CHAPTER- 1.0

INTRODUCTION
1.0 INTRODUCTION

Nanotechnology deals with particles having dimensions of less than 100 nanometres, and the engineering of individual atoms and molecules to achieve enhanced properties. It has materialized as a progressive and promising science for the benefit of the society through its extensive applications in medicines, energy, environment, information technology, defence and aerospace etc [1-3].

Nanomaterials are regarded as the fundamental component of nanotechnology due to their ability to display enhanced characteristics at small dimensions. They facilitate the development of existing technologies and unleash new pathways to develop novel scientific and technological fields due to their outstanding physical, chemical, biological, optical and electronic properties.

1.1. Category of nanomaterials

Different types of nanomaterials can be synthesized in varied shapes depending upon the required applications. Some of the nanostructures include nanocage, nanocrystal, nanobelt, nanofiber, nanoparticle, nanotubes, nanorods, nanowire, quantum dot and nanocomposites. These are briefly described below.

1.1.1. Nanocage:

Nanocages, first reported in 2002 [4], are a category of nanomaterials with hollow interior and porous walls containing metallic nanoparticles inside and size ranging between 10-150 nm. They can be synthesized by reaction among the metallic precursor and the nanotemplates of more reactive metals [4-5]. They find application as photothermal agents for the selective destruction of cancerous tissue and drug delivery vehicles [6].
1.1.2. Nanocrystal:

Nanocrystals are single or multi-phase polycrystalline solids with granule size less than 100 nm [7]. Researchers such as Murray et al [8], Li et al [9] and Hyeon et al [10] have reported different types of nanocrystals. They find applications in memory devices, solar cells, solid-state displays, photo detectors and field-effect transistor (FET) detectors [11-12].

1.1.3. Nanobelt:

Nanobelts are thin, even sheets of ribbon-like structures that are typically 30-300 nm in size [13]. Wang et al. have reported the synthesis of 1D ultra-long nanobelts of lanthanum hydroxide [14]. Nanobelts have applications in FET devices, nanometer-sized ultrasensitive gas and biosensors, resonators, cantilevers, etc [15].

1.1.4. Nanofiber (NF):

Nanofibres are two dimensional structures having diameter less than 100 nm. Electrospinning is the most explored method for large scale production of nanofibres of versatile materials including polymers, metal oxides, carbon based materials, supramolecular dipeptides, etc [16-18]. Other methods to design NFs are emulsion polymerization, self-assembly, melt blowing and phase separation etc [19-21]. They find application in water filtration systems, surgical implants, biosensors, drug delivery systems, electronic devices, tissue engineering, etc [22-24].

1.1.5. Nanoparticle (NP):

According to IUPAC, particle of any shape with dimensions in the $1 \times 10^{-9}$ and $1 \times 10^{-7}$ m range is known as nanoparticle (NP). Different chemical, physical and biological strategies are available to design NPs of various material types (polymers, inorganic oxides, metals, etc.) of diverse sizes, surface characteristics and topography [25]. NPs have a
wide range of applications in almost all categories of industries including construction, food, communication, biomedicals, defence and aerospace industries, etc [26].

1.1.6. Nanotube (NT) and Nanorod (NR):

NT’s are essentially hollow. On the contrary NR is solid structure with aspect ratio of ~ 3-5 and each of their dimensions varies from 1 to 100 nm [28]. Arc-discharge, Laser ablation, and chemical vapour deposition (CVD) are some of the methods used to prepare metallic/semiconducting nanotubes and nanorods [29]. Among the nanotubes, carbon nanotubes (CNT) are extensively being used to design many novel technologies. Multiwall (MWCNT) and single wall CNT (SWCNT) yarns and sheets have already been known to have promising applications in supercapacitors, actuators and electromagnetic shields [27, 30].

1.1.7. Nanowire (NW):

Nanowires are smart one dimensional nanostructural materials which can be synthesized both by top-down and bottom-up approaches [31-32]. Semiconductor nanowires show tremendous electronic and optoelectronic properties and they can be used for fabrication of p-n junctions, transistors, solar cells, sensors, etc [33-34].

1.1.8. Quantum dot (QD):

Quantum dots are nanocrystals of semiconducting material, small enough to exhibit quantum mechanical properties and their excitons are confined in all three dimensions. These exhibit strong size dependent optical and electronic properties. QD can contain as few as 100 to 100,000 atoms within the quantum dot volume, with a diameter of 10 to 50 atoms [35]. Three routes to design QD are: i) Organometallic method, ii) Aqueous synthesis using thiol stabilising agents, iii) Biological method
using microorganisms [36-37]. They can be extensively applied to light emitting diodes, lasers, biomarkers, biosensor devices and biomedical imaging [37-39].

