A Review Article on Nanomaterial: Synthesis, Classification and their Properties

S. Jone Rosy[1], Dr. M. Priya[2]

[1]Assistant Professor, Department of Electronics and Communication Engineering, Aalim Muhammed Salegh college of Engineering

[2]Professor, Department of Physics, Saveetha Engineering College

Abstract: ***Nanomaterials are in the size ranging from 1nm to 100nm. The Interdisciplinary approach is the essential and prime in the development of Nontechnology. The properties of nanomaterials such as their size, shape and Surface area prominently depend on the way the materials are synthesized. The selection of proper synthesis method plays a key role and it dominates the process where it is applied too. Further the nano materials can be used in various application such as health sector, cosmetics, home essentials, Automobile Sectors, Electronics etc. This paper focuses on the synthesis method, properties, classification and applications in health care.***

Keywords: Nanomaterials, Synthesis, Nanoscale

1. Introduction

Nano Technology has developed and gained attraction nowadays. The major part of Nano Technology is the nanoparticle. Nanoparticles are of size in the range of tiny and it is between 1 and 100 nanometers [1]. Nano Particle can be classified broadly as organic and Inorganic. The Organic Nanoparticle exists in nature whereas Inorganic Nanoparticle can be man made by various synthesis method.

By synthesis of Nano particle the properties of nano particle such as physical, chemical and biological can be varied as per the required process. Due to its nanometer scale it has unique material properties and manmade nanoparticle plays a vital role in various Manufacturing sectors. Apart from the material the nanoparticle can be classified based on their shape and size as, Zero Dimensional, one dimensional (1D), Two Dimensional (2D) and Three Dimensional (3D) [14].

A nanoparticle can be either a zero dimensional where the length, breadth and height is fixed at a single point for example nano dots, one dimensional where it can own only one constraint like graphene, two dimensional where it has length and breadth like carbon nanotubes or three dimensional where it has all the parameters such as length, breadth and height like gold nanoparticles [13]. With the progress in properties of nanomaterials, their dimensions at the nanoscale level, new biodevices such as smart biosensors that can detect minute concentration of a desired analyte are evolving.

The nanoparticles exist in different shape, size and structure. It can be spherical, cylindrical, tubular, conical, hollow core, spiral, flat, etc. or irregular and differ from 1 nm to 100 nm in size. The surface of the nanomaterial can be a uniform or irregular with surface variations. Roughly nanoparticles are crystalline or amorphous with single or multi crystal solids either loose or agglomerated [13]. Several synthesis methods are being developed or improved to enhance the properties and reduce the production costs. Some methods are modified to achieve process specific nanoparticles to increase their optical, mechanical, physical and chemical properties [3].

2. Why Nano particle?

Nanoparticle is so small that you cannot see the material of that size with your normal eyes unless with your powerful scanning electron microscope (SEM) [29]. Comparatively the material in smaller size exhibits different properties in terms of physical, chemical, optical and mechanical than with bulk materials [15]. Further the properties of materials can be changed with respect to the process by synthesis of materials rather than by different composition. Thus in the modern world nano materials are most preferred.

3. Synthesis of Nano Particle

NanoParticles Can be synthesizes mainly by two methods, they are. (1) Bottom-up approach and (2) Top-down approach. This classification further be divided into various subclasses based on the operation, reaction condition and adopted protocols.

