A Systematic Review on Synthesis of Zinc Oxide Nanoparticles and Antibacterial Activity

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Abstract: The nanotechnology can offer numerous novel applications ranging from revolutionary fabric additives, food processing and agricultural production to advanced medicine techniques. Significant interest has been received worldwide in the antibacterial activity of zinc oxide nanoparticles (ZnO-NPs), especially through the implementation of nanotechnology to synthesize particles in the nanometer area. The present review will focus on zinc oxide nanoparticles (ZnO-NPs). Synthesized by various preparation method, role of doping metals in improving the optical and magnetic properties of ZnO nanomaterials., this research aimed to explore the properties of Zinc Oxide Nanoparticles and their antibacterial applications with different dopants. This review describes all the antimicrobial applications and the research status and development of ZnO nanoparticles with gram-negative and gram-positive bacteria.

Keywords: Zinc Oxide, *Nanoparticles, Antibacterial Activity.*

INTRODUCTION

In recent years, nanostructured materials have attracted wide attention due to their fascinating optical and electrical properties, which make these materials potentially suitable for applications in electronics, optics, photonics, and sensors.

Numerous methods have been reported for the preparation of undoped and doped nanoparticles such as sol–gel [1], hydrothermal [2], co-precipitation [3], and micro emulsion [4]. Synthesising techniques with different interesting morphologies including Nano clusters [5], nanorods [6] nanowires [7] are also reported. ZnO is an n-type semiconductor with high electron mobility, a 3.37 eV direct energy band gap and a 60 meV high exciting binding energy which is higher than the room temperature thermal energy. ZnO has many attractive features for electronics and optoelectronics because of its good method of growth accessibility and also because of its special properties

Doping is one of the easiest ways to improve the properties of a ZnO nanostructure. Researchers have therefore studied the effect of dopant materials on the ZnO properties to obtain better crystallization efficiency, optical, electrical and ferromagnetic properties. [8-13] The antimicrobial activity in contact with the microorganisms is a function of the surface area. A larger surface area (as in the case of nanoparticles) provides a wide range of possible reactions with bio-organics on the surface of the cells, as well as environmental and organic species

Due to their unusual antibacterial ability, metal nanoparticles with large specific surface area and large fraction of surface atoms have been extensively studied.

A lot of research has also been done to test metal oxide powders and nanoparticles' antibacterial activity. ZnO nanoparticles have received growing attention in this regard over the years [14-24]

This review aims to study and summarize the properties of Zinc Oxide Nanoparticles and their antibacterial applications with specific dopants. Synthesis of ZnO nanostructures and their doping complexes are included. The theories behind synthesis and antibacterial activity of ZnO-NPs have been thoroughly studied.

Within the following sections, we addressed the factors influencing the properties of ZnO NPs, particle size, concentration, morphology, surface modifications A brief presentation of different metal doping within Zinc oxide nanoparticles carried by authors on antibacterial response to E Coli and S. aureus we give a special emphasis on antibacterial studies.

Nam et al. [25] reported the structural, electrical and optical properties of metal-doped zinc oxide films depended on the dopant content ratio in the target. radio frequency magnetron sputtering method was used to prepared doped ZnO film they found that if the variety and quantity of metal dopant change, the optical band gap crystallinity as well as the transmittance were changed. Baek et al. [26] reported the fabrication of and characterization of Al-doped ZnO with nanorods antireflection coating on Si wire solar cells. Combining AZO film and ZnO nanorods on SiMW solar cells shows the best optical and photovoltaic efficiency.

Kung et al.[27] have investigated the role of the Y doping in enhancing the optical and magnetic properties of ZnO nanorod. According to their findings, Y-doped ZnO nanorods display a strong increase in saturation magnetization. Finally, they conclude that the combination of the effects of the optical and magnetic analysis shows that the oxygen defects play a crucial role in the implementation of ferromagnetism that can be improved by Y doping in the ZnO nanorod.

Babikier et al. [28], by a hydrothermal method, prepared ZnO nanorods with exploration of effect of Cu precursors and concentrations on the optical structural and morphological properties. they also summarize, By selecting the correct Cu precursor and concentration, we can monitor the diameter of the Cu-doped ZnO nanorods, essential for the manufacture of nano-optoelectronic devices.

John et al. [29] found that the erbium doping in ZnO improved luminescence characteristics. UV / Visible absorption study of Er^{3+} doped ZnO shows a decrease in doped ZnO Nano crystals' energy bandgap and produces more defective sites on the ZnO surface. Electrical analysis showed conductivity of undoped and erbium doped ZnO increases.

Wang et al [30] synthesized the structural, electrical and optical properties of Fluorine doped ZO thin films and investigated as a function of the temperature of the substrate ranging from room temperature (RT) to 300 ° C. By gradually increasing the substrate temperature from rt to 300C the E.g., value increases indicating the blue shift effect in the FZO thin films.

