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Nanostructured Material: A Review on Smart Drug Delivery System

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Abstract:- Nanomaterials (NMs) have become very important in technological, although nanomaterials prefer over their bulk counterparts in terms of chemical, and biological properties. NMs are divided into groups according to their size, synthesis, shape, and origin. Microstructures in nanostructured materials are smaller than 100 nm. Friction is the main characteristic of nanomaterials. One of the distinctive characteristics of nanomaterials is their small size. The properties of other materials can be changed and much enhanced by the addition of very small amounts of nanomaterial, offering considerable potential and added value. The manufacturing of NMs and their industrial uses are expanding more quickly. The purpose of this review is to explore numerous nanostructured materials, such as dendrimers, nanoparticles, nanocrystals, nanosheets, nano-shells, nanofibers, nanotubes, nanoparticles, quantum dots, and liposomes, as well as their fabrication process and properties. A table defining many terminology that fall under the category of nanostructured materials is also included. This review focus on overview of NMs, their characterization, recent developments in NMs, and patent reported on nanostructured materials techniques are included.

Keywords:- *Nanostructured material (NMs), Nano-object, Nano-crystal, Nanosheet, Quantum- dots, Nano-shell, Nanoparticles (NPs), Liposome, Dendrimers, Characterization.*

I. INTRODUCTION

Nanostructured materials (NSMs) are a technological and economic industry that is actively being researched and is expanding across a several application sectors. Owing of its variable melting point, electrical, catalytically, wettability, dispersion, thermal conductivity and dispersion. NSMs have become more prominent in technological breakthroughs and exhibit superior performance to their bulk counterparts. Regarding the International Unit Recognition System, a nanometer (nm) is a unit that corresponds to 109 metres in width. Although in reality NMs are often described as having a diameter between 1 and 100 nm, in theory NMs are materials with at least one dimension having a length of 1-1000 nm. Several articles of law exist today in the United States and European Union that specifically mention NMs. However, there isn't a single, broadly acknowledged definition of NMs. The definition of NMs is discussed by several groups [1]. The United States Environmental Protection Agency states that Nanostructured materials "may exhibit distinguishing qualities that differ from the identical chemical component in a greater dimension" [2]. The USFDA defines NMs as materials with at least one dimension between 1 and 100 nm and that demonstrate dimension-dependent behaviors [3]. International Organization for Standardization (ISO) and other organizations have similarly referred to NMs are defined as "objects with almost any inner or exterior nanoscale surface structure" [4]. This ISO definition has been used to describe terminology like nanowires, nanoplates, quantum dots, nanofibers, and others that are similar [5]. The EU Commission [6-7] defined the following proposed definitions for the scientific terms that have been employed utilize the term "nanomaterial" to refer to a synthetic or natural material with have been employed to utilize the term "nanomaterial" to refer to a synthetic or natural material that has unbound, aggregated, or agglomerated particles with exterior diameters in the range of 1-100 nanometer range of sizes.

Table 1 Nanostructured Materials (NSMs)

Term	Definition	Ref
Nanoscale	Size range of around 1-1000 nanometer.	[7]
Nanoscience	The investigation of matter at the nanoscale, which includes comprehending these qualities that are based on their size and structure and contrasts the appearance of distinctions relating to specific atoms, molecules, or bulk materials.	[7]
Nano-object	A substance with one or more perimeter nanoscale dimensions.	[7]
Nanotechnology	Control and manipulation of matter at the nanoscale through the use of scientific understanding for diverse industrial andmedicinal uses.	[7]
Nano-material	Material with any nanoscale-scale interior and exterior features.	[7]

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Nano-fiber	A "nanofiber" is a name for a nanomaterial, if it has three dimensions—two identical external nanoscale dimensions and one bigger size.	[7]
Nanostructure	Structure of interlinked nanoscale constituent pieces.	[7]
Nanoparticle	Three exterior nanoscale dimensions on a nano-object. When a nano-longest object's and shortest axes are different lengths, the names "nanoplate" or "nanorod" are used rather than "nanoparticle" (NP).	[7]
Nano-composite	At least one phase in a multiphase structure has a nanoscale dimension.	[7]
Nanostructured material	Products with the internal or external nanostructure.	[7]

The use of several meanings in various jurisdictions presents a major obstacle regulatory activities because it results in legal difficulty to use regulatory measures for identical NMs. Therefore, a significant obstacle to creating a unified international definition for NMs is the requirement to meet divergent considerations [7].

