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Zn-based Nanomaterials for Antimicrobial Applications: A Short Review

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Abstract: In recent past, the investigations on antimicrobial activity of metal-based nanoparticles gained significant interest by implantation of nanotechnology to synthesize the nanoparticles in nanoregion due to their high surface area and high reactivity. Especially, the antimicrobial agents play a pivotal role in various fields where the biological contamination occurs. For instance, microbes control the control the contamination of food in food packaging, in textile industry they can restrict the growth of microorganisms owing to sweat, in medicine they can reduce the risk of contamination in invasive and routine interventions. Owing to their enhanced specific surface area as reduced particle size lead to improved surface activity, zinc based nano particles exhibit good antimicrobial properties. Further, zinc oxide is ecofriendly material which impacts photocatalysis and photo oxidizing on biological and chemical species. This review focused on recent advancements in zinc based nano materials for antimicrobial applications. Specifically, this briefly discussed the various synthesis techniques, shape of various materials, different dopants that enhance the antimicrobial activity of zinc oxide along with antimicrobial properties of those materials.
Keywords: Nanotechnology; Antimicrobial activity; Microorganisms; Surface area; Zinc nanoparticles;

I. INTRODUCTION

In recent decades Nanomaterials have been considered as one of the most vanguard materials. Nanomaterials have broad applications in field of biological sciences, pharmaceutics, agriculture, medicine and industries[1]. Aside from ferrite nanoparticles, metal oxide nanoparticles have intrigued much attention due to their surface area to volume ratios and magnetic properties, which are wholly distinct from their corresponding bulk material. According to magnetic and crystal properties ferrites can be garnet, spinel, orthoferrite or hexaferrite[2-5]. Among them, ferrite nanoparticles synthesized with transition metal with spinel structure have been given special attention due to their well-known magnetic, catalytic, high adsorption, optical and electronic properties[6]. These nanoparticles are magnetically soft and easy to magnetize and demagnetize due to high permeability and good saturation magnetization.[7-9] The properties of ferrite nanocrystals could be mould by adjusting the number of substituted transition metal ions, shape, size and spinel ferrite nanocrystals can be employed in biomedicine to detect cancer cells, magnetic recording , magnetic hyperthermia for diagnostic and treatment of tumor, dopamine investigation, drug delivery, cellular signaling, and sensing magneto-optical devices, catalysis, microwave device [10-13], heat absorbers and generators, energy storage, magnetic resonance imaging (MRI) [14-16], electromagnetic interference shielding and water and wastewater treatment, Different methods are there to synthesise spinel ferrite nanoparticles such as hydrothermal, microemulsions, aerosol spray pyrolysis, auto combustion, sol–gel, ball milling, sonochemical, reverse micelles pulsed laser ablation in liquid, biogenic method using bacteria strains, polymeric precursor and coprecipitation methods [17-21].Even though, different metal and metal oxides nanocrystals exhibits the antimicrobial nature mainly Zinc oxide [22], Aluminum oxide [23],titanium oxide, nickel oxide and copper oxide were researchers reported in the literature based on their intrinsic properties, surface modification, composition and the type of targeted bacteria. However, very little is known about the antimicrobial applications of spinel ferrite nanoparticles substituted with transition metals. Antimicrobial activity of manganese, nickel and copper substituted zinc ferrite NP's to inhibit the bacterial infections, Samavati and Ismail et al. [24]reported that the metal ions substituted spinel ferrite nanocrystals with increase their antimicrobial properties.A different class of metallic nanoparticles are super paramagnetic iron-oxide nanoparticles (SPIONs) (e.g., maghemite (γ-Fe_2O_3) NPs and magnetite (Fe_3O_4)) whose antibacterial efficiency enhance upon the utilisation of an external magnetic field. In order to enhance the antibacterial tendency of metal-based NP's is the use of carbon compounds and silica as delivery systems. In this review huge range of metal substituted nanoparticles, synthesis, and their antibacterial activity were further explored.

A. Zn-based Nanomaterials for Antimicrobial Applications

Metal oxide Nanoparticles are considered as potential next-generation drugs and can be applied in various fields, such as consumer products, clinical problems and other industrial applications. Zinc oxide NPs have attracted considerable attention due to their unique chemical and physical properties, such as high catalysis, UV screening performance, biocompatibility, antibacterial, large excitation binding energy, high photostability photochemical activity and low toxicity.[25-29]. Many bacteria repeatedly cause infectious diseases, causing huge losses to human health and economy. Bacteria such as Enterococcus, Streptococcus and Staphylococcus are the organisms responsible for many infectious diseases. They develop resistance to many antibiotics, which makes their infection difficult to treat. [30-31].Therefore, new drugs or technologies must be developed to kill these bacteria for the benefit of human society. Nanotechnology has proven to be an emerging field where nanoparticles of all sizes and shapes may be synthesized and employed as effective antibiotics. These particles have a very active surface, which increases their reactivity and which increases their toxicity compared to bulk particles. Sometimes they exhibit toxic effects even when their counterparts are non-toxic. Various metal oxide nanoparticles are highly toxic to different bacteria[32].Various metal oxide nanoparticles are highly toxic to various bacteria. Titanium oxide NPs can kill E. coli. Similarly, magnesium oxide and calcium oxide also has bactericidal effects on Escherichia coli, Bacillus sphaericus and Bacillus cereus.

