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Review Article

A Comprehensive Review on Nanomaterials

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ABSTRACT

Nanomaterials have emerged as an outstanding class of materials in Pharmaceutical Technology. Its dimension is in the range of 1 to 100 nm. Nanomaterials has its excellent magnetic, electrical, optical properties that can be molded as desired particularly controlling the size, shape, synthesis conditions and appropriate functionality. Due to its uniqueness, it is rising and is applied in many fields and sectors. This review discusses the brief history of nanomaterials including synthesis methods like top-down and bottom-up approaches. Application of nanomaterials are described including classification. The distinctive features of nanomaterials are highlighted throughout this review. Finally, we conclude by discussing future perspectives relating to nanomaterials.

INTRODUCTION

Nanomaterials are those substances which are developed by the application of nanotechnology. “Nanomaterials are that substance which is having a minimum one dimension is less than 100 nanometres”.[1] A nanometer is one millionth of a millimeter which is near about or up to 100000 times smaller than the diameter of human hair. [2] In another word’s nanomaterial, the prefix word nano means a billionth. A billionth part of meter is called as Nano (10^{-9} meter). The size of nanomaterial is near about to 100nm. If the size range of nanomaterials increases above 100nm then it is said to be a bulk material. In fact, the radius of an atom is lower than a nanometre. A group of 1nm radius consist of almost 25 atoms.

Some facts that are unimaginable like:[3]

a) Human hair having a diameter of 75000nm.
b) A hydrogen atom having a 0.1nm diameter and nucleus of 0.00001nm diameter.

Various application of nanotechnology in different field which is shown in figure-1.

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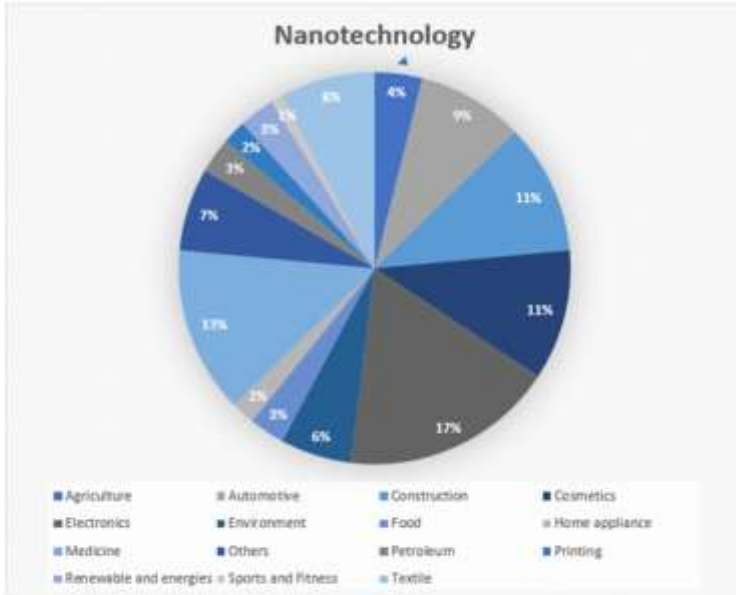

Figure 1: Application of nanotechnology in different sector.[4]

In the areas of nanotechnology research, the production of unusual or unfamiliar and advanced nanomaterials can be achieved by either top down or by bottom-up approach.[5] The top-down approach frequently uses conventional methods in which manual-controlled tools are employed for cutting, milling and shaping the materials into desired shape and order.[6] Attrition and milling for making nanoparticles are classical top-down processes. In bottom-up approach, molecular components fix themselves into more complex buildings like atom-by-atom, molecule-by-molecule and cluster-by-cluster from the bottom.[7] Compare to top-down approach the bottom-up approach produces nanostructures with minimum defects. If both the approaches are applied then it is known as hybrid approach.[8] Some materials which are commonly used for synthesis of nanomaterials, they are defined in Table-1.[9]

TABLE – 1: SOME COMMONLY USED MATERIALS FOR SYNTHESIS OF NANOMATERIAL.

