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A Review on Nanotechnology and it's Classification, Synthesis Method and Applications

Sonali Achyut Todkar [a], Sunanda Bhavrao Kharat [b], Sujata Sahebrao Bobade [ab*], Ayodhya Narayan Ghandge [ab**], Sonali Santosh Borde [ab]***

[a,b] Nandkumar Shinde College of Pharmacy, Vaijapur, Aurangabad. Dr. Babasaheb Ambedkar Technology University Lonere, Maharashtra, India.

ABSTRACT: -

Nanoparticle-based drug delivery systems have drawn more attention in recent years due to their innovative nature. Compared to other traditional drug delivery systems, the nanoparticles have a number of advantages. The organic, inorganic, and carbon-based nanoparticles are typically categorised as having better qualities than their larger counterparts on the nanometric scale of the respective materials. An key step in the effort is the synthesis of nonmaterial's that are comparable to quantum bound atoms. Significant advancements have been made in the processes of solid nonmaterial fabrication by materials scientists and engineers. That is exploring a number of techniques for producing nonmaterial's, including spinning, paralysis, Chemical Vapor Deposition (CVD), mechanical methods, and Sol-Gel techniques. This paper present a review on nanoparticles, its classification, synthesis method and its application on various field.

KEYWORDS: - Nanoparticles, Nanotechnology, food, Dimensions, Non- toxic, etc.

I. INTRODUCTION: -

Nanotechnology makes use to expertise from the areas of physical, chemical, biology, material, health and engineering. It is quite useful in practically all the science areas and human life. The term " nanoparticle " refers to solid particles or particulate dispersions with size between 10 -1000 nm. A nanopartticle matrix is used todissolve, trap, encapsulate and attach the medication. Nanoparticles, nanosperes or nanocapsules can be produced depending on the techniques of preparation. Unlikely nanosperes, which are matrix system in which the drug is physically and uniformally dispersed, nanocapsulas contain drug inside a cavity that is surrounded by a special polymer membrane. [Gaur A. et al 2008] Carbon, metal, metal oxides or organic material make up their composition. [Hasan, s. et al 2015] Material make up their biological applications, including medication administration, imaging and biosensing, nanoparticles hold enormous promise. At the nanoscale, nanoparticles have special characteristics because their surface area is quite big compared to their volume. The physiochemical characteristics of nanoparticles are crucially influenced by their size and shape. Nanoparticles must be created with carefully controlled size and shae order to benefit from these phenomena. Due to more exact control over size and form resulting in a narrower size distribution of particles, micro fluidic devices have demonstrated advantages over convational batch synthesis procedures in the creation of nanoparticles. [Krishnadasan. s et al 2007] One of two basic methods, namely the top - down method and the bottom - up method, is commonly used to create nonmaterial's. Among all the techniques, the synthesis of nonmaterials by physical vapordeposition, chemical vapordeposition,electro spinning, 3D printing, biological synthesis and supercritical fluid have recently gained prominence. These techniques are combined with others to increase the synthesis efficiency. [,Rehan M et al 2019] , [Abdel - Haleem et al 2019]

Different metallic nonmaterials are now being created using copper, silver, zinc, titanium, magnesium, gold, alginate and silver. Nanomaterials are utilized for a wide range of applications, including medical procedures, energy storage in solar and oxide fuel batteries and wide spread incorporation into a variety of materials used in daily life such as clothing and cosmetic. [Dubchak S. et al 2010] An infectious viral sickness began to spread over the world at the end of 2019 in china . On March11,2020, the World Health Organization (WHO) formly proclaimed the corona virus outbreak to be a pandemic. [Wang c, at al 2020], [Perlman s, et al 2020] As an illustration, a revolutionary nano- vaccines metastatic platform, helpful nano medicines for trating SARS - CoV -2 therapies are all being developed as delivery system. As a result, research has been working hard to find to create effective nano-vaccines and treatment options, including novel nano- based technologies. Earlier in the new millennium; SARS - CoV was the main cause of pandemic. [Drosten c, et al 2003], [ksiazek TG et al 2003], [peiris JSM et al 2003] The foundation of photodynamic cancer therapy is the the cytotoxic atomic oxygen produced by lasers that kills cancer cells. When compared to healthy tissue, the cancer cells take up more of a particular dye that is used to produce atomic oxygen. As a result, only cancer cells are eliminated before being exposed to laser radiation. Sadly, the skin and eyes, making the patient extremely sensitive to sunlight up to six weeks may pass before this effect fades. The hydrophobic dyes molecules were contained inside porous nanoparticles to prevent this negative effect. [Roy I et al 2023] Encapsulation, emulsion creation, food contact materials and sensor system are the main applications of nanotechnology in the food industry. Nanofood is a concept that Garber uses to describe the cultivation,production, packing and processing of food utilizing nanoparticles. Application of nanofood have been identified by FSAI, including sensory enhancements (flavour, colour and texture modification),