B. Properties Zn-based Nanoparticles

Zn substituted nanoparticles are inorganic compounds and these are insoluble in water, but soluble in dilute acids and alkalis solutions. Due to its extremely high melting point, it exhibits high thermal stability and can withstand high temperature processing associated with doping and ohmic contact formation. It exists in two common crystal forms, namely sphalerite and wurtzite. They are obtained in different forms such as nanorods, stars, tubes, flowers, flakes, spheres, wires, sheet-like porous zinc NP' snanorings, nanocombs, nanopyramids and nanohelices[33]. They exhibit high values of photosensitivity, electrical conductivity and strong absorption of UV rays. Various surface structures of zinc NP'sactivate anisotropic growth. Because of the high aspect ratio, these NP's exhibit increased reactivity. The contact surface of the NPs with the bacteria is increased, since an increased surface indicates an increased reactivity. As identified against E. coli, zinc oxide nanoparticles showed stronger antibacterial effect than 2 µm particles. In fact, zinc oxide NPs showed antibacterial activity against a variety of microorganisms compared to other antibacterial NPs. zinc oxide NPs have been reported as effective antibacterial agents. They could be the next generation of nanoantibiotics to fight multidrug resistance. Such materials may be synthesized by various chemical, physical and biological methods[34]. Plant-synthesized zinc oxide NPs were observed to inhibit bacterial growth more effectively than chemically-synthesized zinc oxide NPs. It is found to be zinc oxidesmore toxic to Pseudomonas fluorescens, E. coli and Bacillussubtilis than the metal oxides of aluminium, silicon and titanium.

C. Synthesis Methods Of Zn-Based Nanoparticles

In general, there are various methods for the synthesis of ZnO NPs, which are mainly divided into three types, viz. physical, chemical, and biological incorporated[35] in table 1. Zinc oxide NPs are most in demand for their applications in commercial industries, due to they are easy to synthesize, low cost to produce and safe. They are more environmentally friendly and have protein adsorption properties.

Table 1: Synthesis methods of Zn nanoparticles

Synthesis Methods		
Physical	chemical	Biological
Hydrothermal	Micro emulsion	Bacteria
Solvothermal	Sol-gel	Algae
Ball milling		Fungi
Thermal decomposition		Plants/plant parts
Sputtering		Organic waste
Free surfactant microwave		
Infrared radiation		
Laser ablation		
Liquid ultra-sonication		

D. Applications Of Zinc-Based Nanoparticles

Various metal and metal oxide NP's have been successfully commercialized in the fields of health, textiles, electronics, environment and agriculture. Zinc oxide NPs are one of the most widely used nanometer materials along with titanium oxide and silicon dioxide. They can be used effectively as antibiotics against pathogenic bacteria and viruses that show resistance to commercially available antibiotics. They have unique physicochemical properties that can affect the toxicological and biological responses of microorganisms. Because of biodegradability, low toxicity and biocompatibility [36], they are widely employed in biomedicine and personal care product industries. They can be used in combination with antibiotics and anti-inflammatories to enhance the antimicrobial activity of against pathogenic bacteria without developing antibiotic resistance in non-clinical and clinical conditions. ZnO NPs interact electrostatically with bacterial cell membranes and damage them, leading to cell leakage and bacterial death. They are cost effective and fight many types of bacteria[37]. By combining them with ZnO NPs, the uptake of antibiotics by bacterial cells can be increased. It is a new alternative to treat bacterial infections.

Table 2: Recently introduced zinc based nanoparticles and their antimicrobial studies

Nano particle	Morphology	size	Methods used	Microorganism tested	References
Zinc oxide – Copper oxide	rugged rod-like	500nm	dynamic contact	*Streptococcus mutans*	38
Zinc oxide coated by CuNPs	needle-shaped and spherical	5 nm	agar disk diffusion	*Staphylococcus aureus , Escherichia coli*	39
ZnO	star-like	50– 400 nm	surface contact	*Bacillus subtilis, Enterobacter aerogenes*	40
ZnO	-	20–40 nm	agar disk diffusion	*Escherichia coli and Staphylococcus aureus*	41
ZnO	nanoflowers	-	agar well diffusion	*Escherichia coli*	42
ZnO	-	120–400 nm	dynamic contact	*Bacillus subtilis, Staphylococcus aureus , Escherichia coli Pseudomonas aeruginosa*	43
ZnO	hexagonal	70 nm	surface contact	*Lactobacillus plantarum*	44
Ag-ZnO	flake-like aggregates	40nm	agar disk diffusion	*Staphylococcus aureus , Streptococcus, Escherichia coli, Pseudomonas,*	45
NiO–ZnO/TiO2 nanotubes/Ti	nanotubes	140–210nm	dynamic contact with irradiation	*Candida albicans and Escherichia coli*	46
ZnO	Spherical	18nm	Sol-gel method by post heat treatment	*Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa and Mycobacterium tuberculosis*	47
ZnO	Spherical	10nm	Chemical synthesis	*Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Candida albicans, Aspergillus niger and Trichophyton rubrum*	48
ZnO	rod	90-100nm	Sonochemical method	*Bacillus cereus, Pseudomonas aeruginosa, Staphylococcus aureus and salmonella typhimurium*	49
ZnO	Spherical	4.45±0.37 nm	Chemical precipitation	*Staphylococcus aureus and Escherichia coli*	50
ZnO	Spherical	4,10,30 nm	Solvothermal method	*Escherichia coli and Staphylococcus aureus*	51
ZnO	Spherical, rod	40-1200nm	Wet chemical synthesis	*Staphylococcus aureus and Escherichia coli*	52