1.1.9. Nanocomposites:

It is multiphase material where one or more of the constituent phases have at least one dimension less than 100 nm [40]. The promise of nanocomposites lies in their multifunctionality, the possibility of realizing unique combinations of properties unachievable with traditional immaculate materials [41]. Eg: Polymer-clay nanocomposites, elastomer-clay nanocomposites, conducting polymers-CNT nanocomposites.

Different chemical, physical and biological methods can be employed to derive different nanocomposites depending upon the materials concerned. Applications of nanocomposites are in microelectronic industry, aerospace, electronic packaging, energy storage and also in catalysis [42-44].

To realize such varieties of nanoparticles with diverse applications, it is essential to understand the criticalities in their synthesis methods. Synthesis methods would depend on the ultimate objective of application of the nanoparticle such as biomedical or electronics field etc, as also on the material chemistry.

Synthesis methods are physical, chemical and bio-assisted methods. Some of the important and widely used synthesis methods are briefly described below.

1.2. Methods for the synthesis of nanoparticles

Two types of approach for process flow sequence can be adopted for synthesis of nanoparticles namely (i) top down and (ii) bottom up. The sequences are decided according to the nature of the precursors and the desired final products. The broad outline of the two approaches is:
1.2.1 Top-down approach:
Synthesis starts with the bulk counterpart leading to the generation of fine NPs. Photolithography, electron beam lithography, milling techniques, anodization, ion and plasma etching are some of the commonly used top-down methods for the mass production of NPs.

1.2.2. Bottom-up approach:
The method involves assembling in atomistic or molecular scale to produce NPs. Examples of bottom-up approach self-assembly of monomer/polymer molecules, chemical or electrochemical nanostructural precipitation, sol–gel processing, laser pyrolysis, chemical vapour deposition (CVD), plasma or flame spraying synthesis and bio-assisted synthesis [45].

In general, NP synthesis methods can be divided in three groups - 1) physical methods, 2) chemical methods, and 3) bio-assisted methods (Fig. 1.1.).
1.3. Physical methods for the synthesis of nanoparticles

Physical methods apply mechanical pressure, high energy radiations, thermal energy or electrical energy to cause material abrasion, melting, evaporation or condensation to generate NPs. These methods mainly operate on top-down strategy and are advantageous as they are free of solvent contamination and produce uniform monodisperse NPs. At the same time, the abundant waste produced during the synthesis makes physical processes less economical.

High energy ball milling, inert gas condensation, laser ablation, electrospraying, physical vapour deposition, laser pyrolysis, melt mixing are some of the most commonly used physical methods to generate NPs.
1.3.1. High energy ball milling (HEBM):

High energy ball milling, first developed by John Benjamin in 1970 to synthesize oxide dispersion strengthened alloys capable of withstanding high temperature and pressure, is a robust and energy efficient synthesis method to generate NPs with varying shapes and dimensionalities [46].

1.3.2. Inert Gas Condensation (IGC):

Inert gas condensation is one of the primitive methods for the NP synthesis that employ inert gases (e.g. He or Ar) and liquid nitrogen cooled substrate holder for the preparation of NPs. The evaporated materials are transported within inert gases and condensed on to the substrate attached with liquid nitrogen.

1.3.3. Physical vapor deposition (PVD):

Physical vapour deposition is done by depositing a matter after evaporating in high vacuum as thin layers on a substrate in the range of few nanometers to several micrometers [47]. Most commonly used PVD methods for NPs synthesis are i) Sputtering, ii) Electron beam evaporation, iii) Pulsed laser deposition and iv) Vacuum arc

1.3.4. Laser pyrolysis:

The CO$_2$ laser pyrolysis technique, first developed by Haggerty et al. at the beginning of 1980s, is a vapour phase synthesis process. In this process, the resultant condensable products are generated from the laser-induced chemical reactions at the interface of the laser beam and the molecular flow of gaseous/vapour phase reactants [45]. This method can be used to synthesize NPs of large variety of oxide (TiO$_2$, SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$), non-oxide (Si, SiC, Si$_3$N$_3$, MoS$_2$) and ternary composites like Si/C/N and Si/Ti/C.
1.3.5. Flame spray pyrolysis (FSP):

FSP is a combustion process [48], where the precursor is in liquid form, usually in an organic combustible solvent to produce a self-sustaining flame. It is one of the most exploited techniques for the production of complex and functional NPs. This process is used to synthesise various oxides and engineering ceramics NPs e.g. CeO$_2$, SiO$_2$, Al$_2$O$_3$, MgO, C-Cu, BaCO$_3$, CaO, CaCO$_3$, CaSO$_4$, etc. Main application of these are in catalysis, photonics, sensors, health care, piezoelectric and magnetic materials, etc [49-52].