Materials	Production methods	Applications
Carbon fullerenes	Using two carbon electrodes in a helium or neon atmosphere and generated arc to results in formation of fullerenes	Targeted drug delivery, lubricants, Catalysts, Nano-scale chemical sponges
Metals	Various methods to build materials such as combustion synthesis, mechanochemical processing, chemical precipitation, sol-gel processing, laser ablation, pyrolysis	Wound dressing, Electromagnetic interference / radio frequency interference shielding
Carbon nanotubes	Produced by three techniques such as carbon-arc discharge, laser ablation of carbon or chemical vapour deposition	Scanning probe microscopy, Antistatic materials, carbon nanotube-enhanced plastic
Metal oxides	Combustion synthesis, mechanochemical processing, chemical precipitation, sol-gel processing, laser ablation, pyrolysis	Water and strain repellent textiles, sunscreens

In last few years we have seen an outstanding development of nanomaterials which are useful in many fields such as pharmaceuticals, cosmetic industry, chemical industry, sensor, aviation and space and aeronautic industry.[10] Nanotechnology is the core field for research and development and for discovering the nanomaterials. It is used for design, assemble, production and application of nanomaterials and also understanding basic principle of relation between physical properties.[11] Nanomaterials have its unique properties such as magnetic, electrical and optical. Due to its unique properties the nanomaterial has a greater arising application in electronics, medicine and other fields.[12] About 20, Research centres were eventually capitalized by National Science Foundation (NSF). NSF is an agency responsible only to president of united states and functions to direct the fund for best science and technology projects. NSF was lead U.S agency which extent the NNI. NNI stands for National Nanotechnology Initiative.

Definition of nanoparticle and nanomaterial are outline by various organizations such as: International Organization for Standardization (ISO), American Society of Testing and materials (ASTM), National Institute of Occupational Safety and Health (NIOSH), Scientific Committee on Consumer Products (SCCP), British Standards Institution (BSI), Bundesanstalt fur Arbeitsschutz und Arbeitsmedizin (BAuA).[13] Nanomaterials are different in their size, shape, dimension, arrangement, phases, consistency. Due to this the nanomaterials have been categorized in several classification.[14] Nanomaterials are classified into naturally occurring, incidental, bioinspired, and engineered nanomaterials. During natural physicochemical processes naturally occurring nanomaterials are formed. Incidental nanomaterials, also called as anthropogenic or waste particles, occur because of man-made industrial processes. Engineered nanomaterials are assemble in the laboratory/industry to produce materials with unique features. Bioinspired are engineered nanomaterials the properties of which matches natural nanomaterials or living matter.[15] Nano-engineering leads new opportunities for advance in healthcare, energy, environmental protection, constructions, food processing, agriculture and other fields by developing nanomaterials, nanostructures, and nano systems. Till the date many different research fields such as from organic chemistry to semiconductor physics, are involve in the manufacture of many different nanoparticles and nanostructured materials.[16] Nanotechnology has also related applications from shape, size, design of nanomaterials to direct atomic scale regulation of matters.

HISTORY

The natural source of nanomaterials are forest fire products, volcanic ash, ocean spray, radioactive decay etc. It is assumed that nanoparticles and nanostructured materials are generated from meteorites produced during the big bang process that led to the formation of the universe and earth. Since prehistoric time the nanomaterial and their derivatives have been produced and employed by humans. [17] In past, humans have been using fire. Fire which contains nanoparticles such as smoke and soot (example: fullerenes, graphene and carbon nanotubes) and other combustion products. The oldest art of expression by humans is Hand Stencils in caves of Sulawesi, Indonesia. According to carbon dating results, the painting was made in 40,000BC using fat, charcoal and plant pigments. Analyst claims that the people of ancient civilization used nanomaterials such as graphene without knowing about it.[18] Around 19th century, Nanomaterials appear as a new term Egyptian's were used soot of oil lamps for produce black pigments of high opacity and stability for writing on papyrus. Papyrus is a material similar to thick paper that was used in ancient times as a writing surface. It was made from the pith of papyrus plant. Egyptians did not have any knowledge that soot contains carbon nanomaterials.[19] The best example of nanomaterials used in ancient time (5000BC) are clay minerals, nano-platelets about to 1nm in thickness. Egyptian and Mesopotamian glass manufactures were produced first metallic nanoparticles using chemical methods of 13th and 14th centuries BC.[20] In recent times, many nanomaterials have been developed enhanced the characteristics of bulk materials such as strength, conductivity, lightness, toughness and new interesting features such as self-healing, self-cleaning, anti-freezing, anti-bacterial.[21] At present they are used as building material or safety components or for other biomedical applications. Example is Biosensor and Drug delivery system. Nanoparticles have large number of application due to its size and shape specific effects which increases the external feature of nanoparticle.[22]