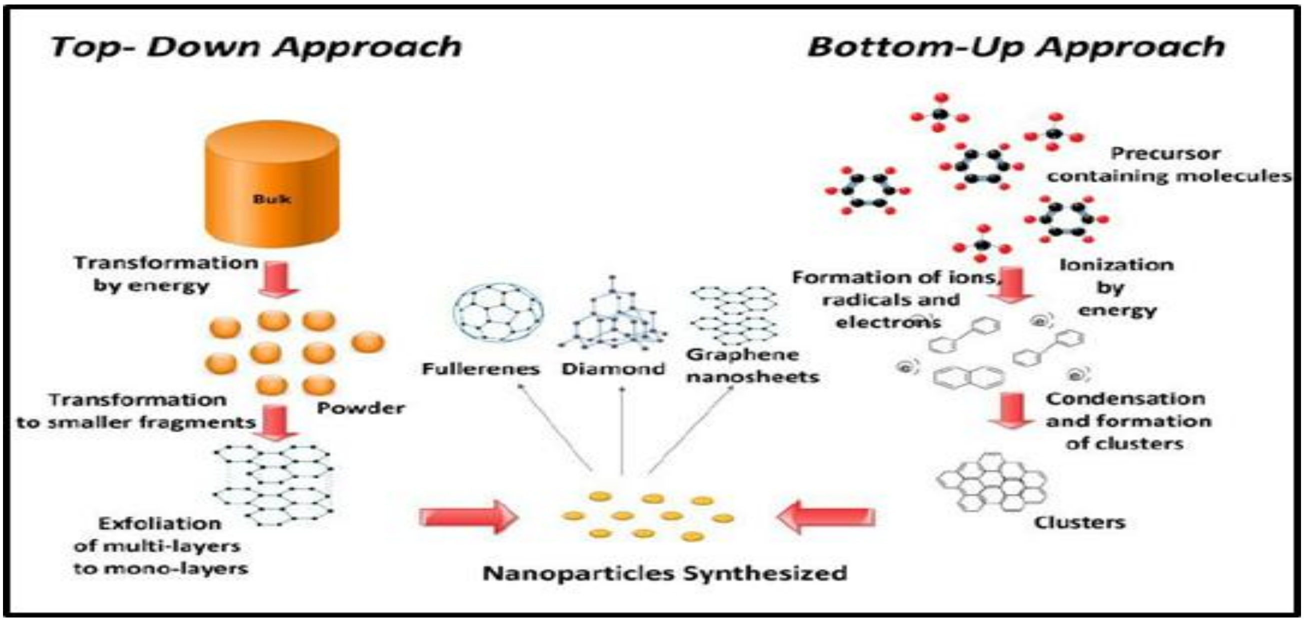

Figure 1: Synthesis of Nanoparticle; Top down and Bottom up Approach

3.1Bottom up approach:

Bottom-up is the approaches which have the ability to produce nanoparticle form basic units. It applies chemical or physical forces operating at the nanoscale to assemble basic units into larger structures [17]. This approach for biological synthesis employs yeast, bacteria, fungi, algae and plants [4]. Further this can be of Sol-gel, spinning, chemical vapour deposition (CVD), pyrolysis are the vibrantly used bottom-approaches for the generation of nanoparticle.

Table: Bottom up approach for the synthesis of nanomaterial

Bottom up approach	Nanomaterials Produced
BioSynthesis	Various oxide nanomaterials
Sol Gel Method	ceramics or metal oxides, sulphides, borides and nitrides.
Spinning	Colloidal and Oxide NanoParticle.
Chemical Vapour Deposition	CNT, fullerenes and nanoTubes.
Pyrolysis	Carbon based nanoparticle

3.1.1 Biosynthesis

Biosynthesis is an eco friendly approach for the synthesis of nanoparticles that are nontoxic and biodegradable [15]. Biosynthesis uses yeast, algae, bacteria, plant extracts, fungi, etc. together with the precursors to produce nanoparticle in its place of convention chemicals for bio reduction and capping purposes. The biosynthesized nanoparticles has unique and enhanced properties that finds its way in biomedical applications [1].

3.1.2. Sol-gel

In sol gel method two types of compounds namely ‘sol ‘ and ‘gel’ involves. This process is a low temperature process, hence less energy consumption and less pollution [18]. Sols are nothing but solid particles in a liquid. They are a sub class of colloids. Gels are nothing but a continuous network of particles with pores filled with liquid. Sol-gel is mostly the preferred method in bottom – up approach due to its simplicity as most of the nanoparticles can be synthesized from this method [30]. This method is useful to synthesize ceramics or metal oxides, sulphides, borides and nitrides. It is a wet-chemical process containing a chemical solution acting as a precursor for an integrated system of discrete particles. Metal oxides and chlorides are the typically used precursors in sol-gel process [9]. The precursor is then dispersed in a host liquid either by shaking, stirring or sonication and the resultant system contains a liquid and a solid phase. A phase separation is carried out to recover the nanoparticles by various methods such as sedimentation, filtration and centrifugation and the moisture is further removed by drying [10].