➢ *Nanostructure Materials: Benefits and Drawbacks [8]*

The following are some benefits of nanomaterials:

- *The compact size of these materials allows for better manipulation and the ability tosupport several tasks.*
- *Nanomaterials' high porosity causes a growth in demand for them in several industries.*
- *The use of these nanomaterials in the energy sector increases the efficiency of the presentenergy producing techniques.*
- *The use of nanomaterials in the electronics industry improves accuracy when buildingcircuits at the atomic level.*
- *These materials' surface-to-volume ratios are sufficiently large to allow for the bondingof cells and active chemicals.*
- *Ceramics formed of nanophase are more ductile at high temperatures than ceramics withcoarser grains.*

➢ *The Drawbacks of these Materials Include*

- *Nanomaterial exposure by breathing. For instance, research on animals shows thatsubstances like carbon nanofibers and nanotubes cause pulmonary fibrosis.*
- *Lack of sufficient knowledge of these materials may make the manufacturing process challenging and complex.*
- *Nanomaterials are fragile.*
- *Nanoparticles are hazardous to people.*
- *It is challenging to recycle these materials.*

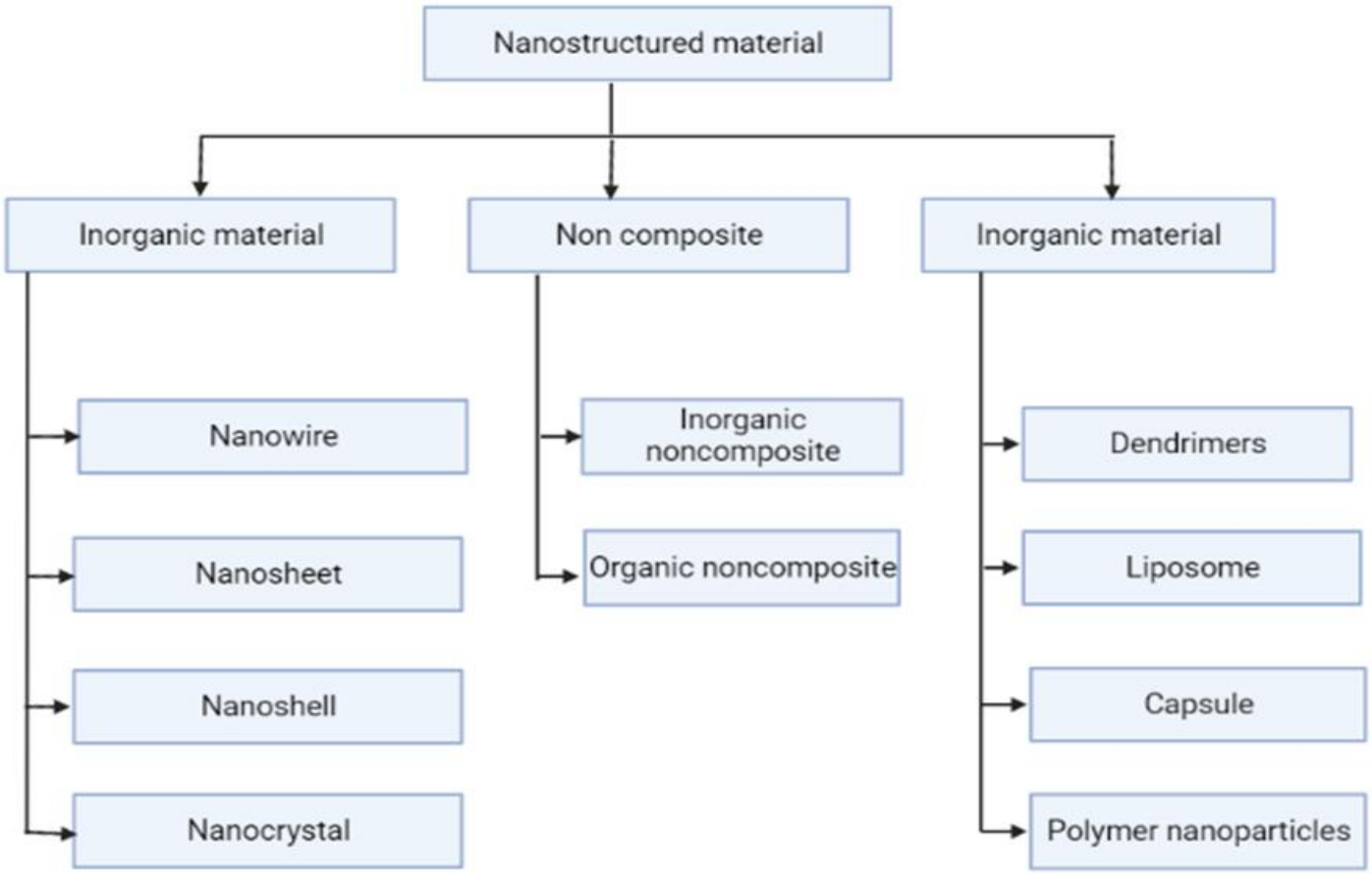

Fig 1 Structure of Various Nanomaterials

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II. INORGANIC MATERIAL

Metal oxide NPs and metal, NSMs are among these nanomaterial structured. These NMs could be produce into ceramics, semiconductors, metal oxides, like silicon, and metal NPs, and Au orAg.

A. Nanowires

Nanowires are nanostructures that take the shape of wires and have a diameter of about one nanometer (10-9 metres). More generally, structures with an unregulated length and a thickness or width limited to tens of nanometers or fewer are referred to be nanowires. The phrase "quantum wires" originated from the importance of quantum mechanical effects at these scales.

There are several different kinds of nanowires, including superconducting [1], metallic (Ni, Pt, Au, Ag), semiconducting (SiNWs), and insulating ones (e.g. SiO2, TiO2).