Long et al. [31] successfully synthesized ZnO with rod-like and plate-like structure from zinc chloride aqueous solution and studied their photocatalytic properties. Based on the concentrations of Zn2ion and ethylene glycohol(EG) additive the morphology of ZnO crystal modified.

Zang et al. [32] presented a new way to obtain Cd- doped ZnO quantum dots grown by sol gel method. They also found that blue shifts of Cd-doped ZnO QD's UV absorption peaks were found with increased Cd concentration, suggesting a decrease in QD size and a reinforcement of the effect of quantum containment after doping. Kim et al. [33] synthesized various silver / aluminum doped ZnO NWs with hot-walled laser deposition with Au catalysts on sapphire substrates They found that this condition in ZnO NWs generates Ag-Al metal compound that functions as an interstitial defect. authors also presented a set of criteria to make optically p-type ZnO NWs for that they sure 3 and 5 at. % Ag/Al co-doping best rather than 1%

Zhou et al. [34] fabricated Pure and Mn-doped ZnSe nanobelts by thermal evaporation method. Mn doped ZnSe crystal prepared the concentration and spatial distribution of the dopant effects optical properties. in the emission property Optical micro-cavity play an important role.

Antimicrobial Activity

In general, bacteria are distinguished by cell membrane, cell wall, and cytoplasma. The cell wall lies outside the cell membrane and is mainly composed of a homogeneous layer of peptidoglycan (which consists of amino acids and sugars). The cell wall retains the cytoplasm's osmotic pressure as well as the typical cell shape.

Grampositive bacteria have a cytoplasmic membrane with peptidoglycan multilayer and a thicker cell wall(20-80nm) Whereas the gram-negative bacteria shell consists of two cell membranes, an outer membrane and a plasma membrane with a thin layer of 7–8nm peptidoglycan. The size of NPs within those ranges can easily pass through the peptidoglycan and are therefore highly susceptible to damage. [35]

Chen et al. [36] developed hydrothermal method which is used in the development of vertically growing ZnO NRs on PDMS at low temperatures; a photo-reduction process for in situ reduction and deposition of Ag NPs on ZnO NRs is produced. Additionally, they demonstrated the antimicrobial efficiency of

the hybrid Ag-ZnO nanorod array with gram-negative and gram-positive bacteria. Compared to the bare ZnO nanorod array, the antimicrobial effect of the Ag-ZnO nanorod array shows clear improvement in early culture time. The Ag-ZnO nanorods showed improved antimicrobial performance to gram-negative bacteria, E. coli, and gram-positive bacteria, S. aureus in comparison with the ZnO nanorods.

Sun et al. [37] have synthesized ZnO powders doped with titanium using alcohothermal methods with varying shapes and sizes from varying zinc salts. Testing of the antibacterial properties indicate that the ZnO powders doped with titanium against E. Coli will be better than S. Aurora

Comprehensive research shows that the antibacterial properties of titanium doped ZnO powders are influenced by the crystallinity and not just by the thickness.

Using a standard microbial method, Guo et al. [38] prepared Ta-doped ZnO nanopowders using a modified Pechini-type system and conducted antibacterial tests of Ta-doped ZnO nanoparticles on several Gram-positive Bacillus subtilis (B. subtilis) and Staphylococcus aureus (S. aureus) and Gram-negative Escherichia coli (E. coli) and Pseudomonas aeruginosa (P. aeruginosa).

All samples including ZnO, Ta-doped ZnO, and Ta2O5 are easily seen to show better biocidal effect on B. Subtle and worse antibacterial activity of the bacteria P. aeruginosa Whereas, with a 3–5 percent increase in Ta content, E Coli, S. Aureus is blocked effectively.

Very recently, Pradeev and coauthors [39] have prepared pure and Mg-doped ZnO nanoparticles with different dopant amount and investigated Antibacterial properties studied against (Gram-positive and Gram-negative) S. aureus, E. coli, and Proteus cultures . They investigate that ZnO NPs doped with Mg2 + inhibit the growth of Gram-negative and Gram-positive bacteria. It has been found that the inhibition zone in ZnO NPs is proportional with the amount of Mg doping.

Conclusion:

We have presented here the various methods of synthesizing of zinc oxide Nanoparticles and their antibacterial activity. We have also studied the antibacterial activity with zinc oxide nanoparticles with various dopant and specific amount of dopant added. It has been shown that the structural morphology and optical properties are greatly affected by amount of dopant added to zinc oxide nanoparticles. It is also found that the doped zinc oxide nanoparticles n showed improved antimicrobial performance to gram-negative bacteria, and gram-positive bacteria, in comparison with the undoped ZnO nanoparticles. Furthermore, interest should be concentrated by the researchers to synthesis and study the performance of the various metal doped zinc oxide nanoparticles and analyze their antibacterial properties.

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