# REVIEW ON GREEN AND CHEMICAL FABRICATIONS OF ZINC OXIDE NANOPARTICLES: SYNTHESIS AND ITS BIOLOGICAL ACTIVITY

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***Abstract*— The physicochemical techniques of the synthesis of zinc oxide nanoparticles (ZnONPs) have been reviewed. Through this review, we able to distinguish the properties of ZnONPs obtained when synthesis using chemical and green synthesis method. Currently, the green synthesis method is preferable by researcher owing to the environmentally friendly and can reduce the non-toxic substances usage. The green synthesis method used several natural sources and involved in various biological and physical activity like photocatalytic, antibacterial, antifungal, antioxidant, and cytotoxicity test to show the role of ZnONPs in various aspects.**

***Index Terms*— ZnONPs, chemical method, green synthesis, Morphology.**

## I. INTRODUCTION

The II-VI Semiconductor compounds include zinc sulphide (ZnS), zinc oxide (ZnO), zinc selenium (ZnSe), zinc telluride (ZnTe), cadmium sulphide (CdS), cadmium selenide (CdSe) and cadmium selenide (CdTe) have the outstanding optical properties, such as have greater exciting binding energy, extensive direct band gap and larger fluorescent product and which can provide the flexibility to devices like photodetectors or light emitting diodes (LED)[1]. In the previous experiment, they revealed that the benefits of II-VI compound semiconductors are to produce abundant optical emission and absorption that applied for optoelectronic device application caused by their wide band gap of semiconductors [2]. For ZnO nanomaterials, its inimitable properties like large surface area, antibacterial activity, and high reactivity led to various potential applications [3]. Furthermore, most of the nanomaterials have a great percentage of atoms at their surface that leads to high surface reactivity.

### *A. Zinc Oxide Nanoparticles (ZnONPs)*

In 2012, Özgür and his co-workers [4] mentioned that ZnO is an II-VI semiconductor compound which exists in the margins between covalent and ionic semiconductor. The crystal structures common by ZnO are rocksalt, zinc blende and wurtzite. At ambient temperature, the thermodynamically steady state is wurtzite. The hexagonal wurtzite exists where the anion is bordered by four cations at the corners of a tetrahedron, and vice versa. This tetrahedral coordination is founded on the characteristic of sp3 covalent bonding nature [5]. In the crystal structure of ZnO, the wurtzite structure has a hexagonal structure with two lattice parameters, a and c. In 2004, Wang described that the lattice parameters of wurtzite structure are a = 0.3296 nm and c = 0.520 65 nm [6].

Zinc oxide is an attractive n-type semiconductor material with wide direct band gap energy 3.37 eV, large exciton binding energy, abundant in nature and environmentally friendly [7,8,9,10,11,12]. Another researcher initiated that ZnO also has an energy gap of 3.3 eV [13] and 3.44 eV [14] at ambient temperature. The different value of band gap for ZnO found by several researchers concluded that the value of energy band gap can be applied to various applications. The electronic band structure of ZnO, as a semiconductor material, comprises of a conduction band (CB) and a valence band (VB). Incident radiation with energy photons greater than 3.3 eV is immediately absorbed, hence the electrons move from the VB to the CB. This electron transfer begins a series of possible photoreactions [15]. The availability of ZnO in bulk, single crystal form and its high exciton binding energy (60 meV) is significant for its application to UV light emitters, wave device, piezoelectric transducers, gas sensing and solar cells [16].

To synthesized the ZnO, the properties of the as-deposited films, crystal structure, chemical composition and surface morphology are discovered [16]. Moreover, Li & Haneda (2003)[17] investigated that the morphology of ZnO particles is very sensitive to the preparation conditions and preparation methods. However, the nanometer-sized zinc oxide is important for inorganic function material purpose [18]. Due to its unique properties, ZnO has been selected as a convenient alternative of TiO2 because of its comparable band gap energy as well as relatively lower cost of production and its photocatalytic capacity is expected to be similar to that of TiO2 [19][20].

*B. Zinc Oxide Nanoparticles (ZnONPs) Synthesis by Chemical Method*

The ZnONPs were synthesized by various chemical methods such as mechanochemical [21], precipitation [22], coprecipitation [9,23], chemical precipitation [24], sol-gel [25], solvothermal [19,26] used polyvinylpyrrolidone (PVP) as capping agent, microwave [27], microwave hydrothermal [28], microemulsion [29], alkali precipitation [17], co-deposition [18], solution free mechanochemical method [30], wet chemical method [31], sol spray combustion [32] and other methods. The selected method depends on the desired application, as different methods produce different morphologies and sizes of ZnO particles [15]. Table 1 shows the various methods and morphological studies of ZnONPs including size, morphology and its application.

