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A Review on Nanoparticles - Classifications, Synthesis and Applications

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Abstract:

This review paper focused on detailed overview of the properties, synthesis and application of the nanoparticles (NP) subsist in different forms. Nanoparticles are in very small size which ranges 1 to 100nm scale. They are classifieds into various classes based on their characteristic, size and shapes. The dissimilar group included metal NP, ceramic NP, and polymeric NP and fullerenes. NP own unique chemical characteristics and physical characteristics due to their nano-scale size and high surface area. Their optical characteristics are informed to be reliant on the size, which imparts dissimilar colors due to absorption in the noticeable region. Their toughness, reactivity and other characteristics are also reliant on on their unique shape, structure and sizes. Due to these features, they are appropriate candidates for numerous commercial and domestic applications, which comprise medical applications, imaging, environmental applications, energy-based research, and catalysis. Heavy metal NP of mercury, tin and lead are reported to be so rigid and steady that their degradation is not simply attainable, which can lead to numerous environmental toxicities.

1. Introduction

Since the last century, nanotechnology has been a well-known field of study. Various revolutionary developments in the field of nanotechnology have occurred since Nobel Laureate Richard P. Feynman's well-known 1959 lecture "There's Plenty of Room at the Bottom" (Feynman, 1960). Nanotechnology has produced a wide range of materials at the nanoscale. Nanoparticles (NP) are particulate substances with a minimum dimension of 100 nanometers (Laurent et al., 2010). Depending on the overall shape, these materials can be 0D, 1D, 2D, or 3D. (Tiwari et al., 2012). When researchers discovered that size can affect a substance's physio-chemical properties, such as its optical properties, they realised the significance of these materials. Wine red, yellowish grey, black, and dark black are the colours of 20-nm gold (Au), platinum (Pt), silver (Ag), and palladium (Pd) NPs, respectively.Figure 1 depicts an example of this illustration, in which Au NPs of various sizes are synthesised. These NP had distinct colours and properties that varied in size and shape, and could be used in bioimaging applications (Dreaden et al., 2012). The colour of the solution changes as the aspect ratio, nanoshell thickness, and percent gold concentration change, as shown in Fig. 1. Changes in any of the above-mentioned factors affect the absorption properties of the NP, resulting in different absorption colours.

Because NP are not simple molecules, they are made up of three layers: (a) the surface layer, which can be complexed with a variety of small molecules, metal ions, surfactants, and polymers; and (b) the interior layer, which can be functionalized with a number of small molecules, metal ions, surfactants, and polymers. (b) The shell layer, which is chemically and physically distinguishable from the core, and (c) the core, which is the NP's central portion as well as generally refers to the NP itself (Shin et al., 2016). Owing to such exceptional characteristics, these materials gained enormous interest of researchers in multi various disciplines. Scanning electron microscopy (SEM) and transmittance electron microscope (TEM) images of mesoporous and nonporous methacrylate-functionalized silica are shown in Fig. 2. (MA-SiO2). Mesoporousness confers additional properties to NP. The NP can be used for drug delivery (Lee et al., 2011), chemical and biological sensing (Barrak et al., 2016), gas sensing (Mansha et al., 2016; Rawal and Kaur, 2013; Ullah et al., 2017), CO2 capturing (Ganesh et al., 2013; Ramacharyulu et al., 2015), and other applications (Shaalan et al., 2016).

2. Classifications of NP

NP are classified into several groups based on their morphology, size, and chemical properties. Some of the most well-known classes of NP are listed below, depending on physical and chemical characteristics.

