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13. Synthesis of Nanoparticles for Various Applications

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Abstract:

Nanotechnology refers to the creation and utilization of materials whose constituents exist at the nanoscale; and, by convention, be up to 100 nm in size. Nanotechnology explores electrical, optical, and magnetic activity as well as structural behaviour at the molecular and sub-molecular levels. The synthesis of nanoparticles is an active area of academic and, more significantly, applied research in nanotechnology. Materials scientists and engineers have made significant developments in the improvement of methods of synthesis of nanomaterials. In this chapter, various methods of preparing nanomaterials including chemical methods like Chemical reduction method, Microemulsion/colloidal method, Sono chemical method, Electrochemical method, Solvo thermal decomposition, and Physical methods like Pulse laser ablation, Mechanical/High ball milling method, ball milling method, Mechanical chemical synthesis, Pulsed wire discharge method are discussed in detail. The distinctive properties of nanomaterials make them uniquely suitable for such a wide range of functions. Due to its wide applications in electronics, coatings, optical materials, and catalysis the alloy, and nanomaterials are of tremendous interest nowadays.

The increased use of nanoparticles in biomedical sciences, electronics, and drug delivery has led to the development of various methods of synthesizing nanoparticles using physical, chemical and biological methods. However, limitations like toxicity, hazardous chemicals and high cost of production led to the development of alternative methods for *the production of nanoparticles. Green synthesis of nanoparticles is an alternative and emerging area of research. The green synthesis of nanoparticles using microorganisms is a promising approach, which is an ecofriendly and cost-effective method.*

Keywords:

Nanotechnology, nanoparticles, Physical methods, Chemical methods, Green synthesis, applications.

13.1 Introduction:

Nanotechnology is an emerging field of science. The base of nanotechnology is nanoparticles. The size of nanoparticles ranges from 1 to 100 nm. One nanometer is one billionth of a meter (10^{-9}). Therefore, nano-science and nanotechnologies deal with at least clusters of atoms of 1nm size. Nano-science is the study of materials that exhibit remarkable properties, functionality and phenomena due to the influence of small dimensions. Today's nanotechnology harnesses current progress in chemistry, physics, material science, biotechnology and electronics to create novel materials that have unique properties because their structures are determined on the nanometer scale. Some of these materials have already found their way into consumer products, such as sunscreens and stain-resistant plants. Nanotechnology is an excellent example of emerging technology, offering engineered nanomaterials with great potential for producing products with substantially improved performances. Nanotechnology is the construction and utilization of functional structures designed from atomic/molecular scale and with at least one of its characteristic dimensions in nanometers [1]. Such materials and systems can be rationally designed to exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes because of their size. Phenomena at the nanometer scale are likely to be a completely new world. Properties of matter at the nano-scale may not be predictable from those observed at larger scales [2]. Important changes in behaviour are caused not only by continuous modification of characteristics with diminishing size but also by the emergence of totally new phenomena such as quantum confinement, a typical example is the colour of the light emitting from semiconductor nanoparticles depending on their sizes[3]. Designed and controlled fabrication and integration of nano-materials and nanodevices is likely to be revolutionary for science and technology. Nanotechnology can provide unprecedented understanding of materials and devices, and is likely to influence many fields.

13.2 Classification of Nanoparticles:

The nanoparticles are classified into different types based on morphology, size and shape. Some of the important classes of nanoparticles to mention are,

13.2.1 Organic Nanoparticles:

The organic nanoparticles include ferritin, micelles, dendrimers and liposomes shown in Figure 13.1. The organic nanoparticles are not toxic, and biodegradable and some organic nanoparticles have a hallow sphere i.e. micelles and Liposomes. It is also familiar with the name of nanocapsules, which are heat and light-sensitive [4]. Organic nanoparticles are an ideal choice for drug delivery due to these characteristics. Then nanoparticles are also widely used in target drug delivery. The organic nanoparticles are also known as polymeric nanoparticles. The most known shape of organic or polymeric nanoparticles is nanosphere or nanocapsule [5].

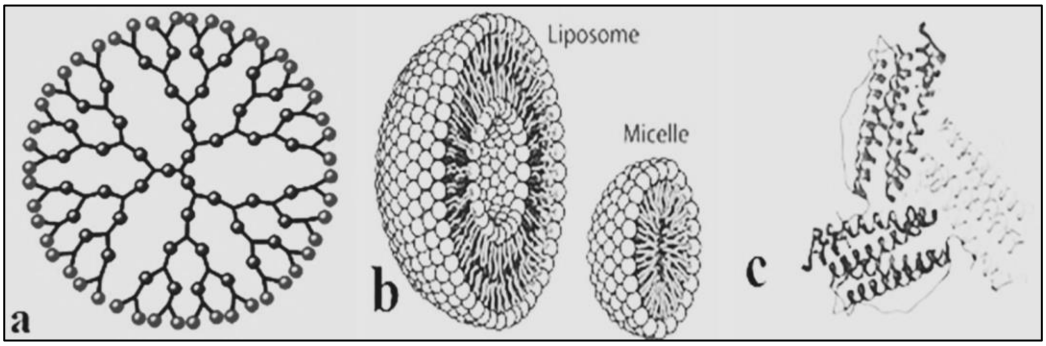

Figure 13.1: Organic nanoparticles (a) Dendrimers (b) Liposomes and Micelles (c) Ferritin

13.2.2 Inorganic Nanoparticles:

Carbon is not present in inorganic nanoparticles. The inorganic nanoparticles are not toxic. The inorganic nanoparticles are biocompatible and hydrophilic. The inorganic nanoparticles are highly stable than organic. The inorganic nanoparticles are classified into metal and metal oxide nanoparticles.

A. Metal Nanoparticles: Metals are used to synthesize Metallica nanoparticles by using destructive or constructive methods. The metal precursors are used to make the pure metal nanoparticles. The metal nanoparticles possess unique optoelectrical properties due to plasma on resonance characteristics. The synthesis of metal nanoparticles is controlled by shape, facet and size [6]. The nanoparticles of all metals can be synthesized [7]. The nanoparticles of aluminium, gold, iron, lead, silver, cobalt, zinc, cadmium and copper are well-known metal nanoparticles.

B. Metal Oxide Nanoparticles: The purpose of the synthesis of metal oxide nanoparticles is to modify the property of their respective metal nanoparticles such as iron nanoparticles being oxidized to iron oxide nanoparticles. The reactivity of iron oxide nanoparticles is increased as compared to iron nanoparticles. Due to an increase in reactivity and efficiency of metal oxide, the nanoparticles of metal oxides are synthesized [8]. Examples of metal oxide nanoparticles are zinc oxide, silicon dioxide, iron oxide, aluminium oxide, cerium oxide, titanium oxide and magnetite.

C. Ceramic Nanoparticles: Ceramic nanoparticles are also known as nonmetallic solid. The ceramics nanoparticles are synthesized via heating or successive cooling. The ceramic nanoparticles may be polycrystalline, amorphous, porous, dens or hollow form [9]. The researcher focuses on these nanoparticles due to their wide application such as photodegradation of dye, photocatalysis, catalysis and imaging applications [10].

D. Bio Nanoparticles: Bio-nanoparticles is an assembly of atom or molecules that is prepared in the biological system having at least one dimension in the range of 1–100 nm. All bio nanoparticles are naturally occurring nanoparticles. These nanoparticles are divided into two categories intracellular structure and extracellular structure. Magnetosomes are an example of intracellular structure and lipoproteins and viruses are examples of extracellular structure. Magnetosomes, exosomes, ferritin, lipoproteins and viruses are examples of bio nanoparticles.

