Chapter I

Introduction

CHAPTER 1

Introduction

1. Introduction of ZnO

Numerous inorganic oxides of metal such as Magnesium oxide, Titanium oxide, Copper oxide and Zinc oxide have achieved rising consideration during the current years. Metal oxide nanostructures have attracted broad attention due to their exclusive properties and great prospective applications in various fields. Currently, metal oxide ZnO has attracted rehabilitated consideration as a prospective material. It gained significant interest in the research area part because of its large exciton binding energy (60meV) which could lead to lasing action based on exciton recombination even above room temperature. Among these listed oxides, multifunctional and versatile semiconducting material of ZnO, with a direct band gap value of 3.37eV that can reveal some particular features like remarkable physical, chemical and bio-compatible properties [1]. ZnO has II-VI semiconductor and it has a variety of attractive individuality for optoelectronics and electronics devices [2]. ZnO most likely has the significant material of nanostructures in semiconducting group, both in structures and optical properties [3].

1.2 Properties of ZnO

Zinc oxide, a desirable environment of eco-friendly material is prepared specially for bio-applications, light sensitive, luminescent and promising material in great attention for a wide range of photo-electronic applications. It is economical, relatively abundant, chemically stable, easy to synthesis and non-hazardous. This is why to study the synthesis of ZnO nanostructures and understanding the ZnO nanostructures is of great interest. Table 1.1 shows the general properties of ZnO [4].

Table 1.1: Different physical and chemical properties of ZnO

Properties	**Values**
Stable phase at 300 K	Wurtzite
Lattice Constant	a = 0.325 nm and c = 0.521 nm
Exciton binding energy	60 meV
Hole effective mass	0.59
Hole hall mobility at 300 K	0.59
Electron effective mass	0.24
Electronic hall mobility at 300 K	200 cm^2/Vs
Band gap (RT)	3.37 eV, Direct
Band gap (4K)	3.437 eV
Refractive index	2.008, 2.029
Static dielectric constant	8.656
Linear expansion coefficient ($^oC^{-1}$)	$a^0 = 6.5 \times 10^{-6}$, $c^0 = 3.0 \times 10^{-6}$
Thermal conductivity	(0.6, 1-1.2 ($Wcm^{-1}\,^oC^{-1}$)
Solubility	Amphoteric
Melting point	1975 ºC
Density	5.606 g/cm^3
Thermal conductivity	White or yellow

From Table 1.1 shows the physical, chemical and other important properties, also it represents the important standard parameters.

1.3 Application of ZnO

Zinc Oxide is an essential and versatile material of semiconductor with an extensive band gap that could exhibit some unique characteristics like chemical, bio-compatibility, high transparency and thermal stability. ZnO has engrossed very much consideration from the industries, being appropriate for many potential applications including photocatalysts, sensors, dye-sensitized solar cells, bio devices and opto-electronic devices. Due to these diverse both physical and chemical properties, zinc oxide is extensively used in numerous areas. It plays an important role in a very extensive variety of applications like as from tyres to ceramics, from paints to chemicals and from pharmaceuticals to agriculture. Moreover, a variety of morphologies of zinc oxides are nanowires, nanorods, nanotubes, nanowhiskers, nanoflowers and nanoballs have been establish to be useful in health care and biomedical [5] applications.

1.4 Processing methods of synthesis

The synthesis of nanomaterial can be well accomplished by two approaches [6]. Bottom up method where small building blocks are produced and assembled into larger structures. The major controlling parameters are crystallinity, particle size, morphology and chemical composition. For examples: chemical synthesis, colloidal aggregation laser trapping, and self-assembly. Further, by Top Down method where large objects are adapted to give slighter features. Example: film deposition and growth, nanoimprint or lithography, etching technology and mechanical polishing.

1.4.1 ZnO nanoparticles by Chemical Precipitation method

Different physical and chemical synthetic methods have been used to prepare the doped ZnO NPs [7-9]. Most of the initial synthesis of ZnO nanoparticles was achieved by the Chemical precipitation. The reactions involved the simultaneous occurrence of growth, nucleation, and agglomeration processes. Due to the difficulties in isolation of each process for independent study, the fundamental mechanisms of precipitation need to be understood.