1.3.6. Electrospraying technique:

Electrospraying is a technique used for the fabrication of nanofibers [53]. A mixture of solution containing the polymer is pushed through a syringe, and a high voltage is applied to the capillary tip that results in the production of charged droplets. The particle or fibre is collected after evaporation of solvent in the pathway to the collector substrate. AuNP’s of 20-100 nm size have been applied in cancer molecular diagnosis and bioinformatics [54,55] while AgNP’s have found applications in biosensors, anti-reflection coatings, artificial joint replacement, cancer diagnosis and antibacterial activity [56,57].

1.3.7. Melt mixing:

This method involves the mechanical mixing of a polymer with modified nanofillers by extrusion or kneading, and less commonly by injection moulding technique [58]. This is one of the oldest methods to design polymer composites with NPs as the fillers to achieve desired material characteristics.
1.4. Chemical methods for the synthesis of nanoparticles

Sol-gel method, micro emulsion technique, hydrothermal synthesis, polyol synthesis, chemical vapour synthesis and plasma enhanced chemical vapour deposition technique are some of the most commonly used chemical methods for the NPs synthesis.

1.4.1. Sol-gel method:

In the sol-gel processing method, there are two types of components viz., ‘sol’ which is a colloidal suspension of solid particles in a liquid and ‘gel’ which are polymers containing liquid [59]. Progressive condensation of ‘sol’ to ‘gel’ results in formation of NPs.

1.4.2. Microemulsion technique:

Microemulsions can be defined as the thermally stable, macroscopically homogenous, isotropic emulsion of the nanoparticle [60]. Microemulsion system consists of monodispersed spherical droplets (diameter ranging from 600 nm to 8000 nm) of water-in-oil (W/O) or oil-in-water (o/w) depending on the surfactant used. W/O reverse micellar system acts as an excellent reaction site for NP synthesis.

1.4.3. Hydrothermal synthesis:

In this process, aqueous suspension of metallic oxides or compounds are simultaneously hydrolysed and thermally treated at appropriate temperatures to produce nano particles. It can be performed in two types of systems, the batch hydrothermal or continuous hydrothermal process. Hydrothermal is a facile and fast process for the synthesis of NPs of various other materials such as CoFe$_2$O$_4$, Ag, FeWO$_4$, La$_{1-x}$Sr$_x$CrO$_3$, CdS, Zr, ZnO, etc [61-67].
1.4.4. Polyol synthesis:

Polyol process is the synthesis of metal-containing compounds using poly (ethylene glycol) as the reaction medium that plays a role of solvent, reducing agent and complexing agent at the same time. This chemical process was used to synthesize a wide range of metal based NPs (Ag, Pt, Pd, Pr, Cu), metal oxide NPs (ZnO, Indium-tin-oxide; ITO, Gd$_2$O$_3$, Cu$_2$O), magnetic NPs and metal hybrid NPs.

1.4.5. Chemical Vapour Deposition (CVD) & Chemical Vapour Synthesis (CVS):

In this method, a chemical reaction takes place with the precursor material at high temperature under a gas flow and the resulting vapour of the nano particle is deposited on a target substrate or collector. When the process conditions are adjusted in such a way that the process produces NPs instead of thin solid films, then the modified process is called as CVS.

1.4.6. Plasma enhanced chemical vapour deposition (PECVD):

Plasma can also be used to enhance the chemical reaction and deposition process as thin films. PECVD process can also be used for the synthesis of NPs.

1.5. Biosynthesis of nanoparticles

Physical and chemical techniques utilize costly and toxic chemicals during the synthesis of nanoparticles during ultraviolet irradiation, laser ablation and aerosol spray. These methods are extensively used, but the utilization of toxic chemicals is a cause of concern. To overcome this problem, biological synthesis of nanoparticles is being explored.
Biological or green synthesis provides an eco-friendly, benign, less-toxic, cost-effective and efficient method to synthesize and fabricate nanoparticles. These methods utilize biological organisms like prokaryotic bacteria, fungi, viruses, yeast, actinomycetes and plant extracts for the synthesis of metal and metal oxide NP’s.