The sol-gel method is extensively used and become main attracted method due to the unique advantages such as simplicity, low cost, low temperature, high yield, preferred morphology and controllable particle size [33,34]. According to Rani et al. (2008)[35], zinc acetate dihydrate was used as a precursor due to accessible control of hydrolysis. Besides, the size and crystallinity of the powder were found to depend strongly on the pH value of sol which pH 9 show the best performance. When the ZnONPs exposed to different annealing temperature, strong luminescence band is appears in UV range at 500 ºC [36]. Referring to Table 1, from the sol-gel synthesis, the various crystallite size exhibited around 4-200nm. While the morphology also showed various shapes like spherical, hexagonal, and rod-like. Overall, for the morphology of ZnONPs formed, most researchers obtained the spherical shape although synthesized from the different method. In 2016, Vidyasagar and Naik [37] found various shape of ZnONPs like triangle, circle, rectangle, and square due to surfactant used.

**Table 1:**Various methods and morphological studies of ZnONPs.

| Method | Size | Morphology | Application | References |
|---|---|---|---|---|
| Aqueous solution growth | ~35 nm | Spherical | Optical properties | [38] |
| Chemical route | 7-21 nm | Nano-rod spherical | - | [39] |
| Co-precipitation | 29 nm | Spherical | Antibacterial | [40] |
| Homogeneous chemical precipitation | 20-50 nm | Quasi-cylindrical | Catalytic | [41] |
| Microwave-assisted irradiation | - | Flower-type, needle-type, spherical | - | [42] |
| Precipitation | 29-86 nm | Spherical | - | [43] |
| | 27-82 nm | Spherical | - | [44] |
| | - | Spherical, granular | Optical properties | [45] |
| | 17 ± 1.5 nm | Hexagonal | - | [46] |
| Sol-gel | 14-16 nm | Spherical | Photocatalytic | [47] |
| | 20 ± 2 nm | Spherical | - | [48] |
| | 80-100 nm | Rod-like | Photocatalytic degradation | [49] |
| | 34 and 54 nm | Spherical | Optical and electrical properties | [36] |
| | 49 nm, 80 nm, 200 nm | Hexagonal-like | | [34] |
| | 84.98 nm | Rod-like | - | [50] |
| | 100-200 nm | Spherical | - | [25] |
| | 4 nm | Spherical | - | [51] |
| | ~12 nm | Hexagonal | Dye-sensitized solar cells | [52] |
| | 20-80 nm | Spherical | Optical properties | [53] |

| | | | | |
|---|---|---|---|---|
| | 20-50 nm | Rod-like | Optoelectronic | [54] |
| Sol spray combustion | 50-60 nm | - | Gas sensing | [32] |
| Solid-state mechanochemical | - | Triangle, circle, rectangle, square | - | [37] |

*C. ZnO Nanoparticles (ZnONPs) Synthesis by Green Synthesis*

Recently, biosynthesis of nanometals using plant extracts have opened a new era in fast and nontoxic techniques for synthesizing of nanoparticles. Many researchers have reported that the biosynthesis of metal nanoparticles by plant extracts and their potential applications. Plants imitative ZnO nanoparticles produced by readily existing plant materials and nontoxic natural plants are convenient for satisfying great demand for ZnONPs with applications in the biomedical and environmental expenses. In recent times, ZnONPs successfully synthesized using various plant parts, including stem, root, fruit, seed, pulp, leaves, flower, peel as resources (Table 2). Certain plants contain a wide range of biologically active compounds, including alkaloids, glycosides, flavonoids, tannins, terpenoids, phenols, saponins, alkaloids and vitamin. These active compounds can be tested through various tests [55]. Table 2 summarizes the synthesis and application of ZnO nanoparticles biosynthesis using plants. Furthermore, some important structure of the ZnO nanoparticles, including size and morphology is revealed.