Chemical precipitation reactions tend to exhibit the following characteristics:

- The products of precipitation reactions are generally sparingly soluble species formed under conditions of high supersaturation.
- Secondary process, such as Ostwald ripening and aggregation, will dramatically affect the size, morphology and properties of the products.
- Supersaturation conditions necessary to induce precipitation are usually the result of chemical reaction.

Reaction conditions due to influence of the mixing process, stirring rate, rate of reactant addition and have to be considered relevant to particle size, morphology and optical parameters. The synthesis of nanoparticles and nanostructred materials, chemical precipitation reactions is the most common method. Chemical precipitation is the generally important methods to synthesis the ZnO nanoparticles with exceptionally low cost. A search for alternative synthesis methods for efficiency doped with ZnO NPs has become the most important of studies with high surface area for improved anti-bacterial appliance and is to develop the optical properties and acquire a small particle size using co-precipitation method.

1.4.2 Introduction of thin film technology

Thin film is a layer of material ranging from nanometer fractions (monolayer) to numerous micrometers in thickness. The controlled synthesis of materials as thin films (a process referred to as a deposition) is a fundamental step in many applications.

1.4.3 Deposition Techniques

The deposition of a thin film is a technique for depositing a thin film of Material onto a substrate or onto earlier deposited layers. “Thin” is a relative term, but most deposition techniques allow layer thickness to be controlled within a few tens of nanometres and some allow single layers of atoms to be deposited at a time.

Thin films can be prepared from a variety of materials like metals, semiconductors, insulators etc., and for this purpose various preparative techniques have also been developed. Newer methods are also being evolved to involve improving the quality of the deposits with maximum reproducible properties and minimum variation in their compositions [10]. Thin films deposition techniques have been classified into two main categories. They are:

1. Physical methods.
2. Chemical methods.

1.4.4 Physical methods

Physical method is the most commonly used technique for the deposition of metals, and also many compounds. Physical Vapour Deposition (PVD) is a process by which a thin film material is deposited on a substrate according to the following sequence of steps.

1. The material to be deposited is converted into vapour.
2. The vapour is transported across a region of low pressure from its source to the substrate.
3. The condensation on the substrate to form the thin film by undergoes the vapourization.

PVD is an adaptable synthesis method and is preparing for the nanomaterials within control of the nanometre scale by helpful monitoring of dispensation conditions of evaporation. This is done in a high vacuum environment, so that the vaporized atoms or molecules will be transported to the substrate with minimal collision interference with other gas atoms or molecules, whereas in sputtering atoms are removed from solid target through impact of gaseous ions.

1.4.5 Chemical Methods

Chemical Deposition Technique is the most important method for the growth of the film owing to their versatility for depositing a very large number of elements and compounds at relatively low temperatures. The processes are very economical and have been industrially exploited on a large scale [11]. The deposition of films on gaseous phases of thermal decomposition or chemical reactions on the substrate surface at a high temperature is known as Chemical Vapour Deposition process. CVD works on the principle of initiating a chemical reaction in a vacuum chamber, resulting in the deposition of a reacted species on a heated substrate. In this method constituents of a vapour phase, often diluted with an inert gas react at the hard surface and to form a solid film at the hard surface of the substrate. The chemical vapour deposition process is used in semiconductor industry and is to generally produce thin films. CVD is mainly used to produce high purity, high performance solid material.