2.1. Carbon-based NP

Carbon nanotubes (CNTs) and fullerenes are two broad types of carbon-based NPs. Nanomaterial made of globular hollow cages, such as allotropic forms of carbon, are found in fullerenes. They have made remarkable commercial interest

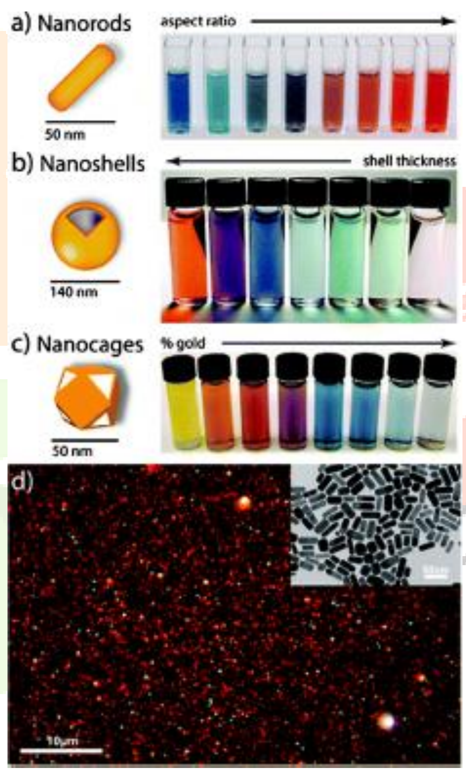


Figure Color dependence of Au NP on size and shape (Dreaden et al., 2012).

due to their electrical conductivity, high strength, structure, electron affinity, & versatility (Astefanei et al., 2015). Each carbon unit in these materials is sp2 hybridised and is arranged in pentagonal as well as hexagonal patterns. The well-known fullerenes C60 and C70 with diameters of 7.114 and 7.648 nm, respectively, are shown in Figure 3.

CNTs are elongated tubular structures with a diameter of 1–2 nm (Ibrahim, 2013). Based on their diameter telicity, these can be classified as metallic or semiconducting (Aqel et al., 2012). These have the appearance of a graphite sheet rolling on itself (Fig. 4). Carbon nanotubes are classified as single-walled (SWNTs), double-walled (DWNTs), or multi-walled (MWNTs) because the rolled sheets can have one, two, or multiple walls (MWNTs). They're commonly made by laser or electric arc deposition of carbon precursors, particularly atomic carbons, vaporised from graphite and deposited on metal particles. Chemical vapour deposition (CVD) has recently been used to synthesize them (Elliott et al., 2013). Because of their unique physical, chemical, and mechanical properties, such components are used as fillers

(Saeed and Khan, 2016, 2014), efficient gas adsorbents for environmental cleanup (Ngoy et al., 2014), and as help medium for various inorganic and organic catalysts. (Mabena et al., 2011).

2.2. Metal NP

Metal NP are made entirely of metal precursors. These NP have unique optoelectrical properties due to their well-known localised surface plasmon resonance (LSPR) characteristics. In the visible zone of the electromagnetic solar spectrum, NP of alkali and noble metals, such as Cu, Ag, and Au, has a broad absorption band. Metal NP syntheses with controlled facet, size, and shape are important in today's cutting-edge materials (Dreaden et al., 2012). Metal NPs are used in a variety of research fields due to their advanced optical properties. Gold NP coating is commonly used for SEM sampling to improve the electronic stream, which aids in the acquisition of high-quality SEM images (Fig. 1).There are numerous other applications, which are thoroughly discussed in the review's applications section.

2.3. Ceramics NP

Ceramics NP are nonmetallic inorganic solids that are made by heating and cooling. Amorphous, polycrystalline, dense, porous, and hollow forms are all possible (Sigmund et al., 2006). As a result of their use in applications such as catalysis, photocatalysis, dye photodegradation, and imaging, these NP are attracting a lot of attention from researchers. (Thomas and colleagues, 2015).

2.4. Semiconductor NP

Semiconductor materials have properties that are average between metals and nonmetals, and as a result, they have a wide range of applications in the literature (Ali et al., 2017; Khan et al., 2017a). Because semiconductor NPs has large bandgaps, bandgap tuning caused significant changes in their properties. As a result, photo catalysis, photo optics, and electronic devices rely heavily on them (Sun, 2000). Because of their suitable bandgap and bandedge positions, a variety of semiconductor NPs are found to be exceptionally efficient in water splitting applications (Hisatomi et al., 2014).