Biological or green methods can be broadly divided into three categories namely biosynthesis using microorganisms, biomolecules as templates and different parts of plant extracts.

1.5.1. Biosynthesis using microorganisms

For the synthesis of nanoparticles viz., Ag, Au, Pd, TiO$_2$, CdS, etc, commonly used bioreactors are prokaryotic bacteria, actinomycetes, fungi, algae and yeast.

Microorganisms take hold of ions from their environment and converts them into the respective metal through enzymes generated by cellular activities. Depending on the location of NP synthesis this can be classified into intracellular and extracellular.

The intracellular synthesis involves transportation of metal ions into the microbial cell to form NPs in the presence of enzymes while the extracellular synthesis involves trapping of metal ions on the surface of the cells and reducing ions in the presence of enzymes [68].

Several anionic functional groups, proteins and enzymes, reducing sugars are being utilized by bacteria to reduce interacting metal ions.

Higher bioaccumulation, economic viability, easy scaling up synthesis method due to simple downstream processing and biomass handling are the numerous benefits for fungal-mediated green chemistry approach for the synthesis of nanoparticles.
Yeast, a eukaryotic microorganism belonging to the fungi kingdom and actinomycetes also find their applications for the biosynthesis of NPs.

1.5.2. Biomolecules as templates to design nanoparticles

Various biomolecules like deoxy ribonucleic acids (DNA), ribonucleic acids (RNA), membranes, viruses and diatoms are being used as templates to synthesize nanoparticles. DNA is widely used as an excellent biomolecular template having a strong attraction with transition metal ions [32].

Fast, electroless, UV-irradiation-/microwave-assisted methods with DNA as reducing as well capping agent was also been reported to synthesize continuous, electrically conductive nanowires of Au, Pd and CdS which can be used as the building blocks for functional nanodevices, miniaturized computers, sensors and optoelectronic applications [69-72].

1.5.3. Plant extracts for synthesis of nanoparticles

Biosynthesis of NPs using extracts of plants or plant biomass is one of the most effective, rapid, clean, non-toxic and eco-friendly methods has been utilized predominantly to synthesize NPs of noble metals, metal oxides, bi-metallic alloys, etc [73]. These nanoparticles are explored for various applications as potent antimicrobial agents, their \textit{in vitro} anticancer efficiency, as electrochemical and biosensors, in medicine and health care, agriculture and crop biotechnology and as pests, nutrients and plant hormones.

Plant-based synthesis of nanoparticles occurs at much faster rate compared to microorganism based synthesis leading to more stable nanoparticles [74, 75]. Microbial synthesis of nanoparticles does not lead to large-scale processing. Also the time required for the synthesis of nanoparticles using microorganism takes longer durations of 24-72 h.
Maintaining microbial cultures requires only aseptic condition; else improper maintenance will lead to contamination.

Moreover, plants are widely known for their extended range of metabolites like tannins, flavonoids, terpenoids, proteins, amino acids and reducing enzymes. These compounds present a more versatile approach, which are yet to be explored and utilized for the synthesis of metallic nanoparticles.

Different metallic nanoparticles such as gold, silver, platinum, zinc, copper, titanium oxide, magnetite and nickel have been synthesized from natural resources and studied exclusively. The different parts of plant such as stem, root, fruit, seed, callus, peel, leaves and flower are being used to synthesize metallic nanoparticles in various shapes and sizes by biological approaches. Green synthesis of metal nanoparticles requires use of an environmentally benign solvent like water replacing toxic solvents, wherein the plant constituents act both as reducing and stabilizing agent.

Several precursor metal salts like AgNO$_3$, HAuCl$_4$.3H$_2$O, PdCl$_2$, H$_2$PtCl$_4$.6H$_2$O are reduced by bioreducing agents like amino acids, citric acid, dehydrogenase, functional groups like alcohol, ketones, amines, carboxyl acids, sulphhydryl, flavonoids, heterocyclic compounds, hydrogenase, intracellular CO$_2$, extracellular proteins, enzymes, proline, phyllanthin, NADH reductase, peptide bonds, phenolics, polyphenols, membrane proteins, polyols, proteins, quercetin, reducing sugars, tannins, tannic acid, tartaric acid, terpenoids, sesquiperpenes, secondary metabolites and result in nucleation and subsequent growth of nanoparticles. The reducing agents also act as capping agents and stabilize the synthesized nanoparticles.