1.4.6 ZnO Thin Films by SILAR Deposition method

The Successive Ionic Layer Absorption and Reaction method [12, 13] is used to create thin films form on glass substrates and to produce different coatings for applications, including solar panels and semiconductors. The SILAR method is a chemical bath solution method that is an extension of the similar chemical bath thin film production method. The thin film production method knew as SILAR requires the film to be immersed in the chemicals required for creating a chemical solution over the substrate. Between each immersion of the film into the chemicals, the film is rinsed using purified water to create the desired coating over the film. In simplicity, SILAR has number of advantages: (i) The deposition can be carried out and/or close to room temperature; (ii) unlike chemical vapour deposition, SILAR does not require vacuum at several stage; (iii) unlike radio frequency magnetron sputtering (high power methods), it does not cause local over heating that can be harmful for materials to be deposited and (iv) more or less no confines on substrate of the material. Therefore, the solution has free access in an insoluble surface will be a suitable substrate for large area deposition of making the convenient technique.

1.5 Importance of addition of Biomolecules and Metal dopants

Preparation of Nanoparticles (NPs) and Thin films (TFs) by the addition of biomolecules of carbohydrate and transition metal will affect the ZnO structure, size and shape. The reduced crystalline size and shape performs the better antibacterial activity. Carbohydrate biotemplate ZnO (Cbts-ZnO) and Transition metal doped (TM-

ZnO) NPs and TFs are prepared by Co-precipitation and SILAR techniques were performed efficient antibacterial activity. The nanoparticles and thin films are annealed in air to improve the crystalline and crystallite sizes. All the synthesized particles and thin films are characterized for their structural, optical, surface morphological, compositional analysis, spectroscopic analysis and antibacterial properties were presented in this section. The salient features of the various studies carried out and the importance for findings of addition of biomolecules and metal dopants.

The advantages of biotemplate are comparatively economical, cheap, environmentally gentle and renewable one [14]. Water soluble glucose, sucrose and starch as renewable raw materials for stabilizing agents to give the invention needs of economy. Interaction of carbohydrate molecules biotemplate into ZnO nanostructure to improve the biocompatibility of nanoparticles and nanostructure thin films and it's attributed the efficient antibacterial resistance without toxic. The organic material of glucose, sucrose and starch plays an important role in controlling morphology [15].

The characteristics of nanoparticles and nano thin films for ZnO, Transition metals (Mn, Co & Ni) doped ZnO nanoparticles suitable for bio- medical applications and its controlled particle size, shape and conditions that influences their properties. Zinc oxide (ZnO) has many unique physical properties, high chemical stability, good piezoelectric properties, non-toxicity and bio-compatibility [16].

1.6 Bioactivity of ZnO nanostructured materials

ZnO Nanostructure may be of important relevance in the context of Nano medicine, were targeted treatment of biological systems for various areas. In the modern decade, the repetition of infectious diseases and bacterial stain in all kinds of materials which is one of the mainly significant challenges faced by the world [17]. Thus, a number of antibacterial agents are extensively used in everyday life for the preclusion of public health issues caused by the ubiquity of micro-organisms and their ability to establish themselves. Though an antibacterial agents are mostly used in the fresh packaging materials for health care and food applications, the most vital parameters to be taken care of high efficiency in controlling bacteria and low toxicity to human beings. The increasing use of inorganic antibacterial agents is of great interest since of their effectiveness towards highest safety and stability when compared with organic antibacterial agents. New nanostructured materials and their antibacterial properties are the need of the every day for preventing microbial growth, for the reason that; the size, structure and surface properties of nanomaterials could be develop the antimicrobial [18] efficacy.

1.7 Antibacterial activities of ZnO Nanoparticles and Thin films

Antibacterial agents are generally two types, inorganic and organic. Basically at high temperatures or pressures of organic antibacterial materials are establishing to be less stable than that of inorganic antibacterial agents. Zinc Oxide has mainly proved to be an influential antibacterial agent in the perfect formulation of the nanoscale and microscale systems for curative applications. ZnO NPs (ZnO nanoparticles) and TFs (thin films) have a broad spectrum antimicrobial activity against several pathogens they are increasingly incorporated into various matrices to extend their utility in materials and biomedical applications. ZnO used as health related personal care product such as catheters bandages etc, to prevention of infection, mainly during the therapeutic of burns and wounds. Nano scale ZnO many common household products such as water purification systems washers, shampoo, tooth paste, fabrics, deodorants, paints, filters, toys, kitchen utensils and humidifiers to impart antimicrobial properties [19].