3.1.3. Spinning:

Spinning disc reactor (SDR) is employed in the synthesis of nanoparticles by the process called spinning. It contains a rotating disc inside a chamber/reactor where parameters such as temperature can be controlled. The reactor is generally filled with nitrogen or other inert gases to remove oxygen inside and avoid chemical reactions [7]. The disc is rotated at different speed where the liquid i. e. precursor and water is pumped in. The spinning causes the atoms or molecules to fuse together and is precipitated, collected and dried [19]. The various operating parameters such as the liquid flow rate, disc rotation speed, liquid/precursor ratio, location of feed, disc surface, etc. determines the characteristics nanoparticles synthesized from SDR.

3.1.4. Chemical Vapour Deposition (CVD):

A broadly used method for depositing structural and sacrificial layer is the chemical vapour deposition. In a Deposition chamber, solid thin films are deposited in the wafers by condensation of vapor or adhesion of solid phase reaction byproducts [16]. The growth of the material is conducted in a sealed chamber to prevent introduction of particles and leakage of reactant gases. There are two types of CVD based on the energy that is used for the process [20]. The energy is provided by heat alone and the process is conducted at very low pressure then it is called Low Pressure Chemical Vapour Deposition (LPCVD) [27] [28]. The plasma is the source of the energy then it is called Plasma Enhanced Chemical vapour deposition (PECVD).

The major materials used in CVD are Polycrystalline silicon, Silicon Nitride and Silicon Di oxide.

Chemical vapour deposition is the deposition of a thin film of gaseous reactants onto a substrate. The deposition is carried out in a reaction chamber at ambient temperature by combining gas molecules. A chemical reaction occurs when a heated substrate comes in contact with the combined gas [8]. This reaction produces a thin film of product on the substrate surface that is recovered and used. Substrate temperature is the influencing factor in CVD. The advantages of CVD are highly pure, uniform, hard and strong nanoparticles. The disadvantages of CVD are the requirement of special equipment and the gaseous by-products are highly toxic [28].

3.1.5. Pyrolysis

Pyrolysis is the process used in industries for production of nanoparticles in largescale. It happens by burning a precursor with flame. The precursor is may be a liquid or vapour that is poured into the furnace at high pressure through a small hole where it burn [13]. The combustion or by-product gases are then air classified to recover the nanoparticles. Some of the furnaces use laser plasma instead of flame to produce high temperature for easy evaporation [14]. The advantages of pyrolysis are simple, efficient, cost effective and continuous process with high yield.

3.2 Top Down Approach

In Top Down approach the nanoscale particle is formed by breaking the objects in large size. In some applications larger scale materials are grinded to the nanometer scale to increase the surface area to volume aspect ratio for more reactivity [24]. Nano gold, nano silver and nano titanium dioxide are such nano materials used in different applications. Carbon nanotube manufacturing process using graphite in an arc oven is another example for top-down approach nanotechnology [29]. The drawbacks to be considered in Top Down approach are difficult to obtain a perfect surface structure.

Top Down Approach	Nanomaterials Produced
Arc Discharge Method	Carbon Nano Tubes (CNT)
Laser Pyrolysis	Broad range of Nano Particle including CNT
Ball Milling	Composites and mixture of Elemental Powders
Inert Gas Condensation	Oxides, Alloys and Semiconductors.

3.2.1. Arc Discharge Method:

The Carbon Nano Tube cab be produced by the Arc Discharge method. Two graphite rods are place in an arc chamber which acts as a anode and cathode with few millimeters apart [21]. At 100 A carbon vaporizes into plasma and a high temperature gas rises and forms like a upward falling arc. This method can produce CNT of diameter varying from 2 to 30nm.

3.2.2. Laser Pyrolysis:

The method is easy and effective in the synthesis of nano powders. It is produced by a form of exchange between the release of carbon dioxide laser and the movement of reagents. The energy current between the two leads to a quick increase in temperature in the reactive zone by arousing the vibration degrees of molecules [14]. There is a disconnection of reactors and a flame that manifests where the nanoparticles are produced and then go through quenching once the flames disappear. The powders are deposited where they will be obtained. The above technique is an easy way for particle synthesis of 15 – 20 nanometers at 100g/h. One of the benefits of this technique is the flow of reaction. Other benefits are high level of purity, excellent chemical and physical properties. Many nano powders have been formed through this process.