**Table 2:** Synthesis and application of ZnO nanoparticles biosynthesis using plants.

| **Plant origin** | **Size** | **Morphology** | **Applications** | **References** |
|---|---|---|---|---|
| *Aloe barbadensis miller* leaf | 25-55 nm | Spherical, hexagonal | - | [56] |
| *Aloe vera* | Less than 5µm | Spherical, hexagonal | Antimicrobial | [57] |
| *Anchusa italica* | 7.60±1.97 nm 14.35±1.92 nm | Hexagonal | Antimicrobial, cytotoxicity | [58] |
| *Aspalathus linearis* | 1-8.5 nm | Quasi-spherical | - | [59] |
| *Azadirachta indica* | 9.6-25.5 nm | Spherical | Antibacterial, photocatalytic | [41] |
| *Camellia japonica* | ~20 nm | Spherical | Optical sensor | [60] |
| *Camellia sinensis* | 8 ±.5 nm | Rounded particles | Photocatalytic | [61] |
| *Campylobacter jejuni* | - | Coccoid | Antibacterial | [62] |
| *Candida albicans* | 30.6 ± 0.3 nm 33.8 ± 0.5 nm | Spherical, triangular | Antifungal | [63] |
| *Carica papaya* (leaf extract) | ~50 nm | Spherical | Photocatalytic & photovoltaic | [64] |
| *Citrullus colocynthis* (L.) | Fruit - 85-100 nm Seed – 20-35 nm Pulp – 30-80 nm | Fruit - flower shaped Seed - hexagonal Pulp – block-shape | Antimicrobial | [65] |
| *Citrus aurantifolia* | 0.15-0.35µm | Spherical | - | [66] |
| *Citrus paradisi* | 12-72 nm | Spherical | Photocatalytic | [67] |
| *Eucalyptus globulus* | 11.6 nm | Spherical, hexagonal | Photocatalytic | [68] |
| *Jacaranda mimosafolia* | 2-4 nm | Spherical | Antibacterial | [69] |
| *Lagerstroemia speciosa* | 40-45 nm | Spherical | Photocatalytic degradation | [55] |
| *Lycopersion esculentum* | 50-90 nm | Spherical | Photovoltaic | [70] |
| *Moringa Oleifera* | 12.27-30.51 nm | Spherical | Potential electrocatalyst | [71] |

| | | | | |
|---|---|---|---|---|
| *Nephelium lappaceum* L. | ~50 nm | Needle like structure | Antimicrobial on cotton fabrics | [72] |
| *Nephelium lappaceum* L. fruit | 25-40 nm | Spherical | Photocatalytic | [73] |
| *Nyctanthes arbor-tristis* | 74.36 nm | Periphery | Antifungal | [74] |
| *Ocimum Tenuiflorum* | 11-25 nm | Hexagonal | - | [75] |
| *Phyllanthus niruri* | 25.61 nm | Spherical | Catalytic | [76] |
| *Punica granatum* | 40 nm | Flower, platelets shape | Antibacterial | [77] |
| *Rosa canina* | Below 50 nm | Spherical | - | [78] |
| *Ruta graveleons* (L.) | 20-30 nm | Spherical | Antibacterial | [79] |
| *Trifolium pratense* | 100-190 nm | Spherical | Antibacterial | [80] |
| *Sesbania grandiflora* | 20-50 nm | Spherical | Photocatalytic | [81] |
| *Solanum nigrum* | 20-30 nm | Spherical | Antibacterial | [82] |
| Tea leaf extract | 20-50 nm | Spherical | Solar cell | [83] |
| *Zingiber officinale* | 23-25 nm | Spherical | Antimicrobial | [84] |

### *D. Applications*

Zinc oxide has been considered as a suitable alternative instead of TiO2 because of its comparable band gap energy as well as relatively lower cost of production. ZnO also acts as effective heterogeneous photocatalysis to remove of organic and inorganic pollutants from water. It is proved that the synthetic parameters have decisive role in enhancing the photocatalytic efficiency of ZnO toward various pollutants by research conducted by [19]. In addition, one of the methods of enhancing the efficiencies of photocatalysts is the use of nano-sized semiconductor crystallites [16]. From the previous study, ZnO is used as electrode material for dye-sensitized solar cells. Fabrication of third-generation solar cells which is dye-sensitized solar cells also known as DSSC. Aggregation has been found to be dominant growth mechanism of microscopic ZnO particles. The influence of nano crystallinity of the ZnO powder has been seen in the band gap enhancement. DSSC made with stoichiometric ZnO powder grown at pH 9 shows the best photovoltaic performance. The synthesized powder consists of aggregated ZnO nanocrystallites with porosity which helps in adsorption of dye and hence capturing larger number of photons [35].