Compare than ZnO micro particle, nanoparticles exhibit superior antibacterial action. The precise mechanisms of antibacterial activity have not until now been evidently recognized.

Zinc Oxide nanoparticles have bactericidal effects on gram positive and gram negative bacteria's. They have better antibacterial activity against spores which are highly resistant with effect of high temperature and pressure. A number of researchers have been proposed to their report that hydrogen peroxide (H_2O_2) generation is one of the major factors for the cause of antibacterial activity. This is also indicated that the particles binding on the surface of bacteria owing to the electrostatic forces possibly will be one more thing. For the analysis of the literature it is evident that the antibacterial action of ZnO nanostructure depends on concentration and the surface area, while the particle shape and crystalline structure have slight effect on antibacterial activity. In most of the literature state, that enhanced antibacterial action duo to lesser the crystalline size of ZnO. In this study is an investigation of the antibacterial activity of ZnO nanoparticles and ZnO thin films are against pathogenic bacteria species like *Escherichia coli*, *Klebsiella pneumonia, Proteus valgaris and Staphylococcus aureus.*

The selected pathogenic bacteria make the following strain and cause [20].

- ★ ***E. coli*:** Gram- negative bacteria, virulent strain causes food poisoning, urinary tractinfections and neonatal meningitis.

- ★ ***Proteus vulgaris***: Gram-negative rod shaped bacteria infect the pulmonary tract, urinary tract, burns and wounds, also causes other blood infections.
- ★ ***Klebsiella pneumonia*****:** Gram-negative coccoid bacterium causes pneumonia, meningitis, sepsis.
- ★ ***Streptococcus aureus:*** Gram-positive spherical shaped bacteria cause food poisoning.

1.8 Mathematical analyses for Antibacterial activity

In this present section to investigate the structure and antibacterial efficiency of prepared NPs & TFs samples. Thus the antibacterial activities verified using statistical analysis like Mean deviations (MD), Co-efficient of Mean Deviation (CMD) and Karl Pearson's co-efficient of Correlation (r) for the comparative study of NPs & TFs samples.

1.8.1 Mean Deviation of NPs and TFs

Mean deviation is the arithmetic average of the variations taken for the zone of inhibitions of the average value of the samples. All the mean deviation values obtained for the two series of data showed positive values and its average difference between the zones of inhibitions for NPs and TFs. The values (1.04 - 2.5) were found out for NPs and TFs.

$$M.D = \frac{\sum|D|}{N} \qquad \text{................ (1.1)}$$

The greater inhibition was found from four different bacterial species were analyzed and mean deviation calculated for all the species of bacteria with reference to five different antibacterial agents for both the NPs and TFs.

1.8.2 Co-efficient of Mean Deviation of NPs and TFs

Co-efficient of mean deviation is obtained by dividing the mean deviation by the average used for calculating of mean deviation.

$$CMD = \frac{M.D}{Mean} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

In this present investigation CMD values were calculated between NPs and TFs for the prepared samples.

1.8.3 Karl Pearson's co-efficient of Correlation

Karl Pearson's method is popularly known as Pearsonian Co-efficient of Correlation is the most widely used mathematical method for measuring the magnitude of the linear relationship between NPs and TFs. It is denoted by symbol 'r'. The formula for computing Pearsonian r is:

$$r = \frac{\Sigma(xy)}{\sqrt{\Sigma x^2 . \Sigma y^2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$

Where, x and y are the mean deviations of the zone of inhibition for NPs and TFs respectively.

$x = X - \overline{X}$ and $y = Y - \overline{Y}$. X and $\overline{X}$ be the inhibition taken from five trial values and deviation with mean values respectively for NPs. Similarly $Y\ and\ \overline{Y}$ is the inhibition taken from the average value and deviation with mean values respectively for TFs prepared samples.