The building blocks of molecular nanowires are repeating molecules, either organic (like DNA)or inorganic (like Mo6S9xIx) [9].

➢ *These nanowires can be categorized based on their morphological and structural characteristics.*

- *Basic Nanowires*
- *Coating or Core-Shell Nanowire*
- *Heterostructured or Hierarchical Nanowires*
- *Mesoporous or Porous Nanowires*
- *Hollow Structures*

Production of basic nanowires - Simple nanowires are regular, basic nanowires, ‖ which means they are solid, straightforward structures made of a single substance and completely lacking any unique structural topologies. In actuality, controlling a fundamental issue is the formation of linear structures at the nanoscale. Many techniques, including vapor deposition, template- directed approaches, and others, have been used to achieve this [10].

Traditional methods for growing nanowires include *vapor deposition*, which typically employs using metal flakes as a catalyst to generate better absolute nanowires in a vacuum. This technique has been used to create various nanowires on materials like silicon, silicon oxide, zinc oxide, germanium, etc. Several works in this field have been produced by Morales and C.M. Lieber. They successfully produced germanium nanowires and single-crystal silicon germanium nanowires using VLS growth [11]. In the previous study, He et al. [12] successfully created N- doped germanium nanowires on silicon substrates via vapor-liquid-solid low-pressure chemical vapor deposition.

There are two types of *template-directed methods*: soft template methods and hard template methods. As hard templates, anodic aluminum oxide [13], silica [14], carbon nanotubes [15], and molecular sieves [16] are frequently utilized. Surfactant, soft template, surfactants [17], polymers [18], biomolecules [19], and similar substances are frequently used. To create simple nanowires of different materials, Studies can use solvothermal, hydrothermal, sol-gel, or electrochemical deposition techniques.

The manufacture of polymer nanowires or inorganic nanowires, for example polycaprolactone nanofibers or zinc oxide nanowires, is also possible using other techniques, such as electro- spinning [20–21].

Through directional attachment utilising the oriented-attachment method, 0D nanoparticles may naturally create single crystal nanowires, such as cadmium selenide quantum wires [22]. Using the salt-molten process, Dong et al. [23] created an environmentally benign Silicon nanowires can be produced directly electrochemically using this technique in large quantities.

In conclusion, hydrothermal or electro-spinning are frequently utilised when producing basic nanowires in large quantities, depending on cost and technology. The techniques for making simple nanowires serve as the building blocks for making other complicated nanowire structures [10].

B. Nanoparticle

Doped nanocrystalline materials, the atomic model with quantum confinement, and the development of nanocrystalline substance are used to achieve this. Both scientific and practical interests are currently high in the research of nanoparticle formation mechanisms. because nanotechnology requires nanoparticles with particular sizes and characteristics. The nanoparticle growth mechanism controls the Size distribution, chemical-physical characteristics, and media properties of nanoparticles, and other parameters. As a result, nanoparticle production can be managed, resulting in particles with the desired characteristics (mean diameter, standard deviation, coefficient of polydispersity, magnetic moment etc). There are further techniques, such as electrospinning. The growth of nanoparticles is a highly complex process that depends on a number of variables (temperature, viscosity, concentration of medium and etc.). Conditions affecting nanoparticle growth change depending on the method used to create them. Solid nanomaterial production techniques have advanced significantly, according to materials scientists and engineers [24–26].

➢ *Synthesis of Nanoparticle*

Compared to the top approach, which entails creating progressively cutting tiny forms from the bulk material, as opposed to the top approach, as is represented by the semiconductor industry, bottom-up production requires assembling the molecular or atomic components [27].

- *Vaporization and Vacuum Depositing*
- *Gas Condensation*
- *Chemical Vapor Deposition (CVD) or Chemical Vapor Condensation (CVC)*
- *Sol-Gel Techniques*
- *Chemical Precipitate*

- *Mechanical Attrition*
- *Sol-Gel Method*

➢ *Electro-Deposition*

Vaporization or Vacuum Deposition

Understanding the words vacuum deposition and vaporisation, also known as vacuum evaporation, is crucial before moving on to the other techniques. Alloys, elements, , or compounds are evaporated and accumulate in a vacuum during vacuum deposition process. The source of vaporisation is the entity that thermally vaporises substances. The procedure is carried out in a vacuum between 10 and 0.1 MPa and at pressures less than 0.1 Pa (1 m Torr). Temperatures of the substrate range from room temperature to 500°C. The vapour pressure of a substance in equilibrium with a solid or liquid surface is referred to as the saturation or equilibrium vapour pressure of that substance. If the vaporisation rate is fairly high, it is possible to achieve a respectable deposition rate for vacuum deposition. A useful accumulation rate can be attained at 1.3 Pa of vapour pressure (0.01 Torr).

Multibody collisions can cause vapour phase nucleation in a dense vapour cloud. Atoms are moved to offer the cooling and collision through a gas that are required for nucleation. They are referred to as ultra fine particles or clusters and range in size from 1 to 100 nm [28–30].

High deposition rates and efficiency are benefits of the vacuum deposition technique. It is challenging to deposit numerous chemicals, though. The majority of the time, nanoparticles are longer than the cluster and originated from a supersaturated vapour. [27].