increased absorption, targeted delivery of nutrition bioactive compounds, stabilization of active ingredients like neutraceuticals in food sources, packaging and product improvement to extend shell life, sensors for food safety, and antimicrobials to eradicate pathogenic microbes in food. [FSAI et al 2008], [Garber C et al 2007]

Drugs can be delivered using nanoparticles more effectively and with better pharmacological properties, which is just one benefit of this method of drug delivery. [Peer D. et al 2007] For instance, nanoparticles enhance the solubility of poorly water - soluble drugs, modify pharmacokinetics, lengthen the half - life of drugs by reducing immunogenicity, Increase the specificity of drug towards the target cell or tissue (thus reducing side effects), enhance bioavailability, reduce drug metabolism, and allow for the more precise release of therapeutic compounds as well as the simultaneous delivery of two or more drugs for combination therapy. [Desai MP et al 1997]A significant obstacle to achieving a tailored response against the disease pathogen has been the efficient delivery of therapeutic compounds. While many medications are successful in trading disease, the majority of them also have drawbacks related to toxicity, low water solubility and cell impermeability. Nanomedicines offer the potential to address certain biological problems. Nanomedicines includes both new medications and new methods of delivery. Research focuses on logical pharmacological delivery and targeting in animals, with therapeutic and diagnostic substances at the forefront of efforts in nanomedicine. [Frietas RA et al 1998]

II. CLASSIFICATION of NANOPARTICES: -

2.1 According To Their Dimensions.

*Zero dimensional nanoparticles (0-D) :*Nanoparticles in this class have all three of their dimensions in the nanoscale range and are classified as zero - dimensional nanomaterials (0-D). Nanoparticles,fullerence, and quantum dots are a few examples.

One Dimensional Nanoparticles (1-D): The nanomaterials in this category have a single external dimension. Atomic scale nanotubes, nanofibers, nanorods, nanowires and nanohorns are few examples.

Two Dimensional Nanoparticls (2-D): The nanomaterials in this class have two dimensionsnanosheets, nanofilms and nanolayers are a few examples.

Three Dimensional Nanoparticles (3–D): Also known as bulk nanomaterials are material that is not in any way restricted to the nanoscale. This class includes bulk powders, nanoparticle dispersion, nanowires and nanotubes arrays etc.

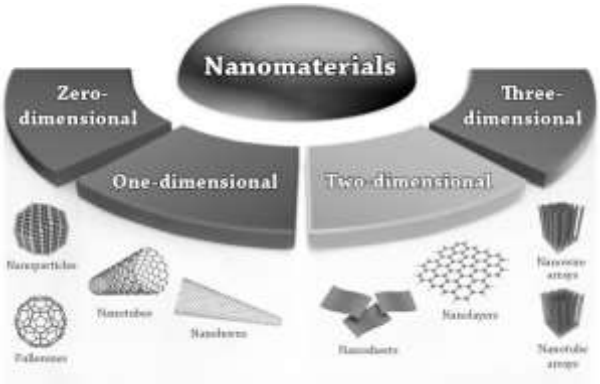

Fig.1 Nanoparticle Classification Based on Dimensions

2.2 According to Their Makeup: -

Organic nanomaterials: - These nanoparticles (NPs) are normally non - toxic, biodegradable and in some instances, such as for liposome's, they may contain a hollow centre. Organic nanoparticles are vulnerable to thermal and electromagnetic radiation, including light and heat. [Ealia SAM et al 2017]This group of NPs includes any organic substances, including protein, carbohydrates,lipids, polymers and fatty acids. [Pan k et al 2016]They are perfect option for drug administration because of their distinctive qualities. The effectiveness of the drug delivery system, whether it be an entrapped drug system or an adsorbed drug system depends on the drugs carring capacity, stability and delivery method. In addition to their typical features like size,content, surface shape etc. Since they are effective and may be injected on specific body locations, which has also known as targeted medication administration, organic nanoparticles are most frequently utilized in the biomedical area.