To enable a wider acceptance of antibacterial application based on ZnO nanoparticles and nanostructure thin films, it becomes imperative to employ less expensive and efficient techniques. According to our investigation, there is limited literature on the successful antibacterial activity of carbohydrates biotemplate ZnO and Transition Metals doped ZnO nanoparticles and nanostrutural thin films. Hence, the mathematical analysis mainly focuses on the improved antibacterial property of selective inorganic and organic materials.

1.9 Review of Literature

Review of Literature is the comprehensive and extensive examination of several research works done by many researchers on a selected field and the briefing of their finding. It excludes the chance of repetition in research works and helps for a comparison. A thorough review of various preparation techniques and characterization of ZnO nanoparticles and thin films have been carried out and lists of the survey are presented in this chapter.

- ❖ Lupan *et al.,* (2009) [21] have prepared zinc oxide films synthesized by successive chemical solution deposition for gas sensor applications. They reported that rapid photo thermal processing is an efficient method for improving the quality of nano structured ZnO films.

- ❖ Fatemeh Nouroozi *et al.,* (2011) [22] reported that the new method for the preparation of brush-like ZnO nanorods using albumen as a natural and nontoxic template, and water as a green solvent. Crystalline ZnO nanorods with wurtzite-like structure and average diameter of 90 nm and length ≥1 μm, was prepared by calcination (700 °C) of a Zn(II)/albumen hybrid obtained by sol-gel method, by the reaction of Zn(II) acetate and egg white (albumen), in aqueous solution.

- Prakash Thangaraj *et al.,* (2011) [23] have prepared the size controlled zinc oxide nanoparticle is synthesized in the isothermal evaporation method with albumen.

- Shoeb *et al.,* 2013 [24] have prepared Zinc oxide nanoparticles (ZnO NPs) have attracted great attention because of their superior optical properties and wide application in biomedical science. Nevertheless, small is known about the antimalarial activity of ZnO NPs against *Candida albicans* (*C. albicans*). This study was designed to develop the immature approach to synthesize ZnO NPs using egg white (denoted as Et-ZnO NPs) and investigated its possible mechanism of antimicrobial activity against *C. albicans.*

- Donya Ramimoghadam *et al*., (2013) [25] reported that rice as a bio-template can be used to modify the shape and size of zinc oxide particles. Different morphologies, namely flake- flower-, rose-, star- and rod-like structures were obtained with particle size as micro- and nanometer range.

- Deepu Thomas *et al.,* (2014) [26] have reported that the antibacterial activity of pure ZnO thin film is enhanced by Cd doping. ZnO thin films were prepared by Successive Ionic Layer Adsorption Reaction (SILAR) method. The structural analysis of the thin films was done by X-ray diffraction.

- Sreetama Dutta *et al.,* (2012) [27] have prepared the ZnO nanoparticles (grown in the template of folic acid) are biologically useful, luminescent material. It can be used for multifunctional purposes, e.g., as biosensor, bioimaging, targeted drug delivery and as growth promoting medicine.

- Ilican *et al.,* (2008) [28] reported that the ZnO thin films have been deposited onto the glass substrates by the sol-gel spin coating method at different chuck rotation rates. The grain size of crystallites was found to be in the range of 25-32 nm. The values of the optical band gap and Urbach energy change with chuck rotation rate.

- Prakash *et al*., (2013) [29] have prepared ZnO NPs by a microwave irradiation method. In the absence of albumen, heterogeneous mixture of $Zn(OH)_2$ and ZnO was obtained. ZnO nanostructures, whisker-like and rod- nanoparticles emwere obtained in the addition of albumen.

- Soosen Samuel *et al.,* (2009) [30] synthesis of ZnO nanoparticles has attracted immense interest because of their unique properties and potential applications in optoelectronic devices.

- Anitha *et al.,* (2013) [31] reported that the anti-bacterial property of the sample was studied using the disc diffusion method. It was experiential that the embedded ZnO was responsible for the hydrophobic (solvent hating) nature of the surface.