2.5. Polymeric NP

These are usually organic-based NP, which are referred to as polymer nanoparticles (PNP) in the literature. Nanospheres or nanocapsulars are the most common shapes (Manshaetal., 2017). The former are matrix particles with a solid overall mass, while the other molecules are adsorbed at the spherical surface's outer boundary. The solid mass is completely encapsulated within the particle in the latter case (Rao and Geckeler, 2011). The PNP is easily fictionalised, and as a result, there are a slew of applications in the literature (Abd Ellah and Abouelmagd, 2016; Abouelmagd et al., 2016).

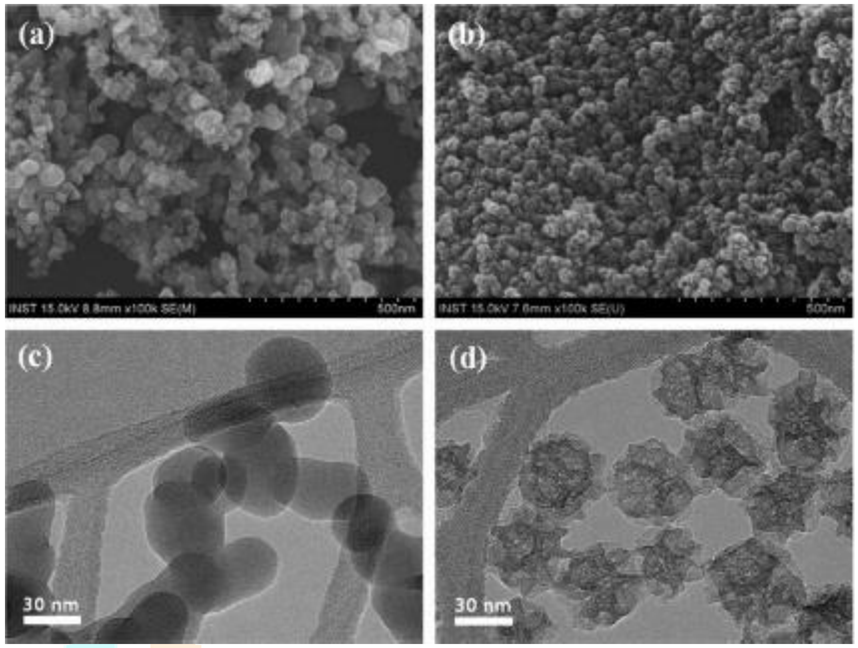


Figure FE-SEM micrographs of (a) nonporous MA-SiO2 NP, (b) mesoporous MA-SiO2 NP. TEM images of (c) nonporous MA-SiO2 NP and (d) mesoporous MA-SiO2 NP (Lee et al., 2011).

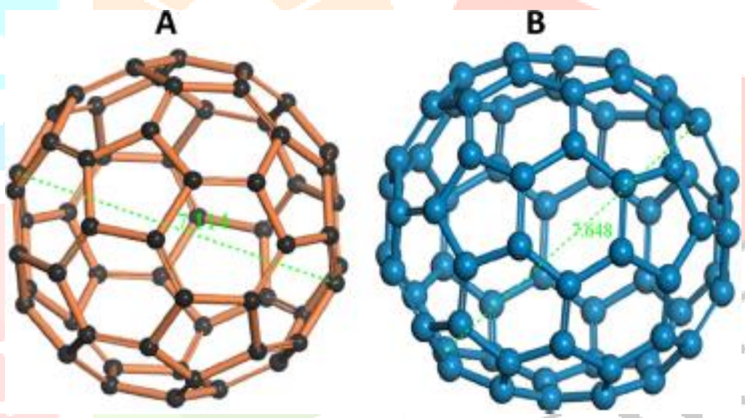
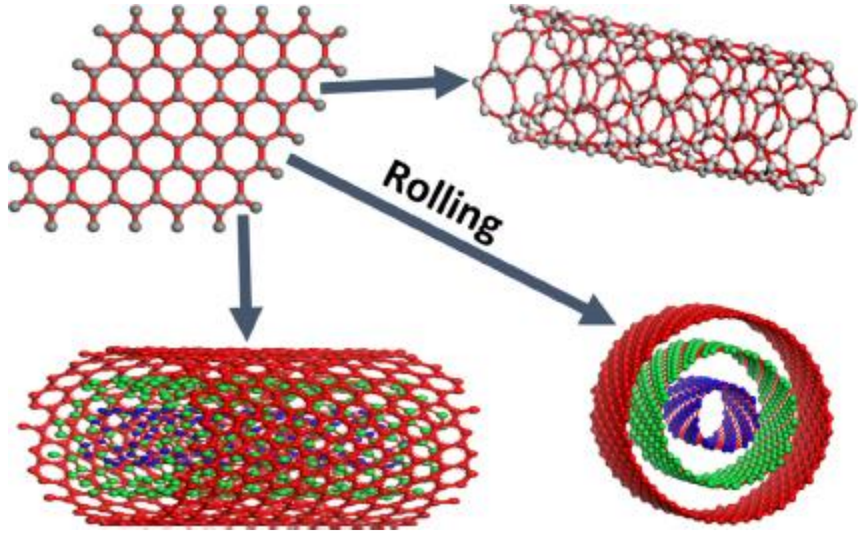