13.3 Classification of Nanomaterials:

Nanomaterial is such material, which has a structural component or unit less than one micrometre in at least one dimension. Building blocks of matter are considered nanomaterial.

13.3.1 Carbon-Based Nanomaterial:

The carbon-based nanomaterials are completely composed of carbon [11]. Fullerenes, carbon nanotubes, graphene, carbon black and carbon nanofibers are the classes of carbon-based nanoparticles.

A. Fullerene:

The fullerenes may be C60 or C70 shown in Figure 13.2. The fullerenes consist of nanomaterials in the form of a hollow cage. Due to their electrical conductivity, electron affinity, structure, strength and versatility, it becomes a noteworthy commercial interest [12]. Fullerenes consist of carbon units in the form of pentagonal and hexagonal shapes. The carbon atoms in fullerenes are linked to each other by sp^2 hybridized. The fullerenes are made of C60 or C70 having diameters of 7.114 and 7.648 nm. The fullerene may be a single layer or multilayer.

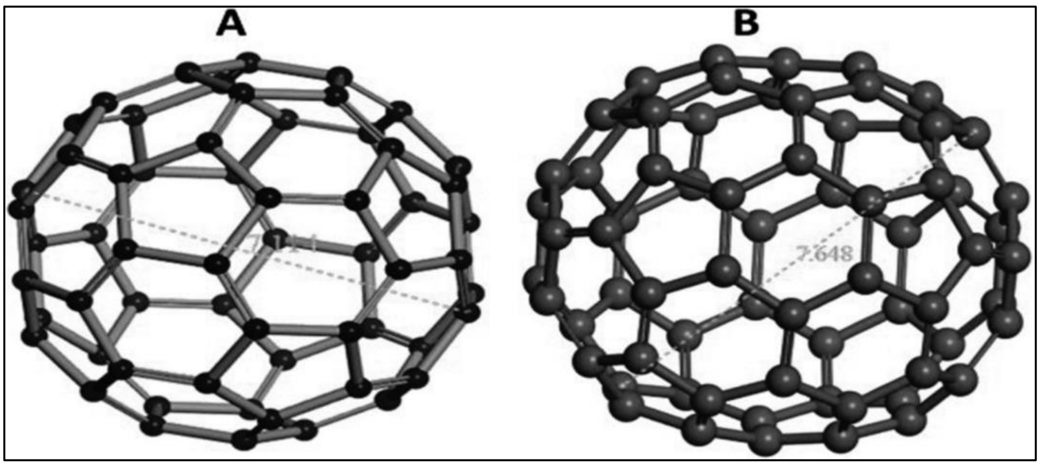

Figure 13.2: Different forms of Fullerenes (A) C60 and (B) C70

B. Carbon Nanotubes (CNT):

Carbon Nano Tubes are tubular elongated structures having 1–2 nm diameter [13]. The carbon nanotube can be predicted as semiconducting or Metallica based on diameter [14]. The structure of CNT resembles with graphite sheet rolling upon itself. Based on rolling CNT categorize into single-walled (SWNTs), double-walled (DWNTs) and multi-walled (MWNTs) as shown in Figure 13.3.

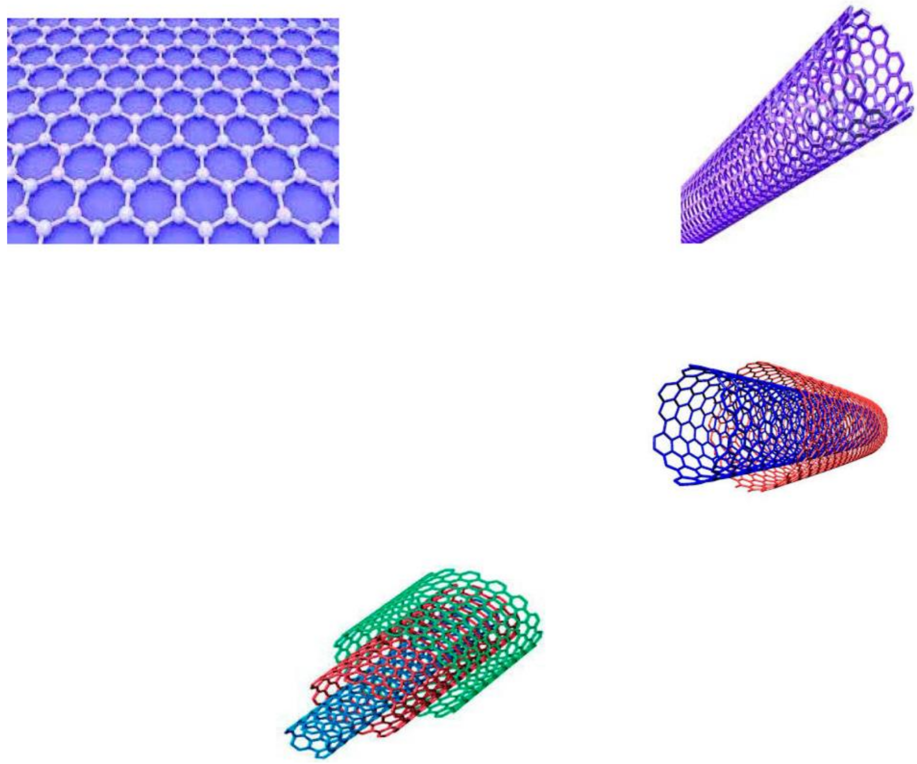

Figure 13.3: Types of CNT

a. Single-walled carbon nanotubes (SWTs). - Single-walled Nanotubes (SWTs) consist of single rolled sheets. The least diameter of nanotubes for single-walled is 0.7 nm.

b. Double-walled carbon nanotubes (DWNTs). - Double Walled Nanotubes (DWNTs) consist of double-rolled sheets.

c. Multi-walled carbon nanotubes (MWNTs). - Multi-walled Nanotubes (MWNTs) consist of multiple rolled sheets. The Nano foil of graphene having honeycomb carbon lattice is wound into a hollow cylinder to form nanotubes. The length of carbon tubes ranges from a few micrometres to several millimetres. CNT is strong, it can be easily bent and regain its original shape without brittle when released [15]. CNT shows various structures and shapes, different thicknesses, lengths and number of layers but the characteristics of CNT are based on sheets of graphene [16].

D. Graphene:

A graphene is an allotropic form of carbon. It is a hexagonal network of honeycomb carbon atom lattices having a two-dimensional planar surface. The graphene is 1 nm in thickness.

E. Carbon Nanofiber:

The nano foil of the same graphene is transferred into carbon nanofiber as carbon nanotubes but nano foils are wound into cups or cones instead of elongated cylindrical tubes.

F. Carbon Black:

It is an amorphous material which is made up of carbon. The shape of carbon black is spherical. The diameter ranges from 20 to 70 nm. High interaction between the particles is present and so bound in an aggregate shown in Figure 13.4.