- Kairyte Kristina *et al.,* (2013) [32] have analyzed ZnO NPs properties, further it used for the development of effective fungicides for agriculture areas or innovative physical antibacterial agents and it represented in visible light reveal strong antifungal and antibacterial activity.

- Haritha Meruvu *et al.,* (2011) [33] have been prepared by Zinc oxide nanoparticles using a chemical method and characterize zinc oxide nanoparticles using scanning electron microscope and X-ray diffractometer. Further its antimicrobial activity against *Bacillus subtilis* and *Escherichia coli* was studied. Gagandeep Singh *et al.,* (2012) [34] have analyzed to report the antibacterial activity of ZnO NPs. Various tests were performed to ZnO NPs against Gram negative *Escherichia coli* and Gram positive *Staphylococcus aureus*.

- Durga Prasad *et al.,* (2014) [35] reported the antibacterial activity of the formed nano ZnO were investigated against the pathogenic bacteria namely against E-coli.

- Shailaja raj *et al.,* (2012) [36] reported that the nanosized ZnO has been used in sunscreens (coatings and paints) because of its transparency to visible light and exhibits strong antibacterial activities on a broad spectrum of bacteria, ZnO nanoparticles have great potential of becoming safe and effective for relevant application in treating acne vulgaris and other *P.acnes* associated diseases.

- Thanh Thuy Trinh *et al.,* (2011) [37] prepared that the ZnO and Sn doped ZnO (ZnO:Sn) thin films at various doping concentrations from 1 to 10 in % was prepared by the sol–gel method for an ethanol sensing application. Sn doping significantly influenced the film growth, grain size and response of the films. XRD patterns showed that the hexagonal wurtzite structure of the ZnO film was retained even after the Sn doping.

- Yu-Jun Zhang *et al.,* (2013) [38] analysed on the Mg/Cd doped Mn: ZnO thin films by a sol-gel method. Our results indicate that Mg and Cd-doping can tune the band gap of ZnO film (3.17-3.30 e V), and all of these thin films show room temperature ferromagnetic behaviors. As the band gap of ZnO-based thin films changes, it affects the strength of the magnetic exchange interaction in the transition metal doped ZnO films, which result in the tunable ferromagnetism. This may be a practical way to achieve appropriate dilute magnetic semiconductor materials for future spintronic devices.

- Jimenez-Garcia *et al.,* (2011) [39] reported on ZnO and ZnO-Mn thin films obtained by the successive ionic layer adsorption and reaction (SILAR) method. XRD patterns of these films were polycrystalline with wurtzite hexagonal structure. The morphology of ZnO films were constituted by rice-like and flower-like structures that changed significantly to Nano sheet structures with the Mn incorporation.

- Kharroubi *et al.,* (2012) [40] reported on the synthesis and characterization of Mn-doped ZnO thin films with different percentages of Mn content (0, 1, 3 and 5 at %) and substrate temperature of 350 °C, deposited by a simple ultrasonic spray pyrolysis method under atmospheric pressure.

- Sheng Hong Yang *et al.,* (2013) [41] reported about the undoped and Mn-doped ZnO thin films were prepared on quartz glass and Si (1 0 0) substrates by the sol–gel method at room temperature, and the effects of Mn content on the structural, optical, and magnetic properties of these films were investigated. X-ray diffraction patterns revealed that all the films were single phase and have the wurtzite structure with (0 0 2) preferential orientation along *c*-axis, indicating there were not any secondary phases.

- Srinivasan *et al.,* (2008) [42] reported on Mn-doped and undoped ZnO Nano crystalline thin films were synthesized by the sol–gel method using a spin-coating technique. The microstructure, morphology and optical properties of ZnO films were studied.

- A several number of effective chemical techniques have been utilized to deposit ZnO thin film. Spray pyrolysis technique is used to prepare the transparent conducting films of zinc oxide materials. It is useful, low cost and simple technique for the effective preparation of different semiconducting material of thin films. It has been found to be suitable for the preparation of ZnO films particularly for solar cell and gas sensor applications [43 - 54].