Figure Different form of Fullerenes/buck balls (A) C60 and (B) C70.

2.6. Lipid-based NP

These NPs have lipid moieties and can be used in a variety of biomedical applications. A lipid NP is typically spherical in shape, with a diameter ranging from 10 to 1000 nm. Lipid NP, like polymeric NP, has a solid lipid core and a matrix of soluble hydrophilic molecules. The external core of these NPs was stabilised by surfactants or emulsifiers (Rawatet al., 2011). Lipid nanotechnology (Mashaghi et al., 2013) is a subfield of nanotechnology that focuses on the design and synthesis of lipid nanoparticles for a variety of applications, including drug carriers and delivery (Puri et al., 2009) and RNA release in cancer therapy (Mashaghi et al., 2013). (Gujrati et al., 2014).

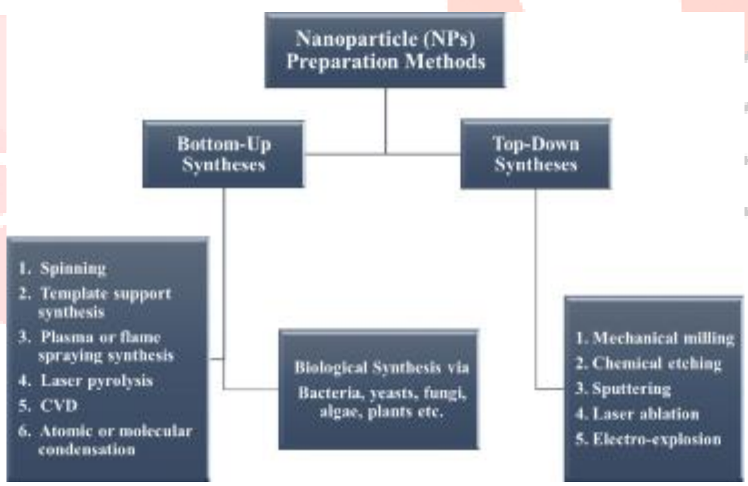


3. Synthesis of nanoparticles

For the production of NP, various methods can be used, but they are broadly divided into two classes, as shown in Scheme 1: (1) bottom-up approach and (2) top-down approach (Wang and Xia, 2004). (Iravani, 2011). These methods are further divided into subcategories based on the operation, reaction condition, and protocols used.

3.1. Top-down syntheses

In this method, destructive approach is employed. Starting from larger molecule, which decomposed into smaller units and then these units are converted into suitable NP.



Scheme 1 Typical synthetic methods for NP for the (a) top-down and (b) bottom-up approaches.