APPROACHES / METHODS FOR SYNTHESIS OF NANOMATERIALS

Generally, two main approaches are apply for production of nanomaterials. These approaches are Top-down approach and Bottom-up approach shown in figure-4. In Top-down approach the production of samller materials is due to application of external force to solid substance. Nanoparticles produces in bottom up method from atoms of gas or liquid which is based on atomic transformations or molecular condensations. The Top-down method consists of breakdown of solid substance. The top-down method is only of solid-phase method. Solid phase method includes griding system, Mechanochemical methods and Mechanical alloying method. Griding system consists of dry griding and wet griding system.[23]

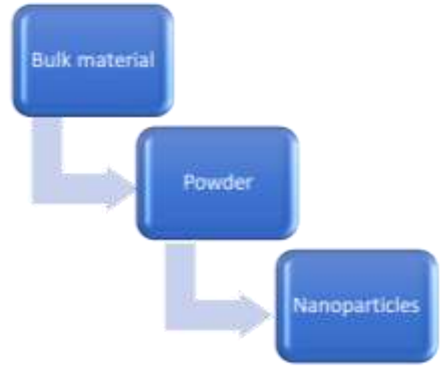

Figure-2: Top-down approach.

The bottom-up approach is mainly categorized into gaseous phase methods. In gaseous phase methods, reduce formation of organic impurties in particles compared to liquid phase methods because it require the use of vaccum instruments. The demrit of vaccum instruments are high in cost and low in productivity. The liquid phase methods are sub classified into liquid/liquid methods and sedimentation methods. Chemical reduction of metal ions is a example of a liquid /liquid method.[24] Microwave radiation use as a heat source which produces a quality nanoparticles at short duration of time period. Other reduction methods are photoreduction using gamma rays, ultrasonic waves and liquid plasma which can be used to preapre nanoparticles. Following requriements for device or process to produce nanoparticles:[25]

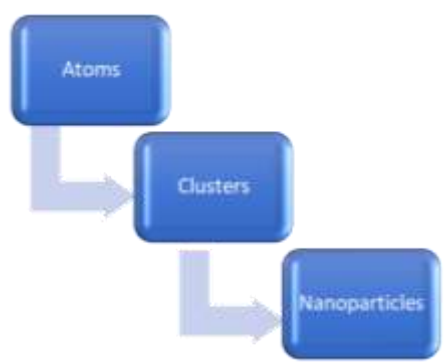

Figure-3: Bottom-up approach.

Control of particle size, size distribution, shape, crystal structure and composition distribution, Improvement of purity of nanoparticles, Control of aggregation, Stabilization of physical properties, structure and rectants, Higher reproducibility, Higher mass production, scale-up and lower costs.

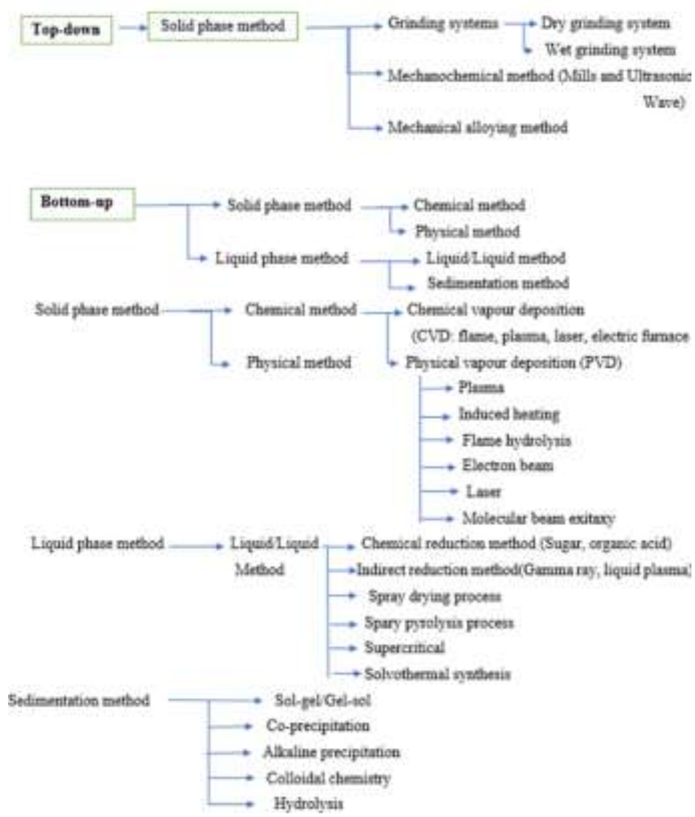

Figure-4: Approaches / Methods for synthesis of Nanomaterials.