- Gumus *et al.,* (1987) using ultrasonic nebulization of zinc acetate solution by spray pyrolysis technique. ZnO thin film is clearly obtained on silicon and silica substrates at 380 ^{o}C. This process allows the coating of large surface on selected substrates and it is well-suited with their mass production systems [55].

- Nicolau *et al.,* (1992) [56] with the name SILAR because it involves adsorption of a layer of complex ion on the substrate followed by reaction of the adsorbed ion layer on the same substrate.

- Lupan *et al.,* (1991) synthesized zinc oxide thin films by the process of successive chemical solution deposition (SCSD) using sodium zincate bath as cationic precursor [57].

- Raidou *et al.,* (1992) have reported that the synthesis of ZnO thin films by SILAR method using cationic precursor of ammonium zincate. It includes choice of suitable metal salt complex as a precursor, concentration, temperature of deposition and pH of the reactant solution along with many others [58].

- Hiten Sarma *et al.,*(1999) [59] have prepared a novel and simple chemical route was used for the deposition of ZnO thin film from aqueous solution of zinc-ammonia complex, integrating the qualities of chemical bath deposition and successive ionic layer adsorption and reaction (SILAR) methods.

- Pay-Yu Lee *et al.,* (2003) [60] reported that the average diameter of ZnO was around 100 nm when the fabrication of a ZnO PD involving the use of ethylene glycol by SILAR.

- Chitra *et al.,* (2004) [61] have prepared that the synthesis of ZnO NPs using the wet chemical method and it was used as an antimicrobial agent against Food borne Pathogens. Antibacterial activity of ZnO NPs was tested against *Pseudomonas aueroginosa and E. coli*, the maximum inhibition was obtained at 100 μl.

- Ghaffarian *et al.,* (2004) [62] prepared Zinc oxide (ZnO) NPs were synthesized in an aqueous solution of zinc acetate at various concentrations from 5 to 25 wt % by spray pyrolysis method.

- Soosen Samuel *et al.,* (2006) [63] reported that the syntheses of ZnO nanoparticles was prepared by chemical method, using PVP as capping agent.

It has attracted immense interest because of their unique properties and potential applications in optoelectronic devices. Zinc Oxide, a wide band gap semiconductor with larger excitation energy becomes one of the most essential functional materials with optical transparency, near UV-emission, piezoelectricity and electrical conductivity.

- ❖ Aneesh *et al.,* (2008) [64] reported that the Zinc Oxide NPs were synthesized by varying the growth temperature and concentration of the precursors using hydrothermal method.

- ❖ Saravanakumar *et al.,* (2008) [65] reported that the ZnO nanopowders simultaneously doped with Sn and F are synthesized by employing a simple soft chemical route.

- ❖ Mondal *et al.,* (2011) [66] have prepared for Aluminum doped zinc oxide (AZO) thin film was deposited on microscopic glass substrate following a chemical technique called successive ion layer adsorption and reaction (SILAR). It involves copious dipping of the substrate in an aqueous solution of sodium zincate kept at 25 ºC and near boiling point using deionized water.

1.10 Objectives of the present work

➢ To synthesis and cahracterization of ZnO nanoparticles and ZnO nano thin films from different Zinc compound sources and to optimize the best quality of the samples.

➢ To improve the property of ZnO nanoparticles by addition of carbohydrate biotemplate and transition metal dopant [organic materials (Glucose, Sucrose &

Starch), inorganic materials (Mn, Co & Ni)] and to study their characteristics (structural, optical and antibacterial activity).

- To enhance the behaviour of ZnO nano thin films by addition of carbohydrate biotemplate [organic materials (Glucose, Sucrose and Starch)] and transition metal dopant [inorganic materials (Mn, Co & Ni)] to analyse their characteristics (structural, optical and antibacterial activity).

- To compare the improved antibacterial property of selective inorganic and organic materials using basic mathematical analysis for biomedical applications.

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