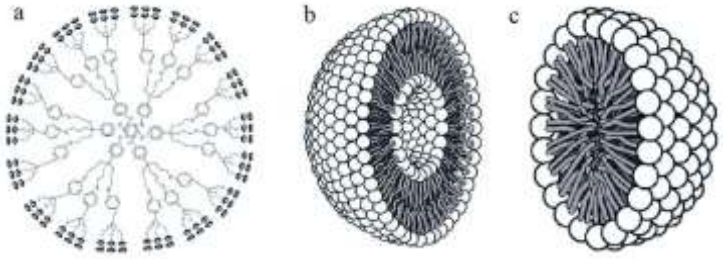

Fig.2 Organic Nanopoarticle: a-Dendrimers, b- Liposome, c- Micelles [Salavati- niasari Met. Al 2008]

*Carbon - Based Nanoparticles: -*The term carbon-based refers to nanoparticles that are entirely comprised of carbon. [Bhaviripudi s, et al 2007]They can be divided into Fullerens, Graphene, Carbon nanotubes (CNT), Carbon nanofibers, Carbon black and occasionally activated carbon in nano size.

Fullerenes:A spherical carbon molecule with the chemical formula C60, fullerenes is bound together by their SP2 hybridization of the carbon atoms in the compound. For a single layer and multi layered fullerenes the sperical structure is made up of about 28 to 1500 carbon aroms and has a diameter of up to 8.2 nm

Graphene: A kind of carbon is called graphene. A two dimensional flat surface formed of a hexagonal honeycomb lattice of carbon atom is known as graphene. Typically, a graphene sheet is 1nm or less thick.

Carbon Nano Tube (CNT): A graphene nanofoil with a honeycomb lattice of carbon atoms, known as carbon nanotubes (CNT), is wound into hollow cylinders to form nanotubes with diameter as small as 0.7 nm for a single layered CNT and 100 nm for a multi - layered CNT as well as a range of lengths form a few micrometers to several millimeters. Either the ends are hollow or a half fullerence molecule seals them.

Carbon NanoFiber: nanofiber made from CNT is twisted into a coneusing the same graphene nanofoils that were used to make CNT.Carbon

Carbon Black: Carbon based amorphous substance with diameter ranging from 20 to 70 nm and a typically spherical shape. Because of the intense particle contact, aggregates of about 500 nm in size are generated.

*Inorganic nanoparticles: -*This category includes non-carbon and non-organic nanoparticls (Nps), Metal, ceramic and semiconductor NPs are common examples of this class of material NPs made of metal. They can be nanometallic , bimetallic [Toshima N , et al 1998] or polymetallic [Nascimento MA et al 2018]since they are entirely formed of metal precursors.Inorganic nanoparticles such as those made of metal or metal oxide , are typically categorized in this way.

Metal based: Metals are used to create nanometric sized nanoparticles, either through metal based nanoparticles - based techniques can be harmful or constructive. The nanoparticles of almost all metals can be created synthetically. [Salavati-niasari M, et al 2008] The most often the manufacture of nanoparticles are Aluminium (Al) , Cadmium (Cd) , Cobalt (Co) , Copper (Cu) , Gold (Au) , Iron (Fe) , Lead (Pb) , Silver (Ag) , and Zinc (Zn) . Sizes as small as 10 - 100 nm and surface characteristics that make up the nanoparticles stand out. High surface to volume ratio , pore size , surface charge and density , crystalline and amorphous structures , spherical and cylindrical geometries , colour , reactivity and susceptibility to external elements like air , moisture , heat and sunlight etc.

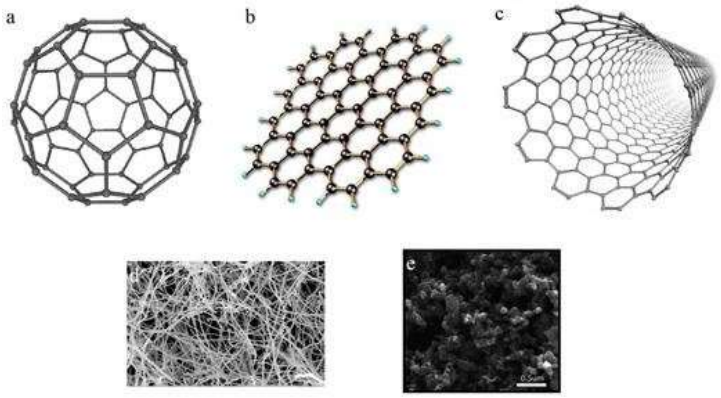

Fig.3 Carbon Based Nanoparticke [Ramesh S et al 2013]