C. Nanosheet

It has been noted that a hydrophilic polymer with a metal coordination unit (simplified HPMC) and PdII ions exhibit self-assembled gelation activity. The HPMC was composed of hydroxyl groups for hydrophilicity and thiocarbonyl groups for metal coordination. Thiocarbonyl sulphurs and PdII ions coordinated to produce cross-linked gels through self-assembled gelation. A liquid phases of PdII ions and HPMC were instantly separated by adding a distributed liquid hydroxyl propyl methyl cellulose (HPMC) solution drop by drop to an aqueous solution of PdII ions. This liquid/liquid parting resulted from the fast cross-linking at the interface and the HPMC phase's hydrophobicity in comparison to the PdII ion phase. The self-assembled spherical gels were created by the PdII ions cross-linking the HPMC droplets from the surface to the interior. This motivated us to create nanosheets at the interface between aqueous layers of HPMC and PdII ions by cross-linking at the liquid-liquid interface. Here, we provide the first example of aqueous/aqueous interface nanosheet production, which resulted in nanosheets with evenly distributed PdII ions. Its turn over frequency (TOF), catalytic activity, and turn over number (TON) were further assessed [31–32].

D. Nanocrystal

Pure solid drug particles in the 1000 nanometers are called as nanocrystals. They are 100% drugswith no carriers or other molecules attached, and Surfactants or polymeric steric stabilizers are frequently used to stabilize them. Use a surfactant called nano-suspension often improves the suspension of nanocrystals in a poor liquid media. Everything aquatic or non-aqueous substance, including water, such as oils and liquid polyethylene glycol, serve as the dispersing medium in this scenario [33–35].

In order to address challenges including higher constant solubility, enhanced velocity and dissolution, higher glueyness to cell membranes, nanocrystals contain unique properties. These are two types of techniques for creating nanocrystals: bottom-up and top-down. The precipitation, sono-crystallization method, multi-inlet vortex mixing methods, high gravity controlled precipitation technology, and method for limiting impinging liquid jet precipitate are all examples of top-down approaches. Unfortunately, due to this organic solvent can be used and for cleanup, that procedure is relatively expensive. The bottom-up method includes homogenization under increased speed and grinding operations. The three most popular processes for creating nanocrystals are homogenization under increased speed, milling and precipitation. The augmentation of suspension rate, solubility, and ability to grasp the abdomen lining strongly are just a few of the ways by which nanocrystals help a medicine enter the system and be absorbed [34]. For the delivery of pulmonary medicine, Ni et al. combined hydrophobic drug nanocrystals with chitosan microparticles. The muco-adhesive and swelling properties of the polymer were used to create the nanoparticles for continuous medication release. They discovered that inhaling effectiveness could be compromised in the presence of illness, therefore additional research is required to demonstrate the greater potential of this system [36].

E. Quantum dots

Quantum dots (QDs) were the first type of nanotechnology to be used in biological sciences, commonly referred to as "artificial atoms," which has found extensive use in numerous commercial and therapeutic goods [37–38]. Narrow emission spectra, have a great absorption spectra and photochemical stability are only a few of the distinctive electrical and fluorescent properties of QDs [39]. They are more suitable for biomedical and biotechnological usage due totheir exceptional electrical and optical properties, high surface area and small size [40–42].

One should evaluate the ecotoxicological data of QDs before using the use of synthetic elements in biological applications. The main factor contributing to the release of Cd^{2+} during oxidization of the particles is the cause of the toxicity of Cd-based QDs [43]. DNA deterioration and cell growth suppression are caused by QDs [44]. Mercaptoundecanoic acid QDs have the ability to cause cell harm and possibly death [44–45] adding QDs to nanotubules, which greatly altered the root inhibition and leaf withering of tomato plants, decreasing their viability

[46]. It was also observed that QD exposure caused oxidative stress in Arabidopsis roots. Chlamydomonas algae's ability to photosynthesize was decreased by the water-soluble ZnS or CdSe QDs adhering to the surface of cell [47].QDs can be transferred throughout the environment, as evidenced by their destiny and movement in soil, plants, and insects [48].

III. ORGANIC MATERIAL

A. *Dendrimers*

Molecules with many branches make up dendrimers. It has become extremely challenging to explain this subject in a clear and straightforward manner due to the massive amount of studies on dendritic structures, as well as dendronized, dendrimers, hyper branched, and encounter polymers. Generally speaking, a dendrimer is a macromolecule with a three-dimensional structure that is highly branching and provides a high level of surface functionality and adaptability. "Polymers of the twenty-first century" have frequently been referred to as dendrimers. Fritz Vogtle and colleagues made the initial introduction of dendrimer chemistry in 1978 [49]. The first "cascade molecules" were created by him. Donald A. Tomalia created the initial class of dendrimers in 1985 [50]. The synthesis of related macromolecules was independently reported at the same time by [51]. Their name, "arborols," is derived according to the Latin term "arbour," which also has a tree-related meaning. Although "cascade molecule" is another name for it, the dendrimer is the most popular. Dendrimers have sparked significant interest since they are multivalent and monodisperse, they are particularly useful in chemistry and biology. particularly in applications like chemotherapy, gene therapy, and drug administration. Due to dendrimers' distinctive molecular design, scientific interest in them has since grown.