Besides, ZnO also examined as potential scientific tools that used in pharmaceutical products to prevent or treat topical or systemic diseases because of the antimicrobial properties of ZnO and it is barely used as preservative in topical formulations. In medications for topical use, ZnO acts as a soothing and protective coating against skin irritation and abrasions, as a mild astringent, and as an antimicrobial agent. ZnO regulates skin overactive sebaceous glands functions and dries up excess sebum [85]. It is also extensively used as protective agent in sunscreen products because of its ability to filter UV radiations [86,87]. ZnO particles with smaller size, larger specific area and higher porosity exhibit higher antimicrobial activity [85].

Apart from that, the application of ZnO antibacterial bioactivity was debated in food packaging industry where ZnONPs is used as an antibacterial agent facing foodborne diseases to protect the food from microbial pollution. The ZnONPs insert into the packaging materials can cause interaction with foodborne pathogens, hence releasing NPs onto food surface where they come in contact with bad bacteria and cause the bacterial inhibition [15]. In agreement with Hatamie et al. (2015)[88], they stated that once the nanoparticles are introduced in a polymeric matrix, it permits interaction of food with the packaging possessing functional part in the conservation. For example, ZnO has been included in a number of food linings in packaging to avoid spoilage plus it maintains the colours. Additionally, bestowing to Liu et al. (2009)[89], ZnONPs also possibly well chosen as an effective antibacterial agent for protecting agricultural and food safety.

In terms of antimicrobial textiles, an awareness of general sanitation, contact disease transmission, and personal protection has been developed. The application of zinc oxide has been seen as a practical solution to stop infectious diseases due to the antimicrobial properties of these nanoparticles. In 2010, Rajendran and his co-workers [31] observed that the essential for antimicrobial textiles goes hand-in-hand with the upsurge in resistant strains of microorganisms. Useful textiles include all from antimicrobial finished textiles, to durable, or permanent press finished garments, to textiles with self-cleaning properties, and also textiles with nanotechnology.

## II. Literature Study

### *A. Photocatalytic activity*

Semiconductor group of metal nanoparticles like titania ($TiO_2$), zinc oxide (ZnO), cadmium sulfide (CdS), Iron (III) oxide ($Fe_2O_3$) and zinc sulfide (ZnS) displays the good sensitivity for light-induced redox processes because of the electronic structure of metal atom in chemical combination [20]. Most research on photocatalytic degradation of ZnO has been carried out using methylene blue (organic dye) as a symbolic of biological contaminants [9,18,20,90]. According to Shen et al. (2008)[18], during the photocatalytic activity, the equilibrium concentration of the methylene blue (Ceq) must be in contact with the catalyst at the start of irradiation due to the adsorption of the dyes from aqueous solution onto ZnONPs. Further, Reddy and Mandal (2017)[68] stated that they used MB and (methylene orange) MO dyes for photocatalytic test. In their research, after exposure to UV light, they found that MO has slightly higher photodegradation than MB. Hence, MO also one of the effective dyes in photocatalytic test. Similarly, Saraswathi et al. (2017)[55] also used MO as dyes for photocatalytic degradation against ZnO catalyst synthesized using Lagerstroemia speciosa leaf. In a study conducted by Fouad et al. (2006)[16], they used C.I. Reactive Black 5 dye solution in photocatalytic degradation instead of MB as it is a typical contaminant in the industrial wastewaters and nonvolatile. Recently, Kusumam et al. (2016)[19] used rhodamine B in aqueous solution for photocatalytic degradation of ZnO due to the toxicity of it to the aquatic organisms and can be a source to long-term negative effects in the aquatic environment.

Some researcher also led the photoactivity of pure ZnO and Manganese (Mn) doped ZnO [9]. It is proved that the photodegradation of ZnO is preferred than doped with Mn. The low degradation rate of Mn-doped ZnO happens because of the large band gap of the sample. In contrast to Rekha et al. (2010)[9], R and Rajalaxshmi (2016)[79] initiated that the degradation efficiency of Ceion (Ce) doped with ZnO is higher compared to pure ZnO nanoparticles due to Ce ion have a good effective resistance. Besides doping, calcination temperature also plays an important role in photocatalytic activities. When low calcination temperature applied to the ZnONPs, the crystallite size becomes smaller and the pH of suspension was advantageous for photocatalytic degradation. In 2017, Barhoum et al. [12] identified that the porous ZnONPs exposed to good photocatalytic activity comparing to nonporous ZnO nanoparticles. From the review, most researchers investigating that the good photocatalytic degradation is depends on the nanoparticles crystallite sizes due to more active sites, the band gap energy values, and the better light preservation capability of ZnONPs.