Mechanochemical method (mills and ultrasonicwave) :

The maufacturing of nanomaterials pathway is consists of griding and miling. Such as ball milling process includes griding of macro and micro particles using well-organized and high energy mills to produce uniform size range particles.[26] Various techniques are used during this method such as:[27]

- Mechanical compostion
- First monitoring and vitrification process
- Strong deformation techniques
- Scrubbing method
- Griding method

Mechanical compostion: A material which is produce by crushing between the range of micrometric particles 1 to 30. This techniques allows the production of nanomaterials. This techniques is also used for production of huge materials from several tons.

Griding method: This method is used to produce nano-materials. Nanomaterials also produced are in the form of powder. In this method the basic material is introduce to a very high energy. Afterwards, material is grinded using balls which is made up of steel that move in a vibratory, planetary or vertical manner. The size of nanomaterials which are produced ranges between 3 to 25 nanometers. Crystals of sulphur, carbonate and chloride sands are taken at rates of 20gm each then grinded with the ball mills and tube mills. The produced mixture turns into a powder as precipitation and rotation contiune.[28]

Mechanical method: Mechanical griding method is a classical example of top-down method of synthesis of naanomaterials. In which the materials is formed by structural decompostion instead of cluster arrangement. The mechanisms involved for formation of nanocrystalline structures by mechanical attrition of single phase powders. The production of powder depends on refactory or steel balls rotational(vibrational) speed, size and number of balls, time of milling and milling atmosphere. Nanoparticles are produced by the shear action during griding. Milling in cryogenic liquids can increase the breaking or cracking process of powder. Thus, the production of fine particles demand that the milling process should take place in an inert atmosphere and the powder particles should be handled in vaccum system or glovebox.[29]

Chemical vapour depostion: Electric furnance

To produce nanoparticles are by heating desired material in a heat-resistant crucible. This method is only applicable for those materials which having a high vapour pressure and the temperature as high as 2000° celsius. By arc heating, electron-beam heating or joule heating energy is introdued into the precusor. As the temperature is high as 2000°celsius the atoms are evaporated into an atmosphere. Where the atmosphere is either inert (eg: helium) or reactive (so as to form compound). In the beginning of process the very low vapour pressure have to be introduced into the furnance in the form of a suitable precursor such as organometallics, which disintegrate in the furnance to produce a condensable material. Evaporated hot atoms lose energy by collision with the atmos of cold gas. Homogenous nucleation takes place due to collision of hot atoms with cold gas. The cluster size and its distrubtion are controlled by only three parameters these are:[30]

- The rate of evaporation (energy input)
- The rate of condensation (energy removal)
- The rate of gas flow (cluster removal).

Physical vapour deposition: Electron beam

An electron beam physical vapour deposition approach is another stainless steel thin films fabrications method. This method with controlled layer thickness and unifrom particles distribution capability. The films were put together at a range of starting electron beam powder percentages of 3 to 10% and thickness of 50-150nm. With the as-prepared surfaces, surface topography and wettability analysis of the samples were investigated to identiy the changes in surface microstructure and contact angle behaviour of 20° celsius to 60° celsius deionised waters, of pH 4, pH 7 and pH 9. The results shows that films put together at low controlled deposition rates produced unifrom particles distribuion and had the closet elemental percentages to stainless steel 316L and that increasing deposition thickness caused surface roughness to reduce by 38%.[31]

Chemical reduction method: polyol method

This method is based on liquid phase synthetic approach. Polyol method involves suspending the metal precursor in a glycol solvent and afterwards, heating the solution at a refluxing temperature. This techniques has been used to synthesize metallic, oxide and semiconductor nanoparticles. The example of polyol family is ethylene glycol and it is the simplest glycol solvent. Polyol is made up of series of various glycol such as diethylene glycol, triethylene glycol, tetraethylene glycol upto polyethylene glycol. Some other examples of this family are propanediol, butanediol, pentanediol, glycerol, pentaerythritol and some various types of carbohydrate polyol method is a very favourable approach for production of uniform magnetic iron oxide nanoparticles. These particles are used in magnetic resonance imaging. The reason behind the success of the polyol method is due to all these polyol which are water-comparable and chelation polyols immediately orgsnize nuclei formation which gives potential over control of particle size, dispersity and particle distribution. For removal of polyols from substance or particles can be achieved by frequeant washing with simple water, cordination exchangers like carboxylates, amines etc, and thermal annealing. With increasing in precursor's concentration and water, the particle size increases.[32]