Metal oxide based: The purpose of creating metal oxide - based nanoparticles is to alter the properties of the corresponding metal based nanoparticles. For instance, iron nanoparticles (Fe) instantly oxidize to iron oxide (Fe2O3) at room temperature which increases iron's conductivity. When composed to iron nanoparticles, it's reactivity. Due to their increased reactivity and effectiveness, metal oxide nanoparticles are primarily created through synthetic process. [Tai C Y et al 2007] Aluminium oxide (Al2O3), Cerium oxide (CeO2), Iron oxide (Fe2O), Magnetite (Fe3O4), Silicon dioxide (SiO2), Titanium

oxide (TiO2) and Zinc oxide (ZnO) are the most frequently manufactured material. When compared to their metal counterparts, these nanoparticles exhibit extraordinary qualities. [Bhaviripudi S, et al 2007]

3. METHOD OF SYNTHESIS: -

3.1Top-Down Synthesis:

Destruction is the approach used in this synthesis. The bulk material, which was made up of larger molecules, broke down into smaller molecules, which subsequently changed into nanoparticles. Example of damaging methods including milling and grinding, physical vapour deposition, and other methods. [Iravani , S. et al 2011]

Thermal decomposition method: Heat causes chemical bonds in a substance to a break down endothermically, leading to thermal breakdown. [Salavati-niasari M, et al 2008] A precise temperature at which an element decomposes chemically may be referred to as the decomposition temperature. Because of the Meta'sbreakdown at a certain temperature,nanoparticles are produced. Thermal decomposition was used to functionalize gadolinium oxide nanoparticles that had been synthesized with paramagnetic polyethene glycol. [Siwach OP et al 2008]

Mechanical method / Ball - milling method: Mechanical milling is the most popular top - down technique for creating different nanoparticles. When synthesizing nanoparticles, different components are milled in an inert atomsphere using mechanical milling, which also serves as a post - annealing step. [Munoz JE et al 2007] In mechanical milling , the influencing factor include plastic deformation , which results in particle shape , fracture , which result in a drop in particle size and cold - welding , which results in an increase particle size . [Ahab, A et al l 2016]

*Lithographic methods:*Generally speaking lithography is the process of printing a needed shape or structure onto a light - sensitive substance while only removing a piece of the material to create the shape and structure you want. One of nanolithography's key benefits is that can produce anything from a single nanoparticle to a cluster. With the necessary dimensions complex equipment requirements and accompanying costs are the drawbacks. [YadavT P , et al 2012]

*Laser Ablation:*The creation of nanoparticles from various solvents using a laser ablation approach is a straight forward process. Different metals immersed in solution are exposing to laser radiation, which condenses plasma to create nanoparticles [pimpin A et al]It is trustworthy top - down technique that offers a different approach to the traditional chemical reduction of metals to create metal based nanoparticles.

*Sputtering:*Sputtering is the deposit nanoparticles on a surface through the ejection of particles from it through collisions with ions. [Hulteen JC et al 1999] The conventional procedure for sputtering for involve depositing a thin coating of nanoparticles, followed by annealing temperature and time, and layer thickness, among other factors . Is what controls the nanoparticles size and form [Amendola V et al 2009]

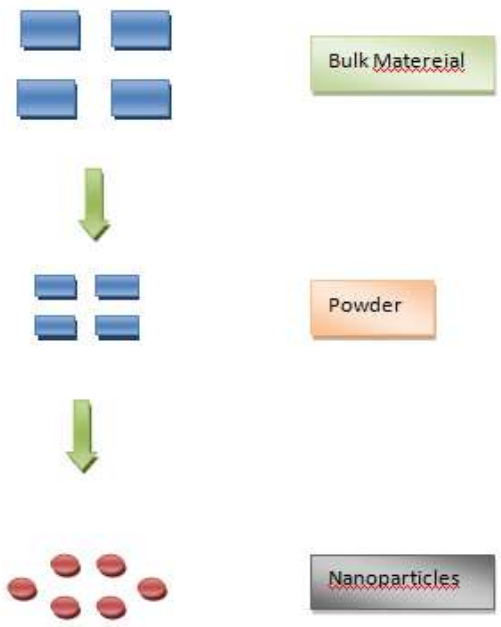

Fig.4 Top-Down Synthesis Approaches [Siwach OP et al 2008 & Munoz JE et al 2007]]

3.2 Bottom-Up Synthesis:

The constructive method is another name for the bottom up approach. It is the opposite of the top -down approaches. With this technique, significantly less complex chemicals are used to create nanoparticles.