A core initiator, inner layers made up repetitive units that are radially in immediate contact to the inner core, and an external that is connected to the most recent generations of the interior are the three distinctive architectural components of dendrimers [52–53].

➢ *Synthesis of dendrimers*

The important design molecular factors including shape, size, surface , interior chemistry, topology and flexibility can be totally controlled by the process of making process used to make dendrimers. While some dendrimer synthesis uses more new methods and chemistry, like modern organic techniques such as solid-phase production, organo-phosphorus chemistry, organo-transition-metal chemistry, organo-silicon chemistry, others rely on more conventional reactions, like the Williamson ether synthesis or the Michael reaction. The method for adding branching to the dendrimer depends on the selected growth response that is selected. The building blocks may already have branching, as is higher frequently the case, or branching must be produced as a result of the growth process, Similar to the situation with polyamidoamines and polypropylene imines [54].

➢ *Properties of dendrimers*

Dendrimers have a variety of characteristics, such as: [55]

- *Nanoscale sizes that are comparable in size to crucial bio-building blocks like DNA and proteins.*
- *The quantity of terminal functional groups on the surface (Z) suitable for conjugating signaling, pharmacological, targeting or biocompatibility groups in biological systems.*
- *Surfaces having potential functional group designs to promote or inhibit transcellular, epithelial, or vascular bio-permeability.*
- *Imaging moieties, metals, or small-molecule medicines may be enclosed in an inner empty area. Reduced drug toxicity and easier regulated release are benefits of encapsulating in that empty region.*
- *The positive biocompatibility patterns of lower generation polar terminal surface groups that are anionic or neutral are not present neutral in higher generation a polar and surface cationic groups, etc.*
- *The majority of dendrimer surfaces coated with polyethylene glycol (PEG) or minor functional groups have limited or no immunogenic potential.*
- *Groups of surfaces that may altered for target-mediated by a receptor, therapeutic dose, and limited discharge of drugs from the internal environment.*

B. *Liposome*

A single bilayer or a concentric series of several bilayers surround the center aqueous compartment of liposomes, which appear to be self-assembling (phospho) liposome material vesicles [56–57]. The phospho lipid-bilayer of liposomes is 4-5 nm thick and ranges in size from 30 nm to the micrometre scale [56, 58]. In the middle of the 1960s, Alec Bangham a British scientist at Babraham Cambridge colleagues established the subject of liposomology. In 1964, they published the first study describing the structure of liposomes [56, 59]. Have since liposomes have just been extensively researched as delivery systems for proteins, nucleic acids, small-molecule medicines, and imaging agents [60–64].

To increase treatment efficacy and patient compliance, various delivery routes, including sterile, respiratory, oral, topical, ocular, and nasal routes, have been devised [65-69]. Liposomes have also been extensively used in the industries of food [70] and cosmetics [71].

➢ *Structures of Liposomes*

Depending on the lamellarity and compartment structure, liposomes can be categorised as oligolamellar vesicles (OLVs), unilamellar vesicles (ULVs), and multi-vesicular liposomes (MVLs) [72]. Oligolamellar and Multilamellar vesicles both exhibit anonion-like structures but contain 2–5, or more, concentric lipid bilayers. In contrast to MLVs, MVLs have a structure resembling a honeycomb and contain a single bilayer lipid membrane divides hundreds of non- concentric aqueous compartments [73]. Gaint, larger and small unilamellar vesicles, can all be classified as ULVs based on particle size [74]. There have

been reports of ULVs in a variety of sizes, including LUVs and SUVs with sizes ranging from 200 to 500 nm [75].

➢ *Manufacturing Process of Liposome*

Several liposome preparation techniques have been created. The frequently employedmanufacturing techniques include:

- *Thin Film Hydration*
- *Ethanol Injection*
- *Double Emulsion Method*

- *Thin-Film Hydration*

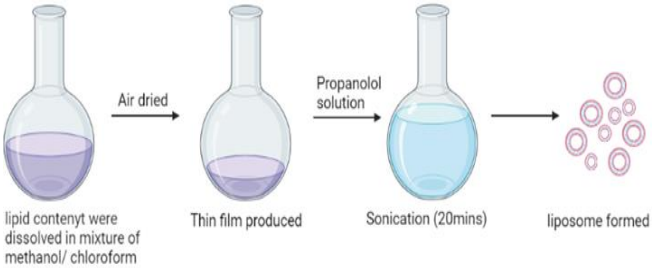

Fig 2 Thin-Film Hydration

- *Ethanol Injection*

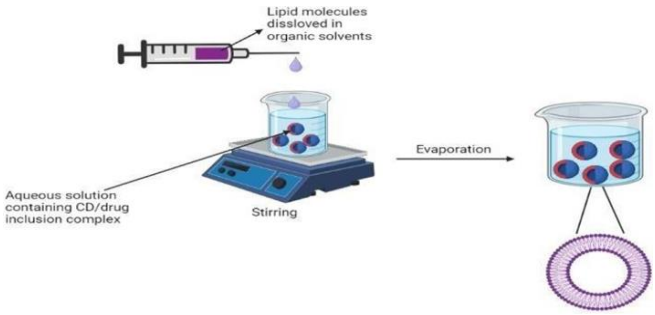

Fig 3 Ethanol Injection

C. Capsule

Drug delivery techniques at the nanoscale that could be enable limited release and targeting efficiency include lipid and polymeric nanocapsules [76–78].