Supercritical fluids

There are many types of drugs which may have poor physico-chemical and pharmacokinetic properties, which determine the capacity to deliver the drug on site of action. To overcome these limitation a classical nanocarrier formulation is used. These nanocarriers can provide increased bioavailability, increased chemical stability of drug, sustained drug delivery, modified biodistribution and lower organ toxicity, increased solubility of lipophilic drugs and co-delivery of drug combinations. Drug nanocarriers may be of nanocrystals, nanosuspensions, microemulsions, liposomes, solid-liquid NP(NLNs), polymeric nanoparticles(NPS) metal NPs, quantum dots, fullerenes, non-organic NPs and different non-ionic surfactant vesicular systems (Niosomes, proniosomes etc). Nanocarriers can be produced using top-down techniques (griding, crashing, milling) or by bottom-up approach (emulsification-solvent evaporation, solvent displacement, polymerization methods). Thermal and chemical degradation are conventional methods which having several drawbacks due to excessive use of solvent and high resdiual solvent concentration, time and energy consumption. Due to these factors, it is difficult to control the particle size distribution and drug loading during the process of prepartion. Supercritical fluid is a substitute technology for production of nano-particles. ScF can overcome above mentioned factors. ScF is a condition in which a substance above its critical temperature and pressure of liquid has unique properties such as liquid-liquid density, gas-like viscosity and larger diffusivities than those of typical liquid (intermediate to that of a liquid and a gas), resulting in higher mass-transfer rate. Generally used ScF are water and carbon dioxide. There are many types of ScF are available but most widely used ScF is carbon dioxide due to, it avoids water discharge, it is chemically inert, non-toixc, non-flammable and readily available at high purity and at low cost. It can also be used at low critical parameter (304.19K and 73.8bar) because of its less harmful/toxic. Because of its poperties and the capability to be recycled, supercritical CO_2($ScCO_2$) is defined as "green" solvent. ScFs use is based on various precipitation processes for the production of solid composites of drug delivery systems. In these methods the ScF performs different functions as solvent, anti-solvent, co-solvent or solute, propellant etc. Above mentioned functions, after modification some of these functions can be applied for obtaining solid-liquid composites. Some other methods are used for the production of micelles or liposomes such as supercritical extraction from emulsions (SFEE) and improved supercritical reverse-phase evaporation method. For production of dry precursors of liposomes the methods are super-critical anti solvent process (SAS) or the aerosol solvent extraction systems (ASES). Various supercritical fluid technologies which are used mention below;[33]

- Rapid expansion of supercritical solutions(RESS)
- Supercritical anti-solvent precipitation and related processes(SAS, GAS, ASES, SEDS)
- Particles from gas-saturated solutions/suspensions(PGSS)
- Supercritical extraction from emulsions(SFEE).

Sol-gel / Gel-sol

Sol-gel is a process which includes the advanchment of inorganic network through the formation of a colloidal suspension (Sol) and gelation of sol produces a network in a continous liquid phase (Gel). The starting material is required for formation of colloids are generally metal or metalloid elements or materials which are encricled by various reactive ligands. Then the starting material is processed to produce a disperable oxide and forms a sol in contact with water or dilute acid. Exclude of liquid from the sol produces the gel, and the sol/gel transformation or state controls the particle size or shape. Calcination of the gel produces the oxide. Calcination it is a process in which the ore is heated to a high temperature below the melting point of metal in absence of air or limited supply of air. During calcination the change that takes place with reactions are: moisture and water from hydrated ores, volatile impurities and organic matter are removed. Sol-gel, it is a process which includes hydrolysis and condesation of alkoxide based starting material such as $Si(OEt)_4$ (Tetraethyl orthosilicate, or TEOS). In sol-gel process, the reaction is based on the hydrolysis and condesation of metal alkoxides $M(OR)_z$ which can be described as shown below:

⇒ $MOR + H_2O \longrightarrow MOH + ROH$ (hydrolysis)

⇒ $MOH + ROH \longrightarrow M\text{-}O\text{-}M + ROH$ (condensation).

Sol-gel method of producing nano-materials is widely noteable method amongst chemists and this method have wide application for production of oxide materials. The sol-gel process consists of sequences of steps which are shown below ;

- Production or formation of various stable solutions of the alkoxide or solvated metal precursor.
- A polycondensation reaction take place due to which gelation results formation of an oxide or alcohol bridged network (the gel) which increses the viscosity of the solution.