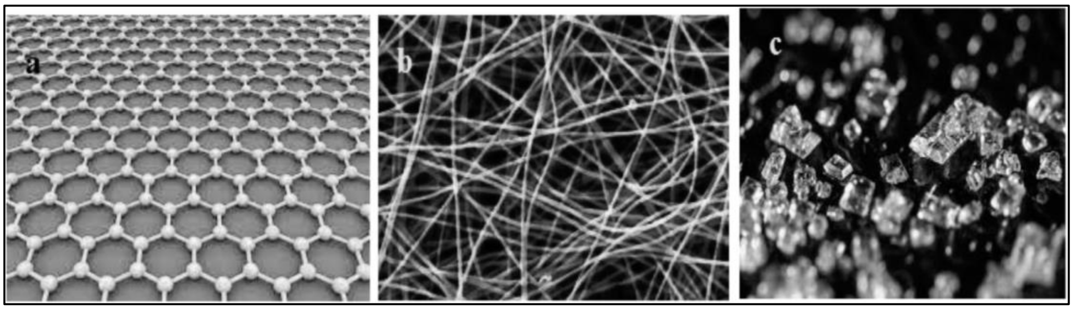

Figure 13.4: (a) Graphene sheet (b) Carbon nanofiber (c) Carbon black.

13.4 Synthesis of Nanoparticles:

The synthesis of NPs can be carried out following two different approaches, viz., (i) top-down approach, and (ii) bottom-up approach as shown in Figure 13.5. Furthermore, three different strategies such as physical, chemical, and biological methods are adopted for the synthesis of NPs.

Top-down approach: In this method, the suitable starting material is reduced in size using physical or chemical means. Several methods including the commonly used attrition and pyrolysis can be used for the physical synthesis of metallic nanoparticles. In attrition, macroscale or microscale particles are ground by a size-reducing mechanism.

Bottom-up approach: It refers to the construction of a structure atom-by-atom, molecule-by-molecule, or cluster-by-cluster. In this approach, initially, the nanostructures' building blocks are formed and, subsequently, assembled into the final material using chemical or biological procedure(s) for synthesis.

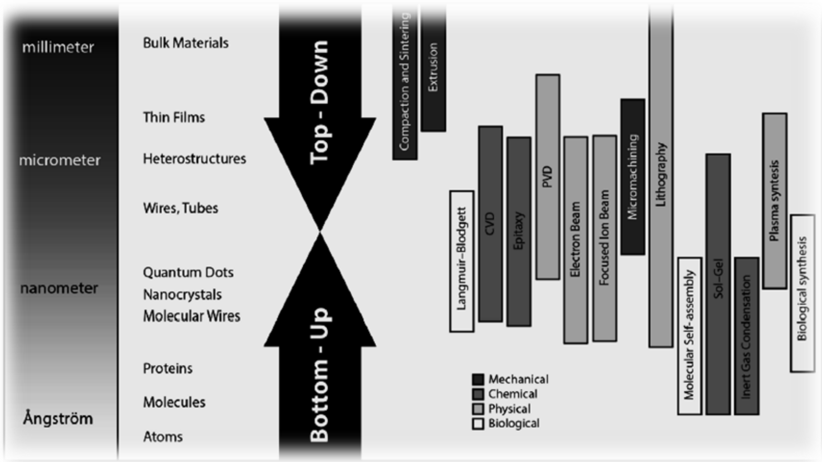

Figure 13.5: Schematic Representation of Building Nanostructures

A part to direct atom manipulation, there are various widely known methods for producing nanomaterials: physical, chemical, and mechanical

13.4.1 Physical Methods:

A. Physical Vapour Deposition:

This technique involves the use of materials of interest as sources of evaporation, an inert gas or reactive gas for collisions with material vapour, a cold finger on which clusters or nanoparticles can condense, a scraper to scrape the nanoparticles and a piston-anvil. All the processes are carried out in a vacuum chamber so that the desired purity of the end product can be obtained. Figure 13.6 schematically illustrates a set-up for carrying out physical vapour deposition and compressing the powder in a pellet form.

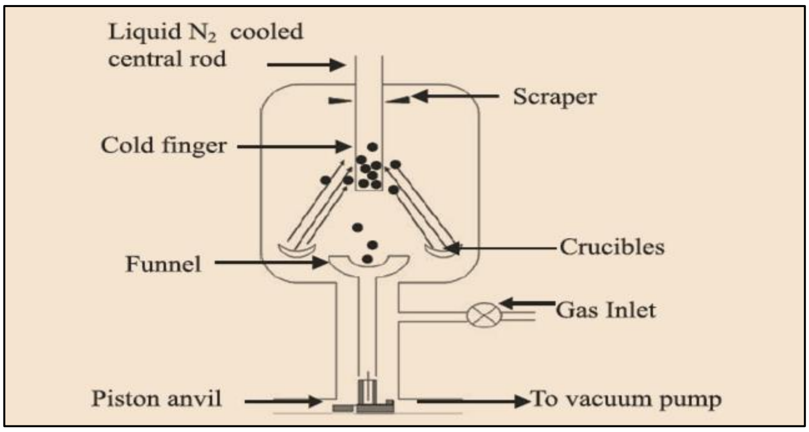

Figure 13.6. Schematic diagram of the synthesis of nanoparticles by physical vapour deposition

Usually, metals or high vapour pressure metal oxides are evaporated from filaments boats of refractory metals like W, Ta and Mo in which the materials to be evaporated are held. Due to small particle interaction, bigger particles get formed. Therefore, they should be removed away as fast as possible from the source.

This is done by forcing an inert gas near the source, which removes the particles from the vicinity of the source. In general, the rate of evaporation and the pressure of gases inside the chamber determine the particle size and their distribution. Distance of the source from the cold finger is also important. Evaporated atoms and clusters tend to collide with gas molecules and make bigger particles, which condense on the cold finger.

While moving away from the source to the cold finger the clusters grow. If clusters have been formed on inert gas molecules, on reaching the cold finger, gas atoms or molecules may leave the particles there and then escape to the gas phase.

If reactive gases like O_2, H_2 and NH_3 are used in the system, evaporated material can interact with these gases forming oxide, nitride or hydride particles. Size, shape and even the phase of the evaporated material can depend upon the gas pressure in the deposition chamber. Clusters or nanoparticles condensed on the cold finger (water or liquid nitrogen cooled) can be scraped off inside the vacuum system.

The process of evaporation and condensation can be repeated several times until enough quantity of the material falls through a funnel in which a piston-anvil arrangement has been provided. One can even have separate low and high-pressure presses. A pressure of a few megapascals (MPa) to Giga pascal (GPa) is usually applied depending upon the material.

B. Laser Vaporization:

A powerful beam of laser evaporates the atoms from a solid source and atoms collide with inert gas atoms and cool on them forming clusters. They condense on the cooled substrate. The method is often known as laser ablation.

Gas pressure is very critical in determining particle size and distribution. Simultaneous evaporation of another material and mixing of the two evaporated materials in inert gas leads to the formation of alloys or compounds.

This method can produce some novel phases of the materials which are not normally formed. For example, Single Wall Carbon Nanotubes (SWNT) are mostly synthesized by this method. In this method, vaporization of the material is effected using pulses of the laser beam of high power.

The setup along with the interaction with the evaporation source is depicted in Figure 13.7. The setup is a high vacuum system equipped with an inert or reactive gas, laser beam, solid target and cooled substrate. Clusters of any material made of a solid target can be made are possible to synthesize. Usually, a laser operating in the UV range such as an excited monomer laser is necessary because other wavelengths like IR or visible are often reflected by surfaces of some metals.