The composition of the outer coating, in particular, influences their dispersion stability and the primary physiological reaction. Nanocapsules can be made via a variety of procedures, including layer-by-layer deposition, interfacial polymerization, interface precipitation, interfacial accumulation, and self-assembly. Significant variables include radius distribution, capsule thickness, membrane breakdown, and surfactant type [76].

By attaching antibodies and inserting channels, lipid-based nanocapsules can be modified to target specific tissues or cells and alter membrane permeability. Lipid-based nanocapsules have been shown to stabilize their contents. In comparison to free medicines, cisplatin nanocapsules exhibit significantly increased in vitro cytotoxicity against tumour cells and exhibit a previously unheard-of cisplatin to lipid molar ratio [79]. Lipids' fragility in biological mediums and vulnerability to a variety of environmental influences, including temperature and osmotic pressure, may limit their use, though.

The stability of lipid-based nanocapsules can be improved by making lipid-polymer-conjugate nanocapsules. A polyelectrolyte shell can be applied to the liposome, surface-active polymers can be added to form mixed vesicular structures, and a two-dimensional network can be polymerized in the hydrophobic core of the membrane [80].

Layer-by-layer deposited polyelectrolyte shells have the benefit of allowing control over surface characteristics, membrane thickness, and release kinetics [81]. Various materials may be easily loaded and released since these shells can assume both open and closed states in response to external influences like temperature and pH [82]. Examples include medications, enzymes, nucleic acids, and colours [83–85].

The use of "the cellar," a cellular nanoparticle that occurs naturally and was given that name because of its shape has recently contributed to progress in the search for a biocompatible nanocapsule. Hundreds of protein complexes can fit within these 13-MDa ribonucleoprotein particles inside their interior cavity. Any protein of interest can be locked away inside the cellar cavity by adding a cellar-targeting peptide to it. This allows the construction of cellar molecule with specific functions and features [86–87].

Another interesting development is the development of disulfide cross-linked polymer capsules [88]. Hydrogen-bonded multilayer thin films are more stable at physiological pH because of the disulfide bonds. Moreover, they leave the system open to disassembly in the presence of thiol- disulfide exchange reagents. These nanocapsules have the potential to be used as "bio- destructible" nano-scale drug delivery vehicles because intracellular proteins like glutathione will aid in vivo capsule deconstruction [89–90].

D. Polymer Nanoparticle

Due to their qualities brought on by their small size, polymeric nanoparticles (NPs) have gaineda lot of interest recently [91–93].

The possibility for limited release, the capacity to shield drugs and other environmental chemicals with biological activity, as well as the increase in their therapeutic efficacy and bioavailability are all benefits of using polymeric NPs as drug carriers [91, 94]. The two types of nanoparticles—nanospheres and nanocapsules—are included under the umbrella term "nanoparticle" [95]. A polymeric shell that surrounds a core made of oil, where the drug is typically disperesed, regulates the drug's release profile from the core in nanocapsules [95–97].

Drugs could be maintained into nanospheres or adhered to the surface to their continuous polymeric network. Those two varieties of polymeric NPs are known as a matrix form (nanosphere) and a reservoir form (nanocapsule) respectively [98–99].

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IV. PRODUCTION PROCESS FOR POLYMERIC NANOPARTICLES

Several techniques can be employed to create the particles based on the type of drug that needsto be put into the polymeric NPs and how it needs to be administered [99-100].

In general, either the polymerization of monomers or the dispersion of premade polymers areused [101–102].

List of the most commonly used techniques [103-104].

Table 2 Several Techniques

Polymeric Nanoparticle	Preparation Methods
Nanosphere	Solvent diffusion or EmulsificationSolvent evaporation Nano precipitation Reverse salting out or Emulsification
Nanocapsule	Nano precipitation