During, aging of gel (syneresis) polycondesation reactions resume until the the gel get converted into a solid mass. Ostwald ripening it is a process in which the small particles get digested by large particles during the growth phase. As aging of gel or syneresis phase transformations occur. The process of aging of gels can upto 7 days and it is also important to prevent cracks in gel. During the phase of gel drying water and other volatile liquids are removed from gel network. The drying process is categorize into four different steps : (i). The constant rate period, (ii). The critical point (iii). The falling rate period, (iv). The second falling rate period. Xerogel results from the thermal evaporation. An aerogel is formed if the solvent (such as water) is exclude or extracted under supercritical or near super critical conditions. During dehydration phase surface bound M-OH group are removed which stabilizing the gel against rehydration. By calcinig the monolith at temperatures upto 800°celsius. At high temperatures (T is greater than 800°celsius) desification and decomposition of gels are performed. At which the pores of the gel network are crumble and remaining organic species are volatilized. This method produces non-metaliic inorganic materials like glasses. Glass ceramics or ceramic materials at very low tempertaure compared to high temperature. High temperature synthesis conditions requires melting glass or firing ceramics. For succesful bottom-up approach the major barrier is to overcome on the control of growth of particles and then stop the formation of newly formed particles from agglomerating. Nanopowders are produced by this process is low. The benefits of this process is production of monosized nanoparticles.[34]

CLASSIFICATION OF NANOMATERIALS

In general, Nanomaterials are classified into three classes such as Nanoparticles, Nanoclays and Nanoemulsions. Figure 5 shows classification of nanomaterials.[35]

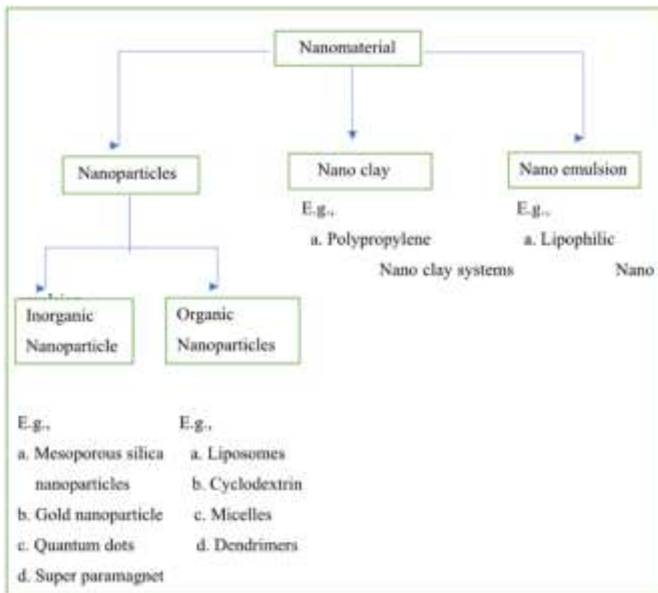

Figure-5 Classification of nanomaterials

Nanoparticles: Nanoparticles can be nanostructures or as composites. Nanostructure can be produce from elementary units(blocks) which have low dimensions such as zero dimension, one dimension, two dimension and three dimension. Depend on the dimension in which the size effect on the resultant property becomes clear and the nanomaterials can be classified as zero dimensional(quantum dots). Zero dimensional(quantum dots) which includes the movement of electrons are limited in all three dimensions. One dimensional(quantum wires) in which the electrons can move freely only in the X-direction. Two dimensional(thin films) in which the electrons can move freely in X-Y plane. Three dimensional(building blocks from nanostructured material which is made up of nanoparticles) in which the electron can move in X,Y and Z directions.[36] From top-down or bottom-up approach the organic nanoparticles can be synthesized. The production of nanoparticle from top-down approach, most commonly used techniques are mechanical milling, microfluidics and lithography.[37] From bottom-up approach, most commonly used techniques are precipitation and condensation for production of organic nanoparticles. Inorganic nanoparticles are more stable than organic nanoparticles, but there is a limitation of their stability in chemical or mechanical and nature of particle. Generally the produced nanoparticles are different in their consistency, size, yield or crystallinity.