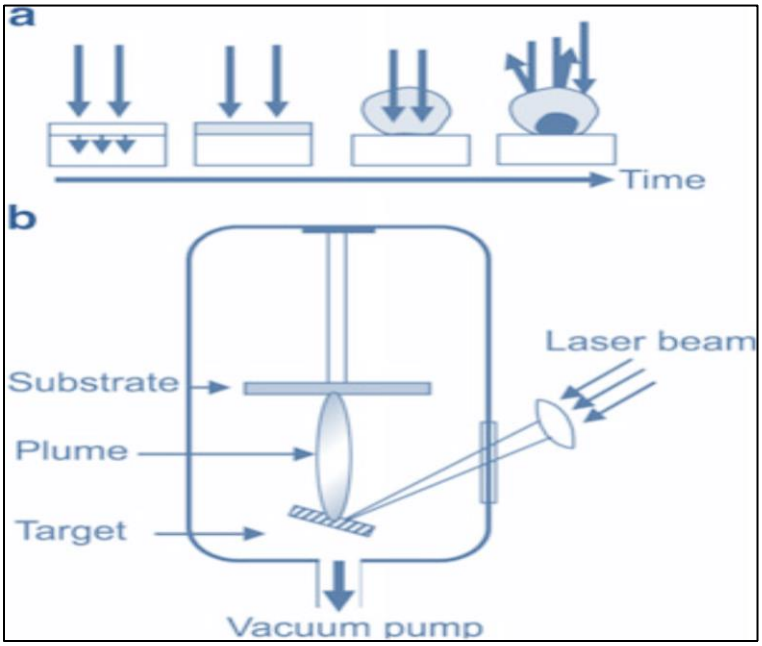

Figure 13.7: (a) Sequence of material evaporation by laser beam interaction with a target material. (b) Schematic Laser deposition

C. Laser Pyrolysis:

Another method of thin film synthesis using lasers is known as 'laser pyrolysis' shown in Figure 13.8. Here a mixture of reactant gases is decomposed using a powerful laser beam in presence of some inert gas like helium or argon. Atoms or molecules of decomposed reactant gases collide with inert gas atoms and interact with each other, grow and are then deposited on a cooled substrate.

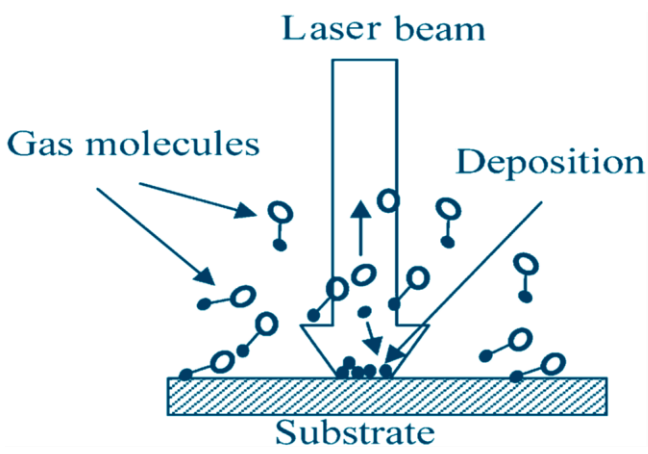

Figure 13.8: Schematic diagram of Laser Pyrolysis

Many nanoparticles of materials like Al_2O_3 and Si_3N_4 are synthesized by this method. Here gas pressure plays an important role in deciding the particle sizes and their distribution.

D. Ion Implantation:

Ion implantation involves the injection of very energetic ions into the surface of a solid substrate. The major components of an ion implantation facility are presented in Figure 13.9 and include a vacuum system, ion source, magnetic analyzer, accelerator, beam scanning, and target chamber.

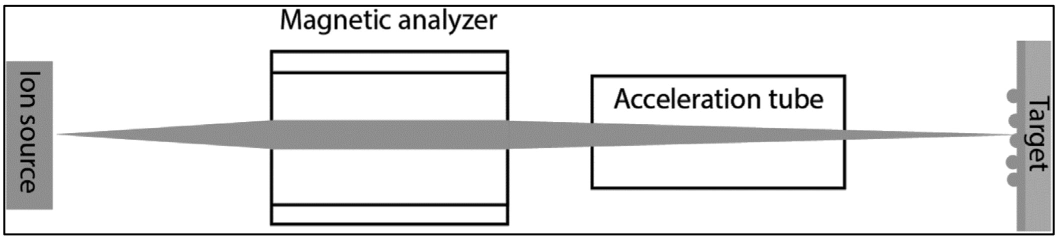

Figure 13.9: Schematic of ion implantation system

There are many examples in which high energy or low energy ions are used to obtain nanoparticles. It is possible to obtain single-element nanoparticles or compounds and alloys of more than one element. Post-annealing also is used sometimes to improve the crystallinity of the materials. In some experiments, it has been possible to even obtain doped nanoparticles using ion implantation. There is also a possibility of making nanoparticles using swift heavy ions employing high-energy ion accelerators like pelletrons.

Examples of ion implantation include the implantation of N to improve the wear resistance of metals and the implantation of Ti and C into Fe alloys to improve hardness and wear resistance. Ion implantation parameters can also be used to control nanocrystallite size distribution.

E. Plasma:

The plasma method is another method that is used to produce nanoparticles. Radiofrequency (RF) heating coils generate the plasma. The initial metal is enclosed in a pestle and the pestle is enclosed in an evacuated chamber.

The metal is then heated above its evaporation point by high voltage RF coils wrapped around the evacuated chamber. The gas that is used in the procedure is Helium (He), which forms a high-temperature plasma in the region of the coils after flowing into the system.

The metal vapour nucleates on the helium gas atoms and diffuses up to a cold collector rod, this is where nanoparticles are collected and are passivated by oxygen gas [17]. Classification of plasma methods based on the feeding materials to the reactor and also the heating source [Figures 13.10 and 13.11].