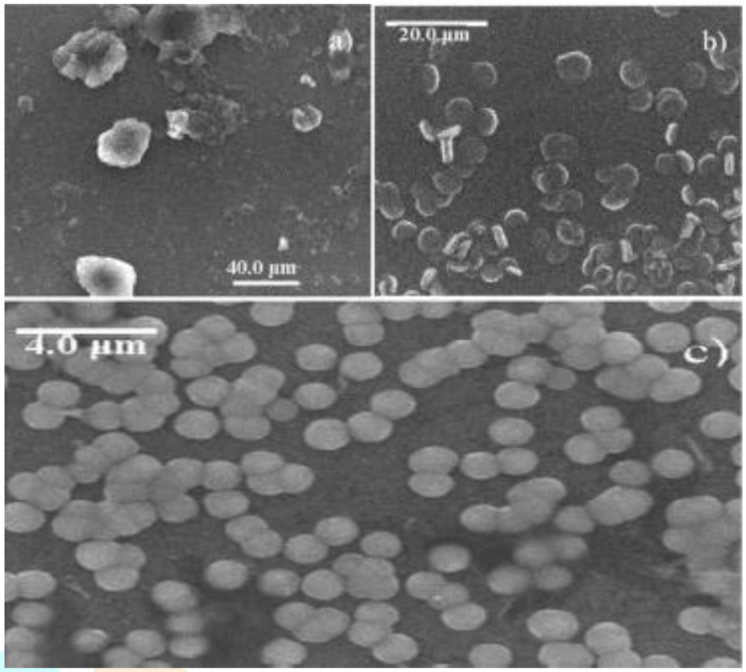


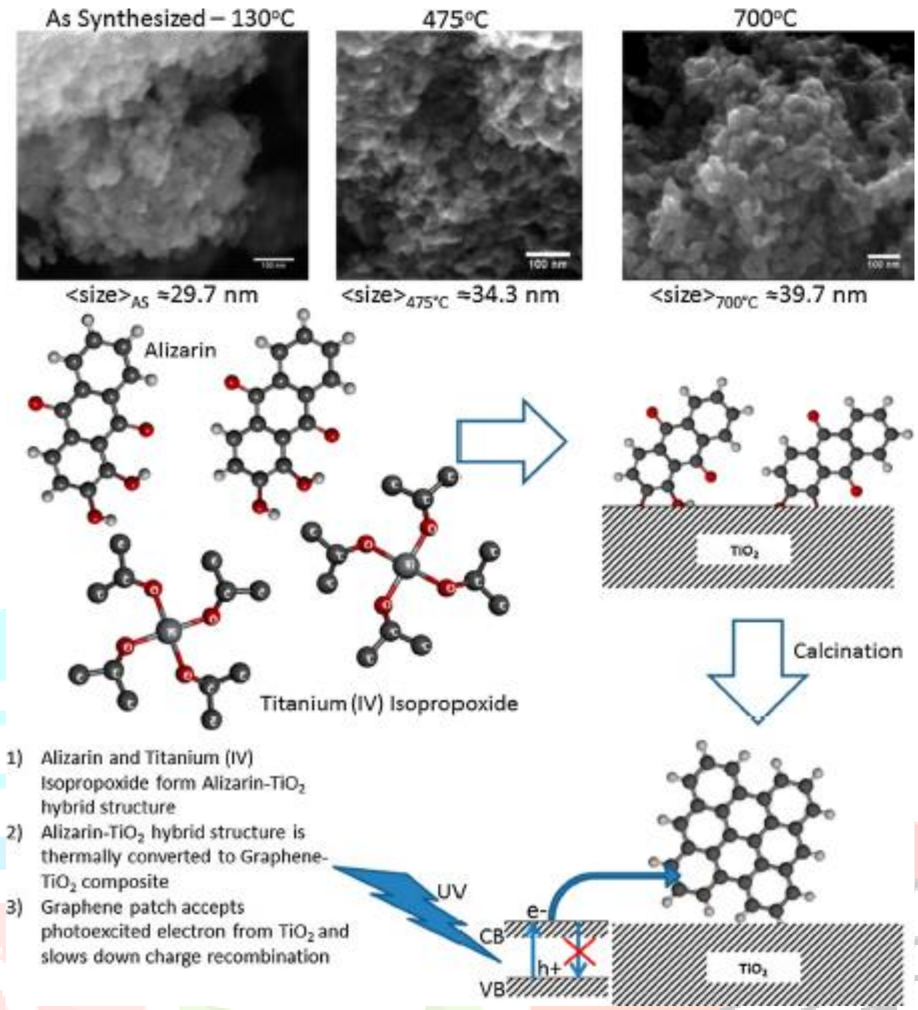
Figure SEM images of (a) The untreated carbon black, (b) and (c) 10 min and 1 h ultrasonically in POM solution (Garrigue et al., 2004).