Nanoclays: The production of nanoclays and organoclays using charged (hydrophilic) clay molecules. These clay molecules are alkyl/aryl ammonium, phosphonium or imidazolium in aqueous or solid state. The two results of ion exchangers reaction, first the gap between single sheet is broaded, allow organic cations chain to move in between them and second, each single sheet surface properties are changed from hydrophilic to hydrophobic or organophilic. It is simple to determine or identify chemical composition of nanoclays by gravimetric analysis, inductive coupled plasma, X-ray diffraction and fourier transform infrared spectroscopy.[38]

Nanoemulsion: In the form of a viscous liquid which leads to formation of soft material is due to dispersion of polymer, droplets and solid material. Generally emulsion consists of two phases one, which is known as dispersed phase and it is also known as discontinous phase and the another one, which is known as dispersion medium and it is also known as continous phase. Sometimes dispersed phase is also known as internal phase and dispersion medium is also known as outer phase. Emulsion consists of emulsifying agent which is also known as intermediate or interphase. Nanoemulsion production can be done by two different methods namely, high energy emulsification and low energy emulsification. High energy emulsification method includes ultrasonification, high pressure homogenization and microfluidizer. Low energy emulsification method includes phase inversion temperature, solvent displacement and phase inversion composition.[39]

SYNTHESIS

Nanoparticle synthesis can be done by three methods:

1. Chemical method
2. Physical method
3. Biological method.

CHEMICAL METHOD

This method enable synthesis of nanoparticle in large amount. It is possible to control the particle size at nanoscale using this synthesis method. Chemical synthesis of nanoparticles includes ranges of methods such as chemical reduction, co-precipitation, nucleation, sol-gel method, flow injection, electrochemical, solvothermal, hydrothermal and microwave-assisted.

Chemical reduction: Generally, used for synthesis of nanoparticle is chemical reduction of organic and inorganic reducing agents such as sodium citrate, ascorbate, sodium borohydride($NaBH_4$), elemental hydrogen, polyol process, tollens reagent, N-dimethylformamide(DMF) and poly(ethylene glycol)-block copolymers. Agglomeration forming colloidal nanoparticles are result of synthesis process. During this chemical reduction process various protective or capping agents are used to steady the particles from sedimentation, agglomeration, or losing their surface properties. These agents are polyvinyl alcohol, polyvinylpyrrolidone, poly ethylene glycol, poly methacrylic acid and polymethylmethacrylate also presence of surfactants groups namely thiols, amines, acids and alcohols.

Polymerization: Polymerization is most common method for production of nanomaterials.

Oxidation process: Raw nanomaterial are oxidizes or deoxidizes in liquid or quasi-liquid phase state. The nanoparticles of metal, alloys or oxides in water solutions or in organic solutions can be produce from oxidation phase.

Irradiation method: Easy and productive technique. An aqeous solution of sliver salt and surfactant can produce sliver NPs with a defined shape and size distribution. Electric dispersion reaction: In this technique, the reactor liquid (metal-alkoxide solution) introduce in electric field results in a precipitation reaction which indicates the production of ultra fine precursors powders of advanced ceramic materials. Due to applied electric field, the solution is worn out into micron-sized droplets, which is known as microreactors. Microreactors consists of hydrous precursor precipitate. To obtain oxide nanoparticles precursor powders are thermally processed.[40]

PHYSICAL METHOD

A well known physical methods for production of nanoparticles are evaporation-condensation, combustion synthesis, arc discharge/plasma, laser/electron beam heating and laser ablation technique. Unifrom distribution of nanoparticles and without any use of solvent are main advantage of physical method.

Evaporation-condesation: This technique includes evaporation of metals, alloys and ceramics by using gas. Afterwards, cool gases are introduce for production of nanoparticles or nanocapsules. Tube furnance, consumption of huge amount of energy and it needs a long time duration for achivement of thermal stability are disadvantage of evaporation-condensation method.

Arc discharge/plasma: Generally, this method or technique is used for production of fullerenes and other releated materials. This method is cateogrized into two class for formation of plasma these are direct current arc plasma and high frequency plasma. In direct current arc method, due to formation of high temperature materials gets melts and the inert or active gases also gets ionized.[41]

Laser/electron beam heating: The principle of this method is to release the electron from electron gun. Due to implementation of high voltage which rise the temperature and thus it produces the vaccum inside the electron gun. For electron beam heating and irradiating transmission electron microscope is used on materials for production or synthesis of different types of nano-material such as carbon nanotubes, carbon nanocapsules and carbon nanoparticles. Heating source of this method which is present outside the evaporation chamber is the main advantage of this method and due to this it prevent the contamination of material which occur due to heat source.[42]

Laser ablation process: Lately invention of laser ablation method for production of nanoparticles with controlled particle size and compostion. This technique includes vaporization of a target by pulsed laser and then controlled condensation in a diffusion cloud chamber and pressure. A range of metal oxides, carbides and nitrides can be produced in nanoscale proportions. [43]

BIOLOGICAL METHOD

Above mentioned methods have complex protocols as well as requires extreme conditions of temperature and also produce toxic chemicals as byproduct which only increases the production of cost and affect the environment. The produced material consists of various toxic contaminations. Due to this biological method for production of nanoparticle is suitable because it is an ecofriendly approach which uses only biological substance as a catalyst. Some of the catalyst that are used for synthesis of nanoparticle are mentioned below in table no:2.