➢ *Solvent Evaporation*

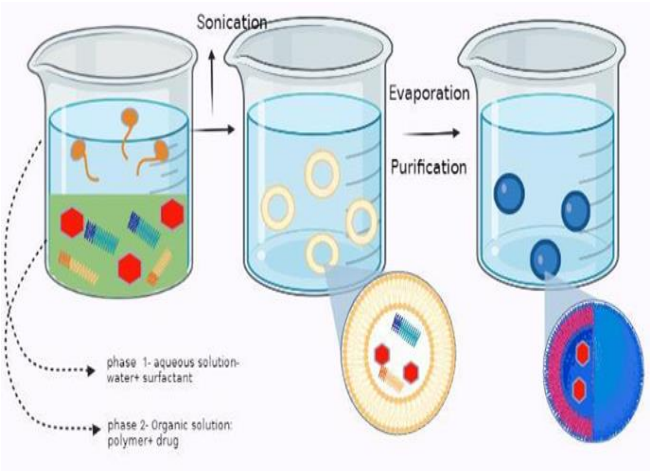

Fig 4 Solvent Evaporation

➢ *Emulsification/ Reverse Salting out*

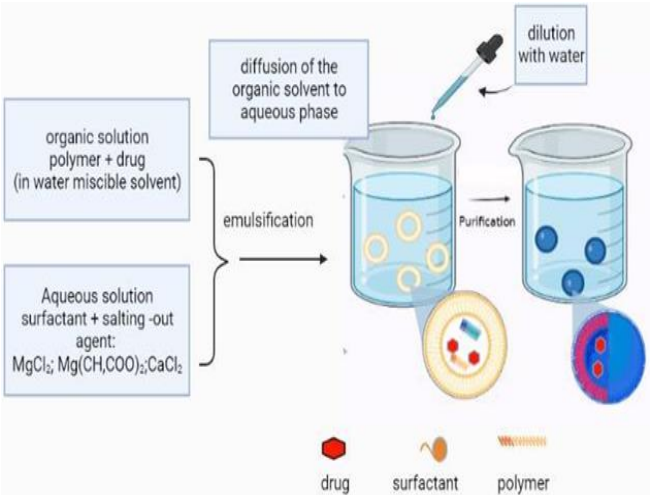

Fig 5 Emulsification/ Reverse Salting out

➢ *Nano Precipitation*

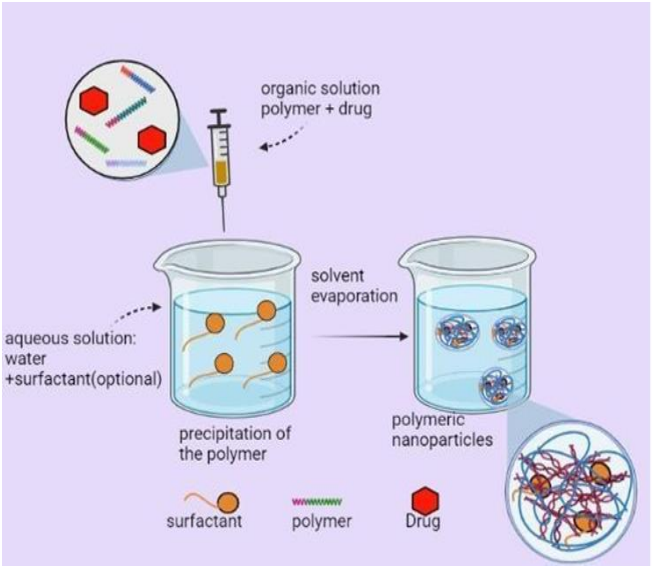

Fig 6 Nano Precipitation

While dissolving the polymer in the initial stage, organic solvents are usually used. in most approaches that call for the majority of approaches that call for the use of premade polymers [105]. These solvents have the potential to cause toxicological and ecological risk issues. The finished product also needs to be cleaned of any remaining solvents. Using methods that include the polymerization of monomers, for the loading of chemicals in polymeric NPs with improved effectiveness and with just one reaction step [106]. The products are typically produced as aqueous colloidal suspensions, regardless of the preparation method used [100].

➢ *Characterization of Nanostructured Material [107] :*

Nanocrystalline materials must be characterized on both the nanometer and atomic scales in order to comprehend the relationship between structure and characteristics. Understanding the interactions between particles and establishing the sizes and shapes of nanoparticles are two characteristics mentioned above. Both from a industrial and an scientific application standpoint, this information is significant. To get structural data on nanocrystalline materials, a variety of experimental procedures have been used. They consist of "direct" microscopic methods like:

- *(AFM) Atomic force microscopy*
- *(TEM) Transmission electron microscopy*
- *(FIM) Field ion microscopy*
- *(SEM) Scanning electron microscopy*

➢ *Application of Nanostructured Materials :*

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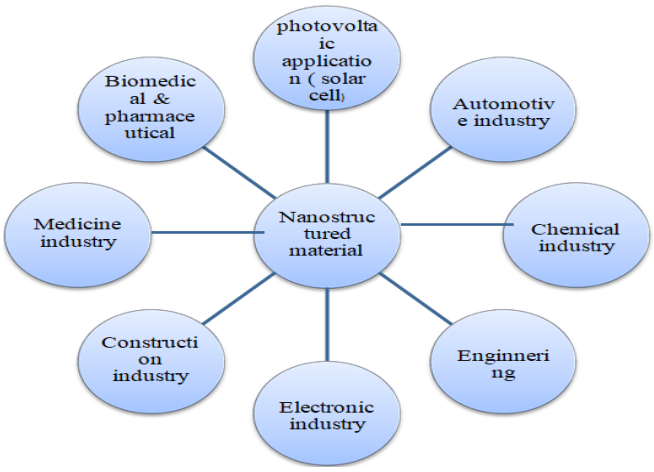

Fig 7 Application of Nanostructured Materials

- *Nanomaterials have distinct, desirable mechanical physical and chemical properties, and that qualities must be utilized for a variety of industrial applications. The following applications are among them, however they're not the only ones:*

✓ *Solar Cell (Photovoltaic Applications)*

Typically, two electrodes with a semiconductor layer in between them are used to build solar cells. TiO2 nanoparticles could be visible and serve in solar cells as electron acceptors. In organic solar cells, the organic semiconductor layer is photo-excited by solar radiation, which causes it to emit electrons. The semiconductor TiO2 nanomaterials receive the released electrons. A patterned TiO2 thin sheet with many pores that are a few nm in diameter can be employed to improve solar cell efficiency [108].