Biosynthesis of nanoparticles using plants is an exhilarating prospect due to its faster duration in synthesis. Several plants have been exploited for the synthesis of nanoparticles and many plants are yet to be
investigated. The size, shape and synthesis of nanoparticles depend on the plant phytoconstituents, reactant pH, temperature and composition of the extract.

### 1.6. Electrospun Nanofibres - Metal nanoparticle composites

Biocompatible electrospun nanofibres are considered as prominent candidates for drug delivery applications. Recently electrospun nanofibres are used in Tissue engineering as a small blood vessel graph, which is flexible and durable to survive in continuous flow conditions [77]. Such fibres are more suitable to release the drug or nanoparticles in tubular systems. The significance of nanofibres is their ability to trap and release the drug or nanoparticles at these specific locations. Hence, controlled release of nanoparticles can be achieved using polymer nanofibres. Electrospun nanofibres can be utilized for various drug release or nanoparticle release applications. Nanofibres act as a carrier medium for release of drug or particles in specific locations. The major and key challenge is to load the specific drug or particles into the nanofibres and initiate the sustained release mechanism. Several types of biological agents, drugs and nanoparticles can be embedded with nanofibres for site specific release applications. Electrospinning is a simple and efficient technique for embedding different types of nanoparticles in the polymer solution to develop nanofibre-nanoparticle composites [78].

Poly vinyl alcohol is one of the familiar water soluble biopolymer and also biocompatible and hemocompatible material [79, 80]. This polymer was used for encapsulation of several drugs and nanoparticles for sustained release mechanism, especially several literature have reported the encapsulation and coating of PVA-Ag and PVA-Au for bio applications [81 - 84].

The drug or nanoparticles embedded with nanofibre form a matrix-type web structure. This process encapsulates the particles and prevents
rapid reaction with external environment [85]. The key process involved in this technique is to regulate the release of the required quantity of the drug or nanoparticles. Electrspun nanofibre plays a major role for the release mechanism. Also, embedding nanoparticles with polymer nanofibre prevents the agglomeration of nanoparticles and it can be precisely released from the nanofibres during flow condition. Thus, a polymer matrix is essential for effective release of drug or nanoparticles at the required region. This mechanism can be utilized for the sustained release of Silver and Gold nanoparticles at targeted locations.

1.7. *Bauhinia tomentosa* Linn.

The genus, *Bauhinia* Linn. belonging to the Family - Fabaceae, and Subfamily – Caesalpiniaceae comprises of 300 species distributed throughout the tropical and subtropical regions of the world. About 15 species of this genus occur in India [86]. *Bauhinia* species such as *B. variegata*, *B. racemosa*, *B. purpurea*, *B. monandra*, exhibit several pharmacological properties such us immunomodulatory activity, anti-tumour, anti-oxidant, anti-inflammatory, anti-ulcer, anti-bacterial and anti-fungal activities [87-89].

Traditionally, *Bauhinia tomentosa* is one of the most widely used plant species as an herbal remedy to treat inflammation in India [86]. It is also known as yellow bauhinia or ball bauhinia. This plant is known as Mandharai or Iruvatchi in Tamil. It is a shrub or small tree of Asia origin which adapt well in climate of India, reaching 6-8m in height.

The taxanomic classification of *Bauhinia tomentosa* Linn, is as follows: Kingdom-Plantae-Plants, Subkingdom-Tracheobionta-Vascular plants, Superdivision-Spermatophyta - Seed plants, Division-Magnoliophyta - Flowering plants, Class-Magnoliopsida – Dicotyledons, Subclass-Rosidae, Order-Fabale, Family-Fabaceae - Pea family, Genus-
Bauhinia L. – Bauhinia, Species-Bauhinia Tomentosa L. - St. Thomas tree.

Ethanolic extract of the leaf contains Kaempferol-3-O-rhamnoside, Kaempferol-3-o-rutinoside, Quercetin 3-O-glucoside and Quercetin 3-O-rutinoside (rutin) [90].

Silver nanoparticles, due to their unique properties like excellent conductivity, chemical stability, catalytic and antibacterial activities are of extreme interest [91]. Gold nanoparticles have found applications in cancer treatment, gene therapy and drug delivery due to their chemical inertness and biocompatibility [92, 93].