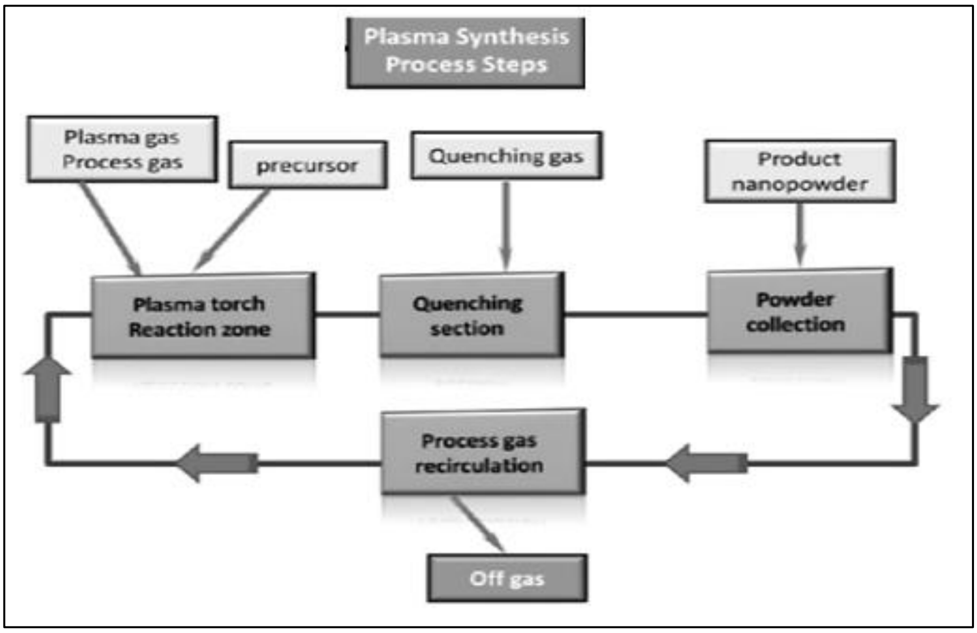

Figure 13.10: ***Flow diagram for production plant based on plasma burners***

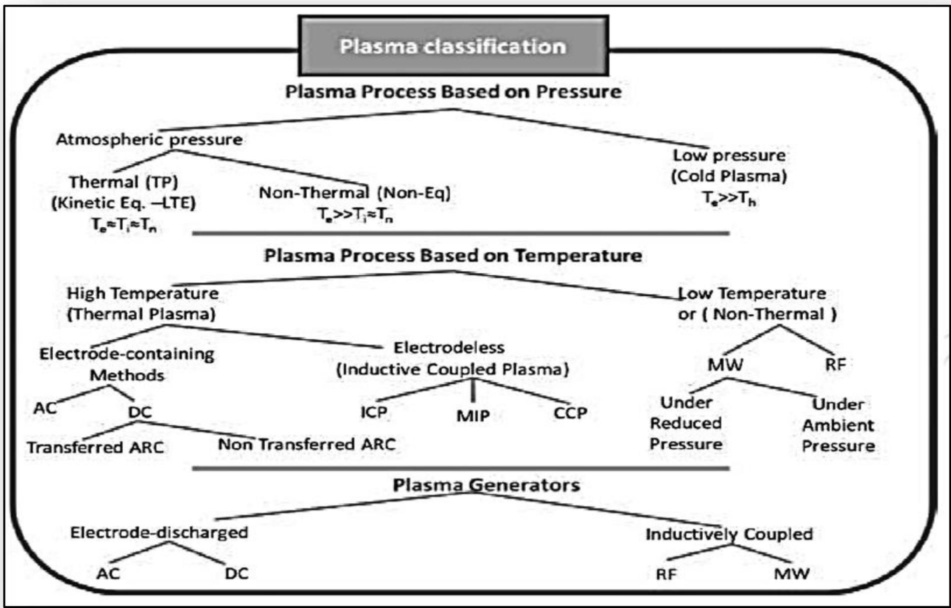

Figure 13.11. Different plasma classification

13.4.3 Chemical Methods:

A. Chemical Vapour Deposition (CVD):

CVD involves flowing a precursor gas or gases into a chamber containing one or more heated objects to be coated [Figure 13.12].

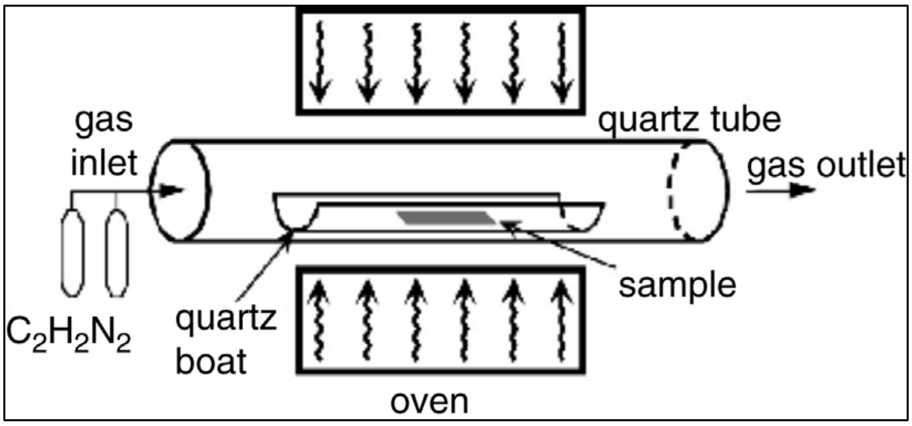

Figure 13.12: Schematics of a CVD Deposition Oven

The CVD method can synthesize ultrafine particles of less than 1 μm by the chemical reaction taking place in the gaseous phase. The reaction can be controlled to produce nanoparticles of sizes ranging from 10 to 100 nm [18, 19]. The basic CVD process can be considered as the transport of reactant vapour towards the substrate kept at some high temperature where the reactant cracks into different products, which diffuse on the surface, undergo some chemical reaction at the appropriate site, nucleate and grow to form the desired material film. The by-products created on the substrate have to be transported back to the gaseous phase removing them from the substrate. Vapours of desired material may be often pumped into the reaction chamber using some carrier gas. In some cases, the reactions may occur through aerosol formation in the gas phase. There are various processes such as reduction of gas, a chemical reaction between different source gases, oxidation or some disproportionate reaction by which CVD can proceed. There are two ways viz., hot wall and cold wall by which substrates are heated. In hot wall setup, the deposition can take place even on reactor walls. This is avoided in cold wall design. Besides this, the reaction can take place in the gas phase with a hot wall design, which is suppressed in a cold wall setup. Usually, gas pressures in the range of 0.1 to 1.0 torr are used. Growth rate and film quality depend upon the gas pressure and the substrate temperature. CVD is widely used in industry because of its relatively simple instrumentation, ease of processing, the possibility of depositing different types of materials and economic viability.

B. Electric Arc Deposition:

This is one of the simplest and most useful methods, which leads to the mass-scale production of fullerenes and carbon nanotubes. The positive electrode itself acts as the source of the material. Inert gas or reactive gas is necessary. Inert gas pressure is maintained in the vacuum system. When an arc is set up, anode material evaporates. This is possible as long as the discharge can be maintained. By striking the arc between the two graphite electrodes, it is possible to get fullerenes in large quantities. In the case of fullerenes, the formation occurs at low helium pressure as compared to that used for nanotube formation. Also, fullerenes are obtained by purification of soot collected from the inner walls of the vacuum chamber, whereas nanotubes are found to be formed only at high He gas pressure and in the central portion of the cathode. No carbon nanotubes are found on the chamber walls.

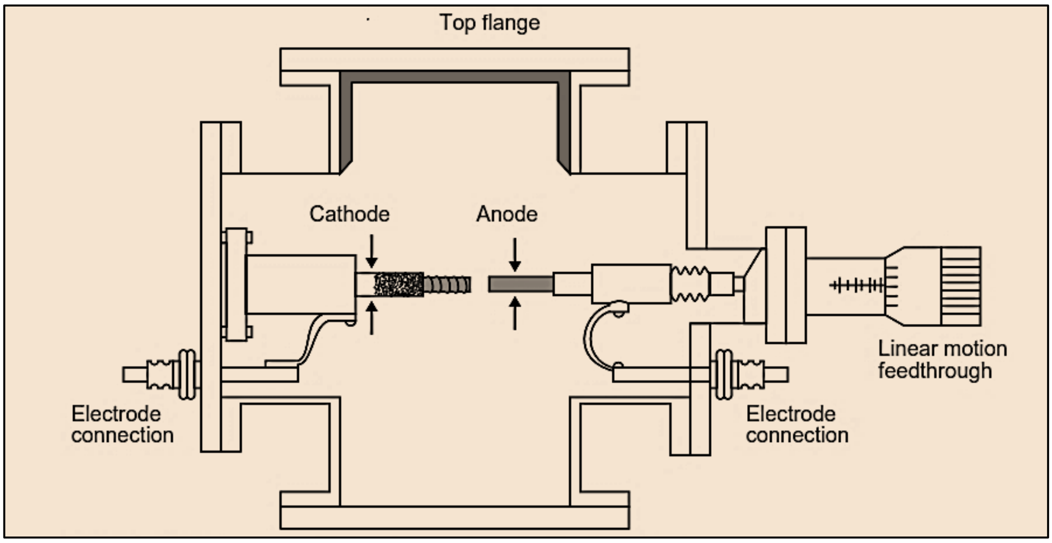

Figure 13.13: Schematic Illustration of the Method of Arc Discharge

Arc discharge was the method used to prepare multiwalled CNTs (MWCNTs) by Iijima in 1991 [20]. In this method, an AC plasma arc is generated between two electrodes maintained in an inert atmosphere as described in Figure 13.13.