### *B. Antioxidant activity*

Antioxidants are important in the defence mechanism of the organism against the pathologies linked to the attack of free radicals [91]. The free radical scavenging activity of ZnONPs using Citrullus colocynthis (L.) Schrad extracts were explored by 1,1-Diphenyl-2-picrylhydrazyl (DPPH) scavenging. (DPPH) is one of a stable free radical that was used in antioxidant activity to determine the percentage of scavenging capacity. In 2017, Azizi [65] and his researchers carried out DPPH activity of the ZnONPs and it is found that the scavenging of DPPH radicals increasing as the concentration of the ZnONPs samples increased. Same with the research conducted by Kumar et al. (2014)[67], the percentage of DPPH increasing ($\geqslant$80% for 1.2mM) as concentrations of ZnONPs increase. Up to now, previous studies have revealed that the ZnO NPs exhibited up to 82% of 500 scavenging capacity with IC50 value as 46.62% lg/mL [68].

### *C. Cytotoxicity test*

The toxic mechanisms of metallic nanoparticles have been effectively studied because of the massive production, use, and subsequent environmental accumulations of metallic nanoparticles [3]. The cytotoxicity of synthesized ZnONPs influenced by various factors, such as a nanoparticle's shape, size, and surface charge. Biosynthesized ZnONPs were synthesized using Anchusa italica flower showed concentration-dependent cytotoxicity. Through various concentration, the cell viability degenerated with the increase in ZnONPs concentration. According to Azizi et al. (2016)[58], the higher IC50 value of sample shown the less cytotoxicity through the in vitro cytotoxicity studies. In the following year, he found that the ZnONPs inhibit 50% of cell growth when synthesized using Citrullus colocynthis (L.) Schrad extracts. They concluded that the green nanoparticles were less toxic and almost biocompatible [65,92]

### *D. Antifungal activity*

Antifungal activity had been done by the researchers to control the fungal related spoilage and fungal pathogens in plants, as well as in nanoparticles made from plants. In 2015, Janaki and co-workers [84] demonstrated the antifungal susceptibility test of ZnO to antifungal activity. They were using fungi Candida albicans and Penicillium notatum against ZnO synthesized using Zingiber officinale by green synthesis method. It shows that the inhibition zone increases with increasing concentrations of ZnONPs. In the following year, Jamdagni et al. (2016)[74] performed the antifungal of ZnO nanoparticles against 5 fungal including Alternaria alternata, Aspergillus niger, Botrytis cinereal, Fusarium oxysporum and Penicillium expansum. From the experiment, they concluded that nanoparticles are one of the potential antifungal agents to overcome the hurdles in fungal disease management and can be exploited for expanding the antifungal agents in the field of agriculture for marketable use.

### *E. Antibacterial activity*

Bacteria are consisting of a single cell with a simple internal structure also known as prokaryotes. They are microscopic single-celled organisms that grow well in diverse environments which can live in soil, in the ocean and inside the human gut. Bacteria normally in spheres, rods, spirals and other shapes. Differential staining technique categorized into two groups which are Gram-positive bacteria and Gram-negative bacteria. Through the staining process, gram-positive bacteria exhibit in stain purple because their cell walls are rich in peptidoglycan with a thickness of 20-80 nm. While gram-negative bacteria whose cells walls have two layers revealed on a red colouring and the thickness is between 7-8 nm [15]. The ZnONPs size within such ranges can eagerly pass through the peptidoglycan and later are highly exposed to damage.

Antibacterial activity is function to inhibit the bacterial growth and it had done by many researchers. According to previous researcher [90], the ZnONPs synthesized using the leaf extract of Azadirachta indica can act as antibacterial agent as they successfully inhibit the growth of both Gram-positive and Gram-negative bacteria. The antibacterial activity was explored by different methods including the disk diffusion method [72,82,93], Agar well diffusion method [77,78,94], and standard plate count method [69]. The previous Gram-positive bacteria that have been used for antibacterial activity are Streptococcus pneumoniae, Staphylococcus aureus (skin bacteria)[31,85], and Bacillus subtilis. While Escherichia coli (E. coli) [3,89,95], Salmonella typhi [9], Pseudomonas aeruginosa [85], Klebsiella pneumoniae and Shigella dysenteriae [9] are the Gram-negative bacteria that was used in the antibacterial activity.