*Bauhinia tomentosa* commonly known as yellow bell orchid tree belongs to the Fabaceae family and is one of the most excellent versatile plants, commonly used as a household remedy for curing several diseases. The cytotoxic and antioxidant activity exhibited by the leaves and the anti-hyperglycemic and antilipidemic activity exhibited by the flowers were reported by Mannangatti et al [94]. Pharmacognostical and phytochemical screening of *Bauhinia tomentosa* leaves was reported by Rhama and Madhavan [95].

Even though extensive work has been done using various plants, *Bauhinia tomentosa* is an herbal plant finding applications as an antiulcer [96], antidiabetic [97], antilipidemic [98], anti-hyperglycemic [99] and antidiarrhoeal [100]. Further this plant has not been studied for green synthesis of metal nanoparticles and composites for various potential applications.

The plant *Bauhinia tomentosa* Linn is a versatile herbal plant finding lot of applications in ayurveda medicine. It will be interesting and useful if this plant can be explored for green synthesis of metal nanoparticles and their applications. Thus the present investigation describes the research work carried out with aqueous extract of *Bauhinia*
tomentosa Linn leaves for synthesis of silver, gold and silver/gold composite nanoparticles, their characterization and applications for antimicrobial, anticancer potential, sustained release of silver and gold nanoparticles.

1.8. Structure of the Thesis

Chapter I describes the introduction section of the research work which deals with nanostructures including nanocage, nanocrystal, nanobelt, nanofiber, nanoparticle, nanotubes, nanorods, nanowire, quantum dot and nanocomposites. This chapter also gives a brief introduction to various methods of synthesis of nanoparticles such as physical, chemical and biological methods.

Chapter II brings out the Literature Survey of various green synthesis methods using plants, scope and objective and scope of the present research work.

Chapter III deals with the experimental section of the research work which brings out the various materials and methods employed.

Chapter IV discusses the collection, identification, pharmacognosy and authentication of the plant Bauhinia tomentosa and preparation of Hexane, Ethylacetate, Isopropanol, Ethanol and Aqueous extracts of the leaves. The phytoconstituents, DPPH scavenging and antioxidant activity of the extracts were determined. The phytoconstituents present in the extracts were quantitatively evaluated by GC-MS and HPLC analysis.

Chapter V discusses the synthesis of Silver, Gold, Silver/Gold nanoparticles by using aqueous extract of Bauhinia tomentosa leaves with aqueous AgNO₃ solution, aqueous HAuCl₄.3H₂O solution, and different ratios of AgNO₃:HAuCl₄.3H₂O (1:1, 3:1, 1:3, 2:1, 1:2, 3:2 and 2:3) at room temperature. Characterization by UV-Visible spectrophotometry, FTIR, FESEM-EDAX, HR-TEM, SAED, XRD, TGA, Cyclic Voltammetry, Dynamic Light Scattering and Zeta sizer confirmed the formation of Ag, Au and Ag/Au nanoparticle composites.
Chapter VI confers the antibacterial and antifungal activity of the Ag, Au and Ag/Au nanoparticle composites performed using Resazurin microplate titre assay and the minimum inhibitory concentration (MIC) of the nanoparticles was determined. The in vitro anticancer efficacy of the synthesized nanoparticles and control leaves extract on Vero, A549, HEp-2 and MCF-7 cancer cells was investigated by MTT assay for the cell viability. The morphological changes in the cells were visualized using an inverted microscope at 40x magnification. DNA fragmentation, Fluorescence analysis and flow cytometry confirmed apoptosis of cells treated with AgNP, AuNP and Ag/Au (1:1).

Chapter VII describes the preparation of PVA-Ag and PVA-Au nanofibre mats by electrospinning and the sustained release of the metal nanoparticles using UV-Visible spectrophotometry with respect to time. HR-SEM, EDAX and XRD analysis were also done to confirm the presence of Ag and AuNP’s. The released nanoparticles were applied for invitro antibacterial and anticancer treatment which showed improved activity.

Chapter VIII concludes the outcome of the research work on the synthesis of silver, gold, silver/gold nanoparticles carried out with aqueous extract of Bauhinia tomentosa leaves, their characterization and applications for antimicrobial, anticancer potential, sustained release of silver and gold nanoparticles.

Chapter IX provides the information about the scope and future work on this research work followed by references and the list of publications.