TABLE-2: PLANT STIMULATED SYNTHESIS OF NANOPARTICLES ARE LISTED.

Plant	Type of nanoparticle	Size range of nanoparticle(nm)	Location/ organelle
Azadirachta indica	Silver, gold	5-35	Leaf extract
Lemon grass	Aluminum oxide	9-180	Leaf extract
Olive leaf	Gold	5-300	Leaf extract
Beet root	Silver	15	Beet root extract

Determination of nanomaterials

Various techniques are used for characterization of the size, shape and stability of nanomaterials. Spectroscopy and microscopy techniques are two major techniques used to determine or identify the nanomaterials. Spectroscopy and microscopy techniques used for indentification of nanomaterials are listed in table-3.[44]

TABLE-3: SPECTROSCOPY AND MICROSCOPY TECHNIQUES USED FOR INDENTIFICATION OF NANOMATERIALS ARE LISTED.

Instruments	mass	Number	Size	Shape	Aggregation State	Surface area and charge	Chemical composition
UV-vis Spectroscopy							✓
X-ray diffraction							✓
FT-IR Spectroscopy							✓
Raman Spectroscopy							✓
Atomic absorption/ optical spectroscopy							✓
Mass Spectroscopy	✓						✓
X-ray photoelectron spectroscopy							✓
Dynamic light scattering			✓		✓		
Zeta potential						✓	
Scanning electron microscopy		✓	✓	✓	✓		
Transmission electron spectroscopy		✓	✓	✓	✓		
Scanning probe microscopy		✓	✓	✓	✓		

APPLICATION OF NANOMATERIALS

Application of nanomaterials are shown in table-4.

TABLE-4: APPLICATION OF NANOMATERIALS.

Sector	Nanomaterial	Reference
Agriculture	TiO_2 Manganese oxide (E350) Iron oxide Aluminium oxide Cobalt oxide Titanium nitride	[45]
Automotive	Nickel (Ni)	[46]

	Aluminium titanate (Al_2TiO_5) Tungsten carbide (WC) Cerium oxide (CeO_2) Titanium oxide (TiO_2)	
Construction	Carbon nanotubes Cu nanoparticles Ag nanoparticles	[47]
Environment	Ag-doped TiO_2 One dimension TiO_2/Fe-doped TiO_2 One dimension TiO_2 Ag-doped TiO_2	[48]
Medicine	Liposome Polymeric nanoparticle Micelle Dendrimer	[49]
Textile	Ag nanoparticles Gallic acid Silica aerogel Graphene oxide Au nanoparticles	[50]

CONCLUSION

Nanomaterials are extremely tiny materials that possess unique physical as well as chemical properties. Nanomaterials show great assurance owing to their exceptional physicochemical properties in the field of agriculture. Apart from this Nanomaterials have different and enormous applications in the field of novel drug delivery system or modified release formulations. Understanding their interactions it plays a major role in the potential use of nanotechnology. Nanomaterials plays an important role in the novel drug delivery system that are potentially Capable and show effectiveness in various aspects of technology, industry and much more. Nanomaterials plays a vital role as it is an emerging and fast growing multifaceted field with large number of applications for sustainable development and growth.The revolutionary works on Nanomaterials have upgraded the quality of life. Nanomaterials can be used for strategic development of new drug delivery systems and reformulating existing drugs to enhance the effectiveness , safety of drugs and decreasing the cost of health care. Advancement of Nanomaterials establishes a new ideal in various field. A new era of hope where medicines will act with increase efficacy, high bioavailability and less toxicity. The biocompatibility of nanomaterials is also very crucial. Past few years several new technologies have been developed for the treatment of various diseases and in chemical industry and many more prospects.The use of nanotechnology in developing Nanomaterials is gathering lots of hope and enthusiasm in the field of drug delivery research. To summon up, this evaluation and the phases Nanomaterials have delivered may revolutionize the entire drug therapy strategy and bring it to a new peak in near future.

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