The high temperature between the electrodes (3000-4000^{0}C) causes sublimation of the carbon. The sublimated graphite is deposited at the negative electrode or the walls of the chamber where the process is carried out.

These deposits contain CNTs [21, 22]. For achieving the single-walled CNT (SWCNT) electrodes are doped with catalyst particles, such as Ni-Co, Co-Y, or Ni-Y [22-25]. Nanotubes produced by this method are generally entangled and have varying lengths. However, the tubes are of high quality with low amounts of defects.

C. Sol-Gel Method:

As the name implies sol-gel involves two types of materials ‘sol’ and ‘gel’. The sol-gel process involves the evolution of inorganic networks through the formation of a colloidal suspension and gelation of the sol to form a net- work in a continuous liquid phase [Figure 14] [26].

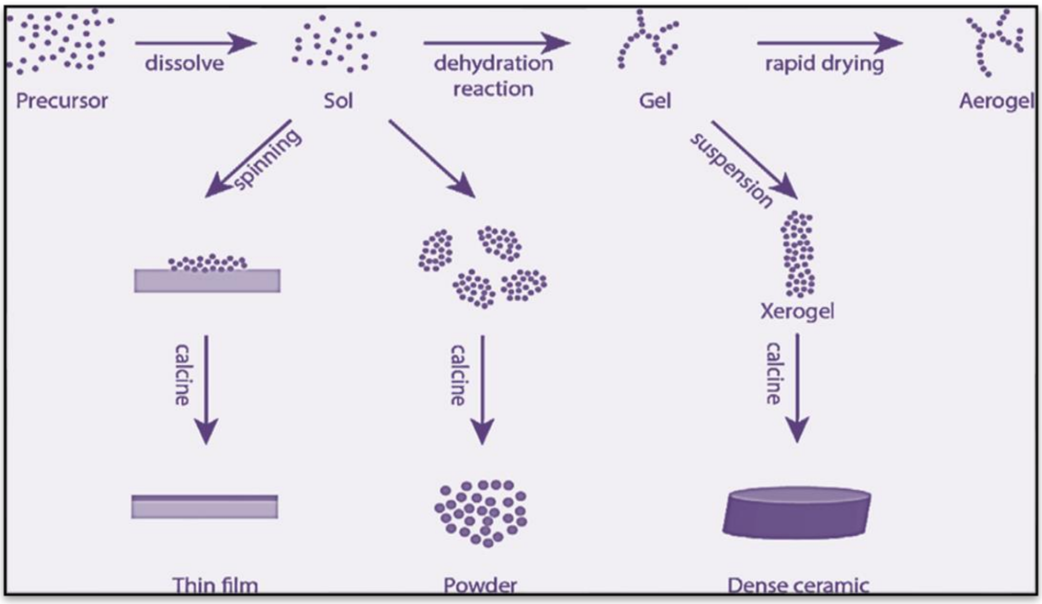

Figure 13.14: Schematic of the Sol-Gel Method

Synthesis of sol-gel, in general, involves hydrolysis of precursors, condensation followed by polycondensation to form particles, gelation and drying process by various routes. Precursors are to be chosen so that they tend to form gels. Both alkoxides and metal salts can be used. Although only oxides do not need to be formed by a sol-gel process, often oxide ceramics are best synthesized by a sol-gel route. By polycondensation process sols are nucleated and ultimately sol-gel is formed.

The sol-gel method is particularly useful to synthesize ceramics or metal oxides although sulphides, borides and nitrides also are possible. All sol-gel formation process is usually low-temperature process. This means less energy consumption and less pollution too. It is also possible to synthesize nanoparticles, nanorods, nanotubes etc., using the sol-gel technique. Sols are solid particles in a liquid. They are thus a subclass of colloids. Gels are nothing but a continuous network of particles with pores filled with liquid.

D. Microemulsion:

An emulsion is a liquid in the liquid dispersion. A solution of polymers can produce emulsions as it is liquid. Emulsions are divided according to the size of the droplet, i.e., macro-emulsions, mini-emulsions, and micro-emulsions [27]. Micro-emulsion synthesis method is widely used for the production of inorganic nanoparticles [28]. Synthesis of nanoparticles in the cavities produced in a microemulsion is a widely used method. Whenever two immiscible liquids are stirred together, they are known to form what is called 'emulsion'. Whenever two immiscible liquids are stirred together, they are known to form what is called 'emulsion'. Emulsions are usually turbid in appearance. On the other hand, there is another class of immiscible liquids, known as transparent microemulsions, and the droplets are in the range of ~1 to 100 nm. This is the size needed for the synthesis of nanomaterials. Microemulsions are stabilized using surfactants. When an organic liquid, water and surfactant are mixed, under some critical concentration, 'micelles' or inverse micelles are formed, depending upon the concentration of water and organic liquid. Micelles are formed with excess water and inverse micelles are formed more than organic liquid or oil. The ratio of water, oil and surfactant is important to decide which type of micelle will be formed and can be represented in a ternary phase diagram, using a triangle. The composition can be determined by drawing lines parallel to all three sides of the triangle.

The advantage of this method is the biocompatibility and biodegradability of synthesized materials. Biocompatibility is useful in drug delivery of nanomaterials and biodegradability is environmentally useful. Among different synthesis processes, the microemulsion method is one of the versatile preparation techniques that enable the control of particle properties such as size, geometry, morphology, homogeneity, and surface area [Figure 13.15] [29].

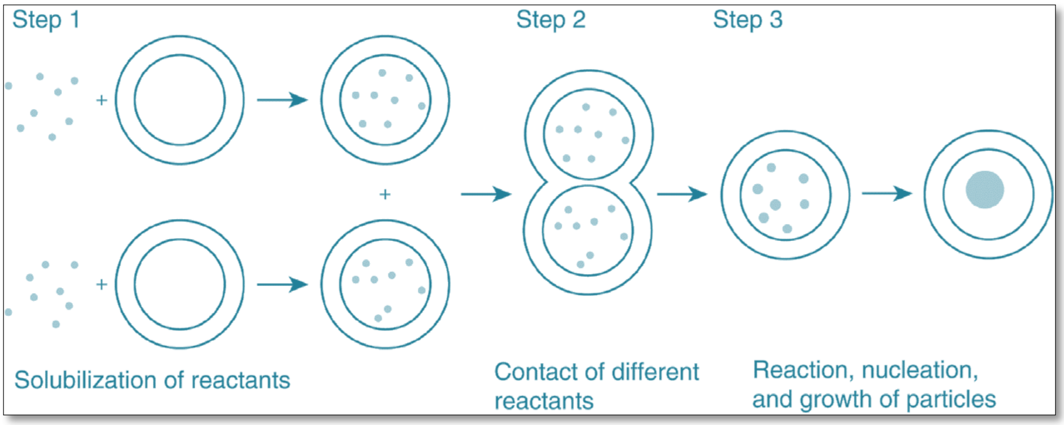

Figure 13.15: Synthesis of Microemulsions

13.5 Various Applications:

13.5.1 Food and Agriculture:

By using nanotechnology, the food industry can also be developed. For example, by using nanotechnology new functional materials and new instruments designed for food preservation and bio-security are developed. Bayer Company introduced airtight plastic packing with the help of nanotechnology.