✓ *Industries of the Automobile*

Many uses for nanomaterials are found in the automobile sector. Nanomaterials are utilised in the automotive industry for windscreen and body coatings, catalysts, sensors, paint (basecoat, clear coat and), and tyres themselves.

✓ *Industrial Chemistry*

In the chemical industry, nanomaterials are utilised as fillers for magnetic fluids, switchable adhesives, impregnation of papers, and coating systems based on nanocomposites.

✓ *Engineering*

Nanomaterials are utilized in engineering for lubricant-free bearings, anti-blocking coating, coatings that prevent scratches on plastic components and wear prevention for machinery and tools.

✓ *Industry Electronic*

In the electronic sector, nanomaterials are employed in conductive and antistatic coatings, displays, data memory, glass fiber, laser diodes, filters (Infrared- blocking), optical switches, andmore.

✓ *Industry Construction*

Building materials for stone, wood, facades, floors, roof tiles, tiles etc., as well as groove mortar and facade coatings all use nanomaterials for thermal insulation, flame retardants, surface functionalization, etc.

✓ *The Medical Industry*

Mechanisms for delivering drugs, therapeutic ingredients, contrast media, fast diagnostic tests, prosthetics and antimicrobial agents, implants, coatings, and cancer therapeutic substance are all made with nanomaterials.

✓ *Pharmaceutical and Biomedical uses*

Numerous industries use nanomaterials, including bio-detection, antimicrobials and bio-magnetic separations, labeling, drug delivery, orthopedic surgery, MRI contrast agents, sunscreens, and spray-on thermal coatings [108-109].

➢ *Recent Advancement on Nanostructured Materials*

Table 3 Recent Advancement on Nanostructured Materials

Author	Year	Title	Indication	Ref.
Bahareh Kho dashenas, at.,el.	2019	Gelatin–Gold Nanoparticlesas an Ideal Candidate for Curcumin Drug Delivery: Experimental and DFT Studies	Antibacterial impact in the administration of the substance curcumin	[110]
Jan Willemde Vries, at,el.	2018	DNA nanoparticles for ophthalmicdrug delivery	Ocular therapy	[111]
Masoudipour , et al.	2017	A targeted drugdelivery systembased on dopamine functionalized nano graphene oxide	Release of Anticancerdrugs	[112]
Fan, Huitao,et al.	2017	Triple functionnanocomposites of porous silica-CoFe 2 O 4-MWCNTs as a carrier for pH -sensitive anti-cancer drug controlled delivery	Imaging agent and drugdelivery	[113]
Kim, et al.	2017	Targeted gene delivery of polyethyleneimine-grafted	Pharmacological target forthe cancer treatment	[114]
		chitosan withRGD dendrimer peptide in αvβ3 integrin- overexpressingtumor cells		

➢ *Patent on Nanostructured Material:*

Table 4 Patent on Nanostructured Material

Patent no.	Assignee	Filed on	Tittle	Ref.
US20140272183A1	Cooper Christopher H.Mikhail Y. Alan G. Starostin Mikhail Y.	2014	Large scale manufacturing of nanostructured material	[115]
EP2789661A1	Mariaenrica Carola EspositoRaffaella StrianiCorcione Frigione	2013	Hybrid organic- inorganic nanostructured UV- curable formulation andmethod for preparation thereof	[116]
US20130210794A1	Zsolt Ötvös Genovéva Ferenc Darvas Gábor HeltovicsFilipcsei	2011	Nanostructured ezetimibe compositions, processfor the preparation thereof and pharmaceutical compositions containing them	[118]
EP2386525A1	Elisabeth Engel Linares Toro Oscar CastañoJosep Anton López Melba Navarro Altor AguirreCano Planell Estany	2010	Nanostructured material comprising a biocompatible calcium phosphate glass, sol-gelprocess for its preparation and medicaluse thereof	[119]

V. FUTURE PROSPECTIVE & CONCLUSION

The creation of nanostructured materials, made from nanocrystal, nanosheet, nanoshell, nanofibers, nanotubes, nanoparticles, quantum dots, dendrimers, liposome, and other nanostructures, has advanced nanotechnology significantly over the past ten years. Natural NMs have been a part of the ecosystem for a long time, and they contain some processes that make them less damaging to living things. Many opportunities have now been made available to change the chemical and structural characteristics of different nanomaterials with an incredible scale of control as a result of the expanding focus on nano-medicine. Combining these nanomaterials to create nanostructured materials is still being researched, though. Many nations have rules and regulations to reduce or eliminate the possible risks of engineered NMs product. To recognize harmful nanoparticles (NPs), extensive research in the field of nano-toxicology is required.

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