Chemical vapour deposition (CVD) method: Chemical vapour deposition is the process of depositing a thin layer of gaseous reactants onto a substrate. By mixing gas molecules, the deposition is accomplished in a reaction chamber at room temperature. When a heated substrate contacts an acid, a chemical reaction takes place in a proximity to the combined gas. [Bhaviripudi S et al 2007]As a result of this reaction, a thin film of the product was generated on the surface of the substrate. This thin film is salvaged and put to use. The CVD process produces nanoparticles that are robust,homogeneous, hard and extremely pure. The downsides of the CVD process include the need for sophisticated equipment and the creation of very hazardous gaseous by products. [Adachi M et al 2003]

Sol - gel method: Combining the words "sol"and"gel", we have "sol - gel technique." A colloid known as sol is created when solid particles are suspended in a liquid that is flowing continuously. Undissolved in a solvent, gel is a solid macromolecule. The easiest bottom - up method for creating nanoparticles is the sol - gel method which is popular due to its simplicity. Using an appropriate chemical solution as precursors is the technique. In the sol - gel process, the common precursors are metal oxide and chloride. [Ramesh, S et al 2013].

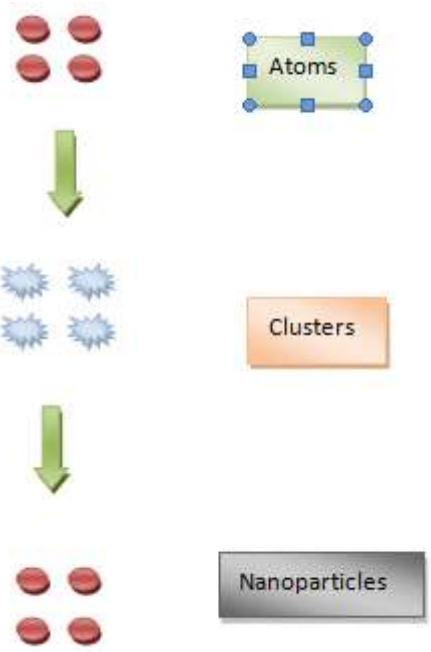

Fig.5 Bottom-Up Method Approaches [Lugscheider E et al 1998 & Adachi m 2003]

Spinning: A spinning disc reactor produces nanoparticles using spinning synthesis (SDR). It has a rotating disc inside of a chamber or reactor where physical characteristics, including temperature, can be regulated. Nitrogen or other inert gases are typically pumped into the reactor to empty the inside of oxygen to prevent chemistry. [Tai C Y et al 2007] The liquid, such as water and precursor, is injected into the disc while it rotates at various speeds. The spinning causes the atoms or molecules to fuse together, which is precipitated, gathered and dried. [Mohammandi S et al 2014]

Pyrolysis: Pyrolysis is the procedure used in industry the most frequently to create nanoparticles. This procedure involves burning the precursor using flame. The precursor is put into furnace under high pressure to receive the nanoparticles. [Kammler, H K et al 2001] Flames are occasionally replaced with laser or plasma to create temperatures. Easy evaporation occurs at high temperature. [D'Amato, R et al 2013]

Biological synthesis: A green and environmentally acceptable method for creating nontoxic, biodegradable nanoparticles is biosynthesis. [Kuppusamy p et al 2014] Instead of using conventional chemicals, biosynthesis creates nanoparticles from precursors and a variety of other sources, including bacterial, plant and fungal extract. Purposes of bioreduction and capping. The biosynthesized nanoparticles are used in biomedical applications because of their distinctive and improved characteristics. [Hasan S et al 2015]

4. APPLICATION OF NANOPARTICLES: -

a. In Drug Delivery :

First, high stability, high carrier capacity, and ease of accommodating both hydrophilic and aqueous molecules are among the most important benefits of nanoparticles utilized as drug carriers. Inhalation and oral application are two different ways to administer hydrophobic substances. [S. Gelperina et al 2005]Some medications are not metabolized after the first pass. In addition to allowing regulated sustained drug release from the matrix, the nanoparticles can be changed to get around this. These qualities can increase the drug's bioavailability and decrease the number of doses needed.[Y. Bae et al 2005]ZnQ Quantum dots is the name given to the most sophisticated quantum dots technology used in anti-cancer medication therapy. This technology's fundamental

idea is that the polymers surrounding the quantum dots are biocompatible and contain anti-cancer chemicals. One of the key uses of quantum dots technology is the delivery of tumor-targeted medications in this manner. [Q.Yuan et al]

b. In Food:

