles Morphology, Hydrothermal Method*

1. INTRODUCTION:

Zinc Oxide is a multifunctional material with its unique Physical and Chemical properties, such as high chemical stability, high electrochemical coupling coefficient, a broad range of radiation absorption and high Photostability [1] [2]. In materials science, Zinc Oxide is classified as a semiconductor in group II-VI, whose covalence is on the boundary between ionic and covalent semiconductors. A broad energy band (3.37eV), high bond energy (60 meV) and high thermal and mechanical stability at room temperature make it attractive for potential use in electronics, optoelectronics and laser technology [3][4]. ZnO particles can be synthesized through various methods by controlling the synthesis parameters.

The properties can be tailored by shape and size, resulting in renewable applications relevant to their structural properties. Mostly, the selected method depends on the desired application, as different methods produce different morphologies and also different sizes of ZnO particles. Accordingly, the chemical and physical parameters such as the solvent type, precursors, pH, and temperature were highly considered. An assortment of ZnO nanostructures with different growth morphologies such as Nanorods, Nanosphere, Nanotubes, Nanowires, Nanoneedles and Nanorings have been successfully synthesized. [5].

2. SYNTHESIS OF ZINC OXIDE BY HYDROTHERMAL METHOD:

The Hydrothermal Method does not require the use of organic solvents or additional processing of the product like grinding and calcination, which makes it a simple and environmentally friendly technique. The process takes place in an autoclave, in this synthesis mixture of substrates is heated gradually to a temperature of 100–300°C and left for several days. Crystal nuclei are formed and grow as a result of heating followed by cooling. This process has many advantages, including the possibility of carrying out the synthesis at low temperatures, the diverse shapes and dimensions of the resulting crystals depending on the composition of the starting mixture and the process temperature and pressure, the high degree of crystallinity of the product, and the high purity of the material obtained [12] [13].

In this review, the hydrothermal methods of synthesis of zinc oxide will be discussed. With the hydrothermal method, synthesized ZnO has a variety of structures and offers a wide range of properties. These methods are described in detail in the following sections (Table 1).

A hydrothermal process was used by Chen D. et al. [6] using ZnCl2 and NaOH in a ratio of 1:2 to obtain ZnO particles with different morphology like a bullet, road, sheet, polyhedron and crushed stone. This synthesis was done in Teflon line autoclaves at temperatures of 100 °C to 220 °C with a reaction time of 5 to 10 hours. The process took place by way of reactions (1) and (2).

$$ZnCl_2 + 2NaOH \rightarrow Zn(OH)_2 + 2Na^+ + 2Cl^- \quad \ldots\ldots \quad (1)$$

$$Zn(OH)_2 \rightarrow ZnO + H_2O \quad \ldots\ldots.. \; (2)$$

The size and the morphology of the resulting ZnO particles were studied using an X-ray diffractometer (XRD) and transmission electron microscope (TEM). The temperature and time of reaction were shown to have a significant effect on the structure and size of the ZnO particles. It was also found that as the pH of the solution increases, there is an increase in the crystallinity and size of the particles, which reduces the efficiency of the process.

Table -1: Summary of Hydrothermal Synthesis of Zinc Oxide.

Method	Precursors	Synthesis Conditions	Properties	References
Hydrothermal method	$ZnCl_2$, NaOH	Reaction: 5–10 h, 100–220 °C in Teflon-lined autoclave	Particles morphology: Bullet-like(100-200 nm), Rod-like (100–200 nm), Sheet (50–200 nm), Polyhedron (200–400 nm), Crushed stone-like (50–200 nm)	[6]
Hydrothermal Method	$Zn(CH_3COO)_2$, $Zn(NO_3)_2$, LiOH, KOH, NH_4OH	Reaction time: 10–48h, 120–250 °C	Hexagonal (wurtize) structure, Size of microcrystalline: 100 nm - 20 μm	[7]
Hydrothermal Method	$Zn(CH_3COO)_2$, NaOH, HMTA (hexamethylene-tetraamine)	Reaction time: 5–10 h, 100–200°C; HMTA concentration: 0–200 ppm	Spherical shape; Particles diameter: 55–110 nm	[11]

A hydrothermal process was also used by Dem Yamets et al. [7], synthesized nanocrystalline ZnO has different particle sizes (100 nm–20 µm) with a hexagonal wurtzite structure. The process was carried out in an autoclave, in isothermal conditions or at variable temperatures (120–250 °C). Increasing the time of the hydrothermal process caused an increase in the diameter of the ZnO particles. It was observed that an increase in temperature by 50–70 °C enabled a fourfold reduction in the time of the experiment, which is a very favorable phenomenon.

$$Zn(CH_3COO)_2 + 2NaOH \rightarrow Zn(OH)_2 + 2CH_3COONa \quad \ldots\ldots \; (3)$$

$$Zn(OH)_2 \rightarrow ZnO + H_2O \quad \ldots\ldots.. \; (4)$$

Ismail A, et al. [11] used a hydrothermal method to synthesize nanocrystalline zinc oxide. This synthesis was done at temperatures of 100 °C to 200 °C with a reaction time of 5 to 10 hours, Obtained zinc oxide by way of reactions (3) and (4).

The shape of the ZnO particles is affected by the time and temperature of the process. With an increase in time, temperature and surfactant concentration, the size of the particles increases. Hydrothermal processing of the precursor, followed by drying, produced spherical particles of ZnO with sizes in the range of 55–110 nm depending on the conditions of synthesis.

3. CONCLUSION:

This study shows that ZnO Structures with different grain sizes can be obtained by controlling the concentration of precursors, temperature and time of growth. Meanwhile, with the hydrothermal method, we get nanostructured ZnO with different Surface Area and different morphologies, Surface Area and Morphology of ZnO plays a critical role in many application such as Photo-emitters, Transducers, Actuators, varistors, sensors, and catalysts by optimizing the dimension of ZnO Nanoparticle. Zinc Oxide is also a very useful material because of its many interesting properties like a wide range of UV absorption, high photostability, biocompatibility and biodegradability. ZnO can also be obtained with a variety of particle structures through hydrothermal methods, which determine its applications in a wide range of fields of technology. Therefore a hydrothermal method of synthesizing crystalline Zinc Oxide which can be used on an industrial scale has become a subject of growing interest in science as well as industry.

4. FUTURE SCOPE OF WORK:

- Synthesis of ZnO nanoparticles under various conditions and study of their optical properties.
- Synthesis of ZnO thin film to study their properties for Solar cells and Optoelectronic devices.
- Mn, Co and Ni Doped ZnO Nanoparticles have a wide range of applications.
- Rare earth (Ce, Dy and Er) doped ZnO Nanoparticles find a variety of applications in Spintronics devices.

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