3.2.3. Ball Milling:

Among various top down approaches ball milling is the commonly used methods is ball milling or shaker milling where nano scale materials are produced by mechanical attrition [22]. In this method the kinetic energy of the material is transferred to coarse-grained material with the objective of size reduction. This process is carried out under controlled atmospheric conditions to prevent oxidation [17]. The advantage of this method is can be done in large scale; several Kgs of nanoparticle can be synthesized. The metal oxide nanocrystal like Co, Cr, Al-Fe, Ag-Fe and Fe can be produced bythis method.

3.2.4. Inert Gas Condensation:

The metallic or Inorganic materials are vapourized using the thermal evaporation sources such as electron beam evaporating device, in an atmosphere of 1-50 mbar [6]. A high residual Gas pressure causes the formation of ultrafine particles by Gas phase collision. Due to the drawback in this method such as temperature ranges and dissimilar evaporation ranges Sputtering or Laser Evaporation is preferred.

3.2.5. Sputtering:

Sputtering is the deposition of nanoparticles on a surface by ejecting particles from it by colliding with ions [20]. Sputtering is usually a deposition of thin layer of nanoparticles followed by annealing. The thickness of the layer, temperature and duration of annealing, substrate type, etc. determines the shape and size of the nanoparticles [21].

4. Properties of Nanoparticle:

The Physical properties of nanomaterials such as melting point, boiling point of a substance are determined by normal laboratory conditions [22]. The nanoparticle is characterized by its physical, chemical and Thermal. These characteristics are different for the particle which is bulk and nanoscale [9]. Hence by changing the size of the particle instead of composition the properties of the Nano materials can be varied.

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Table 3: Properties of Nanomaterials

Properties	Examples	Reference
Catalytic	Higher the surface area to volume ratio, better the catalytic efficiency	[6]
Electrical	Increases Electrical conductivity	[16]
Magnetic	Increased Magnetic coercivity and super paramagnetic behaviour	[24]
Optical	Spectral shift of optical region	[14]
Mechanical	Improves hardness and toughness of metals and alloys	[7]
Biological	Increased Permeability through biological barriers, biocompatibility.	[4]

5. Applications in Medicine and Healthcare

In all countries the availability, efficiency and cost effectiveness of healthcare measures is a prime concern. Nanotechnology plays a vital role in modern medical diagnosis and treatment [11]. Health care Industries are involved in manufacturing Nano devices for early diagnosis of deadly diseases like cancer, Tuberculosis etc. Further the organic Nano materials are employed in Drug Delivery.

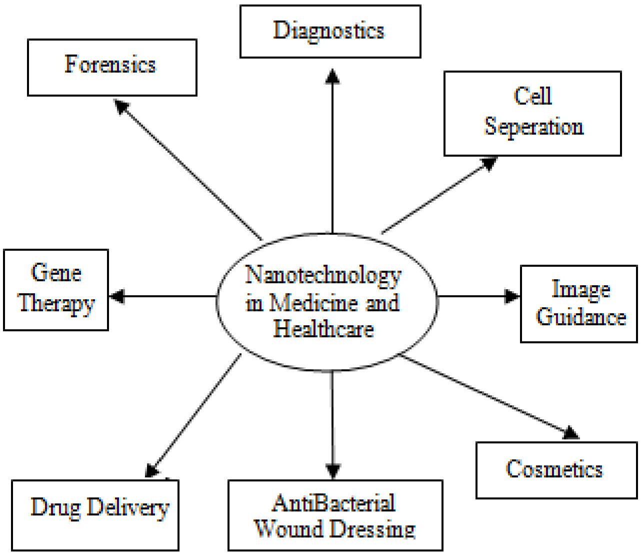

Figure 2: Applications in Healthcare and Medicine

6. Conclusion

Nanotechnology has shown a great impact in science and has made great strides in core technology. There is an exponentially increasing growth of Nanotechnology in every aspect of life. Nanotechnology has made a revolution in Healthcare, Veterinary, Computing, Electronics, Information and communication Technology and energy sectors. Large companies in globe are involved in manufacturing devices made of Nanomaterials in the motto of dominating the market. Yet the synthesis of nanomaterial to vary the properties is the challenging task for scientist and this paves the way to involve newer technologies in the synthesis of Nanoparticles**.**

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