ZnO is one of the suitable candidates for antibacterial activity due to increased specific surface area as the reduced particle size leading to enhanced particle surface reactivity. Furthermore, ZnO also is a bio-safe material that possesses photo-oxidizing and photocatalysis impacts on chemical and biological species [15]. Another researcher also has highlighted the relevance of the enhanced bioactivity of smaller particles is attributed to the higher surface area to volume ratio [96]. For smaller ZnO nanoparticles, more particles are needed to cover a bacterial colony (2µm) which results in the generation of a larger number of active oxygen species, which kill bacteria more effectively. ZnO nanoparticles were found to be more abrasive than bulk ZnO, and thus contribute to the greater mechanical damage of the cell membrane and the enhanced bactericidal effect of ZnO nanoparticles. While conducting the antibacterial activity, Liu et al. (2009)[89] note that the concentration is the important factors that affecting antimicrobial properties. From the results, the inhibitory effects increased as the concentrations of ZnONPs increased. Likewise, Pasquet et al. (2014)[85] assert that the concentration of ZnO and the time of action are important for ZnONPs to inhibit the bacteria growth. The antibacterial activity of ZnO also can be shown under UV light as well as in the dark to inhibit the bacterial growth [15].

### *F. Zinc Oxide Nanoparticles (ZnONPs) Synthesized with Various Parameters*

To obtained the optimize ZnONPs, the chemical and physical parameters like the solvent type, precursors, pH, and the temperature were greatly important to synthesis ZnONPs [15]. In a recent study by Meenakshi and Sivasamy (2017)[33], they investigate the effects of pH, dye concentrations, mass of catalyst and kinetics, the temperature, concentration of the precursors, duration of aging process and time of deposition during synthesis the ZnONPs. Various parameters used will affect the morphology, crystallite sizes, width of the peaks, the functional group, energy band gap, and the photodegradation of the ZnONPs produced. According to Sakthivel and Kisch (2003)[97], the important parameters governing the rate of reaction taking place on zinc oxide particle is the pH of solution due to the amphoteric property (acid-base property) of ZnO semiconductor which influences the surface-charge property of the photocatalyst for photocatalytic activity.

Table 3 shown the different dopant used to dope with ZnO for various application. The most morphology observed when ZnO doped with various dopant is spherical shape. While Ciciliati et al. (2015)[98] and Mote et al. (2016)[99] attained the hexagonal-like shape when ZnO doped with Fe and Mn. Besides, the average crystallite size decreased with the increasing doping (Fe and Mn) amount. Referring to Table 3, the crystallite size of ZnONPs revealed is ranging around 11-45 nm when using different dopant.

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**Table 3**

Different dopant used to dope with ZnO for various applications.

| Doped | Morphology | Size | Applications | References |
|---|---|---|---|---|
| Fe (Iron) | Hexagonal | 11-25 nm | - | [98] |
| Fe (Iron) | Spherical | 30-45 nm | Antibacterial | [100] |
| Fe | Spherical | 25-36 nm | - | [43] |
| $Fe^{3+}$ | Spherical | 14-16 nm | Photocatalytic activity | [47] |
| Mn (Manganese) | Spherical, hexagonal | 30-43 nm | | [99] |

| | | | | |
|---|---|---|---|---|
| Mn (Manganese) | Seed-like | - | Photocatalytic & antibacterial activity | [9] |
| Pr (Praseodymium) | Spheroid-like, rod-like | 25.5-29.7 nm | Varistor properties | [101] |
| Co (Cobalt) | Spherical | 18-30 nm | - | [102] |

## III. CONCLUSIONS

In this review, we have discussed on the ZnONPs synthesized by chemical and green synthesis method. The various chemical method used to synthesize the ZnONPs and the structural properties present the different morphology and crystallite sizes by many researchers. While synthesized the ZnONPs by the green synthesis, various natural source used which can act as reducing agent. Hence, the green synthesis method is environmentally friendly, cheaper and reduce the chemical used. These ZnONPs formed was then tested by cytotoxicity test, antifungal activity, photocatalytic activity, antibacterial/antimicrobial activity and antioxidant test to exhibit the excellent properties of ZnO in many applications. This study will helpful for enabling the future research progress for scientist scheduling to work on ZnONPs and aim for various applications.

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