Hybrid nanoparticles called bionanocomposites have improved mechanical, thermal, and gas properties. They help extend the shelf life of food by being used in packaging. Here is environmentally sustainable because it lessens the reliance on plastic packaging. Zein, a prolamin and a significant portion of corn protein, serves as an illustration. Zein can be dissolved in ethanol or acetone to create a biodegradable zein film with improved tensile and water barrier properties. [Sozer N, et al 2009] Omega-3 fatty acids are added to white bread in Australia using nanocapsules. In Asia, work is being done to create non-toxic nanoscale pesticides that will interfere with weed seeds' seed coats and hinder germination. [Sanguansri P et al 2006]

c. In Medicine:

Nanomedicine helps with improved illness diagnosis, prevention, and follow-up measures. Gold nanoparticles and other nanodevices have made gene therapy more effective. Less challenging sequencing additionally, they are utilized to identify genetic sequences when they are attached to short DNA fragments. Nanotechnology allows for the replication or repair of damaged tissue. Nanotechnology has the potential to revolutionize procedures like organ transplantation and artificial implantation. It has been demonstrated that magnetic nanoparticles are effective at isolating and gathering stem cells. In contrast, quantum dots have been employed in molecular imaging, stem cell tracing, and other applications. Designing special nano particles enables the controlled regulation of stem cell growth and differentiation [Wang Z et al 2009] Therapy of oxidative stress, assessment of intraocular pressure, and choroidal treatment are a few examples of nanotechnology's uses ophthalmology. New vasculature, preventing scarring after glaucoma surgery, prostheses, etc [Zarbin MA et al 2013]. In more recent times, nanotechnology distributed eye ointment (NDEO) has been used to treat severe evaporative dry eye. Histological analysis revealed that NDEO [Zhang W et al 2014] restored the normal corneal and conjunctival morphology. Utilizing zinc oxide nanoparticles can reduce antibiotic resistance, improving the antibacterial effectiveness of ciprofloxacin against pathogens. This is caused by the interaction of these nano particles with the proteins causing antibiotic resistance. [Banoee M et al 2010]

d. In Cosmetics And Sunscreens:

Traditional sunscreen that blocks UV rays doesn't have long-term durability when used. There are a lot of benefits to sunscreen that contains nanoparticles like titanium dioxide. Considering that titanium oxide and zinc oxide nanoparticles are transparent to visible light, they have the UV protection property. Some sunscreens now contain ingredients that absorb and reflect UV radiation as well as light. Iron oxide nanoparticles are a pigment that is used in some lipsticks.[wiechers J W et al 2010]

e. In Electronics :

The increased need for large, brilliant displays used in computer monitors and televisions in recent years is promoting the usage of nanoparticles in display technologies. As an illustration, nanocrystalline lead telluride, cadmium sulphide, zinc selenide, and sulphide contemporary displays' light-emitting diodes (LEDs). [Teng W et al 2008] Gases like NO2 and NH3 are detected using the increase in electrical conductivity of nanoparticles. [Liu X et al 2011]

f. In Catalysis:

High surface area nanoparticles enable increased catalytic activity. The nanoparticles serve as effective catalysts in the synthesis of compounds because of their exceptionally high surface to volume ratio. [Crooks R M et al 2001]

g. In Construction:

Construction procedures have been made more efficient, affordable, and secure thanks to nanotechnology. As an illustration, adding nanoparticles of nanosilica (SiO2) to regular concrete can enhance both its mechanical and durability features. Inclusion of Concrete becomes more sturdy thanks to haematite (Fe2O3) nanoparticles. In the building sector, steel is the most readily available and utilized material. With the help of nanotechnology, the properties of steel can be improved. For instance, stronger steel cables can be produced when building bridges [.Nazari A et al 2011]Glass is a further crucial component in construction. The use of nanotechnology in construction glass is currently the subject of extensive investigation. Due to the fact that titanium dioxide (TiO2) nanoparticles have antimicrobial, antibacterial, and catalyzingcharacteristics [Xu X et al 2007]

CONCLUSION: -

In this review we revealed detail over view about nanoparticles,classification, synthesis and application of various particles. Due to the increased interest in nanotechnology, leading institutions, businesses, and organizations are investing more in its research and development. Although the top-down approach is appropriate for lab testing, it is not appropriate for large-scale production. The idea of molecular recognition underlies the bottom-up strategy.

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