Food is preserved in this plastic packing. From nanotechnology, genetic modifications in the constitution of the crop plant can be made. Nanotechnology revolutionizes the agriculture field in the part of absorbing nutrients, disease detection, disease control and smart delivery system [30]. In the future, nanocatalyst will available in the pesticide and fertilizers to increase its efficiency at lower dosage levels, which protects the environment from high-dose pesticides.

13.5.2 Energy Harvesting:

Generate renewable resources are low-cost materials. NPs are widely used for the production of energy from the splitting of electrochemical water and photoelectrochemical [31]. At the nanoscale level, NPs can also store energy in different forms [32-34]. That is why they are used in energy storage applications [35]. Recently, Nanogenerators can convert mechanical energy into electrical energy by using piezoelectric.

13.5.3 Micro-Wiring:

In the electronic industry, metal nanoparticles are the best candidate for the manufacturing of a printed wired board [36]. The metal nanoparticles have less melting point than the bulk metals. By the conventional electric conduction paste, circuit formation is possible on polymer base material. Whenever particles are used at the nanoscale, the thickness of the wire is decreased to a nano level. The ink-jet method is very important for the formation of wiring at the nano level. The ink-jet method is not very expensive and it does not require long times like conventional techniques such as photolithographic methods and vacuum evaporation that are generally used. Metal nanoparticles paste can be prepared with gold. Gold is expensive that is why Copper is used as a substitute for it. Copper nanoparticles are used as antioxidants.

13.5.4 Electronics:

The interest in the progress of printed electronics has been growing for the last few years because of the high potential for low cost than the traditional silicon printed techniques. It is expected that electronics, which are printed with different inks, may rapidly flow. These inks may also contain CNTs, organics and ceramics nanoparticles [37]. One-dimensional semiconductors and metals have distinctive structural, electrical and optical properties which provide the key structural blocks for the development of electronic, photonic materials and sensors [38-40]. Nowadays, in the electronic industry, new semiconducting materials are discovered gradually. However, diodes and transistors even miniature chips are in use instead of vacuumed tubes [41].

13.5.5 Food Packaging:

Nanotechnology in the food packaging sector was accepted nowadays due to its tangible benefits. Currently, the widely used food packaging material is made of plastic like polyethene, polypropylene, polyvinyl alcohol, etc which are harmful and non-biodegradable. Another development in Nanotechnology in food packaging is carbon nanotubes which are cylindrical structures with nanoscale diameter. It improves the mechanical properties [42].

Nanosensors are sensors being added to the packaging material to detect the gases that rise off from the food when it's spoiled as well as prevent the permeation and transpiration of gases. Packaging materials with silica nanoparticles prevent oxygen penetration inside the package at the same time stops the moisture loss from the product [43].

13.5.6 Medicine:

Nanoscience and technology are currently have been developed in the field of medicine for detecting diseases such as cancer and atherosclerosis at early stages and targeted drug delivery for a cell or tissue of choice. Two important aspects of Nanotechnology in drug delivery systems release drugs and specifically target the diseased cells which improves the drug availability. Nanorobots, which could precisely occlude the specific sites on the teeth quickly, and permanent could prevent it within minutes. Nanosized organic and mineral phases can be an effective and new bone material for implantation because it has greater bone adhesion, durability and flexibility. A large surface-to-volume ratio, increases the bone cell interactions, thus improving the orthopaedic implant efficacy and minimising patient compliance [44].

13.5.7 Antimicrobial Activity:

Metal nanoparticles had anti-microbial activity, The bactericidal effect of metal nanoparticles is attributed owing to their small size as well as high surface-to-volume ratio, which allows them to interact closely with microbial membranes thus facilitating quick penetration of metal nanoparticles into the cell and excluding the internal components of the cell thus inactivate the microorganism. A disk diffusion test was carried out to find the minimum inhibitory effect.

13.5.8 Textiles:

The use of nanotechnology in the textile industry is attractive due to its distinctive and significant properties [45]. Some of the properties are water repellence, wrinkle resistance, anti-bacterial, anti-static and UV protection. Water repellence is imparted to the cotton material simply by a coating of a nano plasma over it [46]. Conventionally wrinkle resistance is done by resins but it leads to a decrease in dyeability, the tensile strength of fibre and abrasion resistance, could be prevented by titanium nanocatalyst and silica nanocatalyst for cotton and silk respectively [47].

13.6 Conclusions:

Nanoscience is the study of materials that exhibit remarkable properties, functionality and phenomena due to the influence of small dimensions. Today's nanotechnology harnesses current progress in chemistry, physics, material science, biotechnology and electronics to create novel materials that have unique properties because their structures are determined on the nanometer scale. Some of these materials have already found their way into consumer products, such as sunscreens and stain-resistant plants.

Various methods of preparation of nanoparticles have been developed and they are suitable for the synthesis of nanoparticles in different sizes and shapes. Nanomaterials possess high surface areas, magnetism, quantum effects, antimicrobial activity, and high thermal and electrical conductivities. The nanomaterial family includes carbon-based nanomaterials, nanoporous materials, core-shell materials, ultrathin 2-dimensional nanomaterials, and metal-based nanomaterials.

More focus is currently being placed on producing nanomaterials with controlled morphologies and nanoscale dimensions to achieve the desired outcomes because of well-organized nanostructures. By using nanotechnology, some commercial devices have already been introduced. Nanocatalyst provides an extremely attractive platform in nanotechnology.

The field of nanobiotechnology is very dynamic and the biosynthesis of nanoparticles using different microorganisms and plants is the focused area of current research. The biosynthesis of nanoparticles is a cost-effective and environmentally friendly alternative to chemical and physical methods. Biosynthesis of nanoparticles has a great potential in nanoparticle production as this method is free from toxic and hazardous chemicals used in conventional physical and chemical methods and is less expensive.