II. CONCLUSION

This review article addressed the recent advancements in zinc-based nanoparticles and their potential use for antimicrobial applications. Further, the main issues regarding antimicrobial nanoparticles, including their synthesis techniques, types, characterization of their properties, and their antimicrobial mechanisms, are discussed. Even though massive research is going on in the advancement of biological synthesis techniques for introducing new materials with improved antimicrobial performance, significant challenges are still remained. In recent years, researchers have put continuous research efforts to overcome the challenges and also toward the development of new variety of materials.

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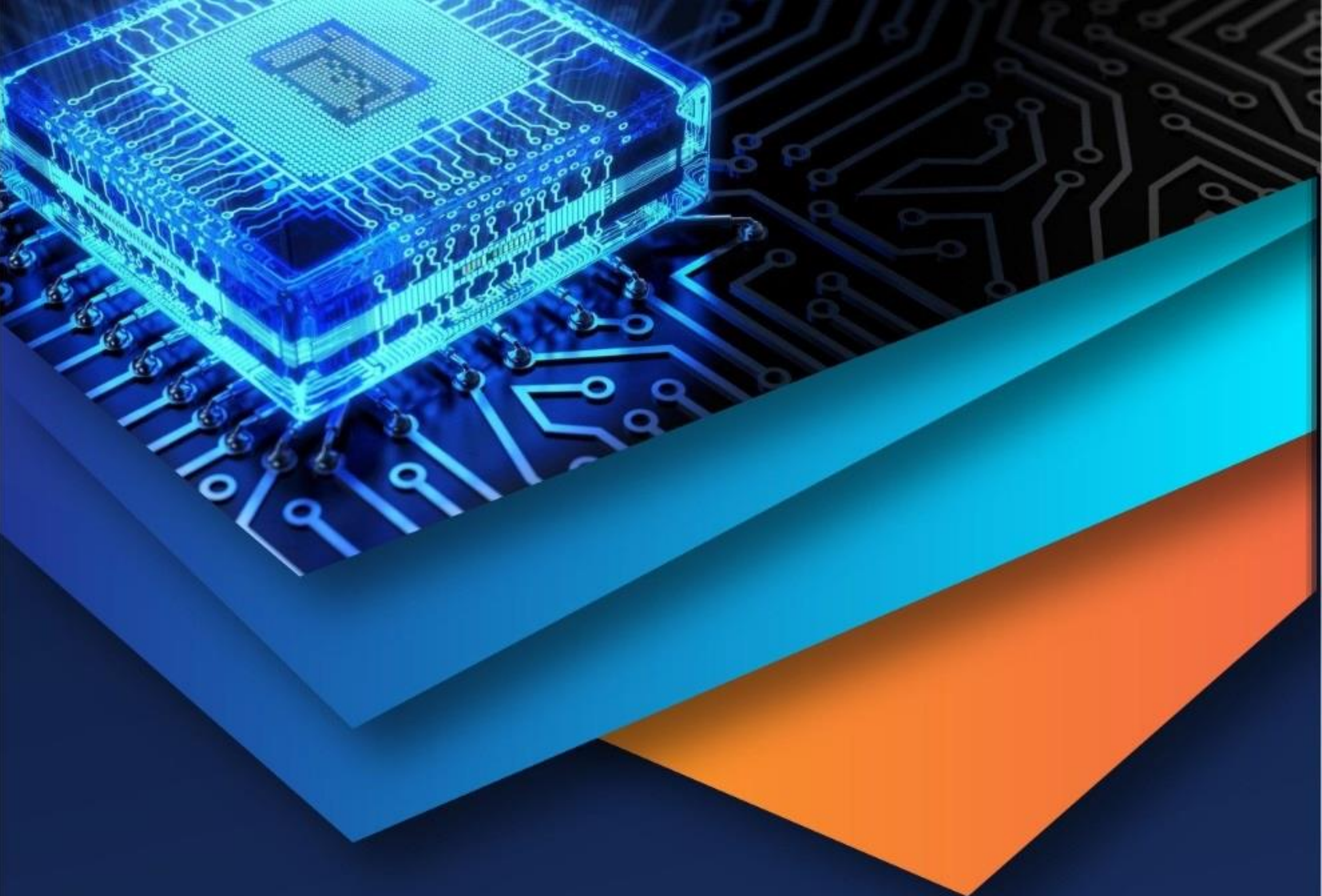

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