13.7 References:

1. Synthesis and Characterization of Pure and Indium Doped Sno_2 Nanoparticles by Sol-Gel Methods Satyanarayana Thodeti, M.V.Ramana Reddy, J.Siva Kumar - ISSN 2229-5518
2. Properties, Application and Synthesis Methods of Nano-Molybdenum Powder-PengfaFeng, Weicheng Cao- ISSN Online: 2327-6053.
3. Boldyrev, V.V. &Tkacova, K., Journal of Materials Synthesis and Processing 2000,8, 121-132
4. Tiwari, D.K.; Behari, J.; Sen, P. “Application of Nanoparticles in Waste Water Treatment 1.” (2008).
5. Mansha, M., et al. Synthesis, Characterization and Visible- Light-Driven Photoelectrochemical Hydrogen Evolution Reaction of Carbazole-Containing Conjugated Polymers. Int. J. Hydrogen Energy 2017, 42 (16), 10952– 10961.
6. Dreaden, E.C., et al. The Golden Age: Gold Nanoparticles for Biomedicine. Chem. Soc. Rev. 2012, 41 (7), 2740–2779.
7. Salavati-Niasari, M.; Davar, F.; Mir, N. Synthesis and Characterization of Metallic Copper Nanoparticles via Thermal Decomposition. Polyhedron 2008, 27 (17), 3514–3518.
8. Tai, C.Y., et al. Synthesis of Magnesium Hydroxide and Oxide Nanoparticles Using a Spinning Disk Reactor. Ind. Eng. Chem. Res. 2007, 46 (17), 5536–5541.
9. Sigmund, W., et al. Processing and Structure Relationships in Electrospinning of Ceramic Fiber Systems. J. Am. Ceram. Soc. 2006, 89 (2), 395–407.
10. Thomas, S.C.; Kumar Mishra, P.; Talegaonkar, S. Ceramic Nanoparticles: Fabrication Methods and Applications in Drug Delivery. Curr. Pharm. Des. 2015, 21 (42), 6165–6188.
11. Bhaviripudi, S., et al. CVD Synthesis of Single-walled Carbon Nanotubes From Gold Nanoparticle Catalysts. J. Am. Chem. Soc. 2007, 129 (6), 1516–1517.
12. Astefanei, A.; Núñez, O.; Galceran, M.T. Characterisation and Determination of Fullerenes: A Critical Review. Anal. Chim. Acta 2015, 882, 1–21.
13. Ibrahim, K.S. Carbon Nanotubes-Properties and Applications: A Review. Carbon Lett. 2013, 14 (3), 131–144.
14. Aqel, A., et al. Carbon Nanotubes, Science and Technology Part (I) Structure, Synthesis and Characterisation. Arab. J. Chem. 2012, 5 (1), 1–23.

15. Winkin, N., et al. Nanomaterial-modified Flexible Micro- Electrode Array by Electrophoretic Deposition of Carbon Nanotubes. Biochip. Tissue Chip 2016, 6 (115), 2153–0777.
16. Zhao, Q.; Gan, Z.; Zhuang, Q. Electrochemical Sensors Based on Carbon Nanotubes. Electroanalysis 2002, 14 (23), 1609–1613.
17. http://shodhganga.inflibnet.ac.in/bitstream/10603/21144/10/10_ chapter%203.pdf [Accessed: April 2016]
18. http://shodhganga.inflibnet.ac.in/bitstream/10603/21144/10/10_ chapter%203.pdf [Accessed: April 2016]
19. Khah V, Sara D, Djafar IR, Rahman N, Jafar IR. A glance at the plasma synthesis methodologies of the nanoparticles. In: Proceedings of the Sixth NanoEurope Congress and Exhibition; St. Gallen, Switzerland; 2008
20. Iijima S. Helical microtubules of graphitic carbon. Nature 1991;354:56-8.
21. Journet C, Bernier P. Production of carbon nanotubes. Appl Phys A 1998;67:1-9.
22. Journet C, Maser WK, Bernier P, Loiseau A, delaChapelle ML, Lefrant S, et al. Large-scale production of single-walled carbon nanotubes by the electric-arc technique. Nature 1997;388:756-8.
23. Bethune DS, Kiang CH, Devries MS, Gorman G, Savoy R, Vazquez J. Cobalt-catalysed growth of carbon nanotubes with single-atomic-layer walls. Nature 1993; 363:605-7.
24. Shi Z, Lian Y, Liao FH, Zhou X, Gu Z, Zhang Y, et al. Large scale synthesis of single wall carbon nanotubes by arc discharge method. J Phys Chem Solids 2000;61:1031-6.
25. Saito Y, Nishikubo K, Kawabata K, Matsumoto TJ. Carbon nanocapsules and single-layered nanotubes are produced with platinum-group metals (Ry, Rh, Pd, Os, Ir, Pt) by arc discharge. Appl Phys 1996;80:3062-7.
26. Brinker, C.J. and Scherer, G.W. (1990) Sol-Gel Science: The Physics and Chemistry of Sol-Gel Processing, Academic Press.
27. Tauer K. MPI Colloids and Interfaces, Emulsions Part 1, Am Mühlenberg, D-14476 Golm, Germany
28. Yu D, Chu Y, Dong LH, Zhuo YJ. Controllable synthesis of CaCO3 micro/nanocrystals with different morphologies in microemulsion. Chemical Research in Chinese Universities. 2010;26:678.
29. Eastoe, J. and Warne, M. (1996) Nanoparticles and polymer synthesis in microemulsions. Curr. Opin. Colloid. Interf. Sci., 1, 800–805.
30. Rai M; Ingle A, Applied microbiology and biotechnology, **2012**, 94(2), 287-293.
31. Ning, F., et al. TiO_2/Graphene/NiFe-Layered Double Hydroxide Nanorod Array Photoanodes for Efficient Photoelectrochemical Water Splitting. Energy Environ. Sci. 2016, 9 (8), 2633–2643.
32. Greeley, J.; Markovic, N.M. The Road from Animal Electricity to Green Energy: Combining Experiment and Theory in Electrocatalysis. Energy Environ. Sci. 2012, 5 (11), 9246–9256.
33. Liu, D., et al. Rapid Synthesis of Monodisperse Au Nanospheres through a Laser Irradiation-InducedShape Conversion, Self-Assembly and Their Electromagnetic Coupling SERS Enhancement. Sci. Rep. 2015, 5 (1), 1–9.
34. Liu, J., et al. Metal-free Efficient Photocatalyst for Stable Visible Water Splitting via a Two-electron Pathway. Science 2015, 347 (6225), 970–974.
35. Wang, D.-W.; Su, D. Heterogeneous Nanocarbon Materials for Oxygen Reduction Reaction. Energy Environ. Sci. 2014, 7 (2), 576–591.

36. Karim, M.E. Nanotechnology Within the Legal and Regulatory Framework: An Introductory Overview. Malayan Law J. 2014, 3.
37. Kosmala, A., et al. Synthesis of Silver Nanoparticles and Fabrication of Aqueous Ag Inks for Inkjet Printing. Mater. Chem. Phys. 2011, 129 (3), 1075–1080.
38. Hu, Y., et al. Two-dimensional Transition Metal Dichalcogenide Nanomaterials for Biosensing Applications. Mater. Chem. Front. 2017, 1 (1), 24–36.
39. Millstone, J.E., et al. Synthesis, Properties, and Electronic Applications of Size-controlled Poly (3- Hexylthiophene) Nanoparticles. Langmuir 2010, 26 (16), 13056–13061.
40. Shaalan, M., et al. Recent Progress in Applications of Nanoparticles in Fish Medicine: A Review. Nanomed. Nanotechnol. Biol. Med. 2016, 12 (3), 701–710.
41. Cushing, B.L.; Kolesnichenko, V.L.; O'Connor, C.J. Recent Advances in the Liquid-phase Syntheses of Inorganic Nanoparticles. Chem. Rev. 2004, 104 (9), 3893–3946.
42. Bhupinder S Sekhon, Nanotechnol Sci Appl, 2010, 3, 1–15.
43. Sozer N; Kokini J L, Trends in biotechnology, 2009, 27 (2), 82-89.
44. Sahoo S K; Parveen S; Panda J, Nanomedicine: Nanotechnology, Biology and Medicine, 2007,3(1), 20-31.
45. Wong Y W H; Yuen C W M; Leung M Y S; Ku S K A; Lam H L I, AUTEX Research Journal, 2006, 6(1), 1-8.
46. Zhang J; France P; Radomyselskiy A; Datta S; Zhao J; Ooij W V, Journal of Applied Polymer Science, 2003, 88 (15), 1473-1481.
47. Chien H Y; Chen H W; Wang C, Journal of the Hwa Gang Textile, 2003. 10 (2), 104-114.