Grinding/milling, chemical vapour deposition (CVD), physical vapour deposition (PVD), and other decomposition techniques are examples of this method (Iravani, 2011). Coconut shell (CS) NP was synthesised using this method. The milling method was used for this, and the raw CS powders were finely milled for various intervals of time using ceramic balls and a well-known planetary mill. Using various characterization techniques, they demonstrated the effect of milling time on the overall size of the NP. According to the Scherer equation, the NP crystal lite size decreases as time passes. They also noticed that the brownish colour faded with each hour increment as the NP's size shrank. The SEM results were also consistent with the X-ray pattern, indicating that particle size decreases over time (Bello et al., 2015).

In the presence of organic oleic acid, one study revealed the synthesis of spherical magnetite NP from natural iron oxide (Fe2O3) ore using a top-down destructive approach with particle sizes ranging from 20 to 50 nm (Priyadarshana et al., 2015). To synthesise colloidal carbon spherical particles with controlled size, a simple top-down route was used. The continuous chemical adsorption of polyoxometalates (POM) on the carbon interfacial surface was the basis for the syn-thesis technique. As shown in Fig. 5, adsorption reduced the carbon black aggregates to smaller spherical particles with a high dispersion capacity and narrow size distribution.. (Garrigue et al., 2004). The micrographs also revealed that as the sonication time increases, the size of the carbon particles decreases. From their bulk crystals, a series of transition-metal dichalcogenide nanodots (TMD-NDs) were synthesised using a combination of grinding and sonication top-down techniques. Due to the narrow size distribution, almost all TMD-NDs with sizes < 10 nm show excellent dispersion (Zhang et al., 2015). Top-down laser fragmentation, which is a top-down process, was recently used to make highly photoactive active Co3O4 NP. The high-intensity laser irradiations produce NP that is well-uniform and has a lot of oxygen vacancies (Zhou et al., 2016).The average size of the Co3O4 was deter-mined to be in the range of 5.8 nm ± 1.1 nm.

3.2. Bottom-up syntheses

Because NP are made up of relatively simple substances, this approach is also known as the building up approach. Sedimentation and reduction techniques are two examples of this. Sol gel, green synthesis, spinning, and biochemical synthesis are all included. Iravani (2011, Iravani, Iravani, Iravani, Iravani Using this method, Mogilevsky et al. created TiO2 anatase NP with graphene domains (Mogilevsky et al., 2014). To make the photoactive composite for photocatalytic degradation of methylene blue, they used alizarin and titanium isopropoxide as precursors. Alizarin was chosen because its axial hydroxyl terminal groups have a high binding capacity with TiO2.



Scheme 2 Synthesis of TiO2 via bottom-up technique. SEM images showing the TiO2 NP (Mogilevsky et al., 2014).

An XRD pattern confirmed the anatase form. Scheme 2 shows SEM images of various samples taken with the reaction scheme. According to SEM, the size of NP increases as the temperature rises (Mogilevsky et al., 2014).

Well-uniform spherical shaped monocrystalline Au nanospheres were synthesised using a top-down laser irradiation technique (Liu et al., 2015a, 2015b). Liu et al. selectively transform the octahedra morphology to a spherical shape by attempting to control the laser treatment time and other reaction parameters.The SEM and TEM images of the prepared Au nanospheres are shown in Fig. 6, with an average diameter of 75 ± 2.6 nm (red column Fig. 6e) and 72 ± 3.1 in edge length of Au octahedra per particle (blue column Fig. 6f).

Needham et al. recently used a solvent-exchange method to achieve limit sized low density lipoprotein (LDL) NP for medical cancer drug delivery. Nucleation is the bottom approach in this method, followed by growth, which is the top approach. The LDL NP were made without the use of phospholipid and had a high hydrophobicity, which is important for drug delivery (Needham et al., 2016).

The monodispersed spherical bismuth (Bi) NP were synthesized by both top-down and bottom-up approaches

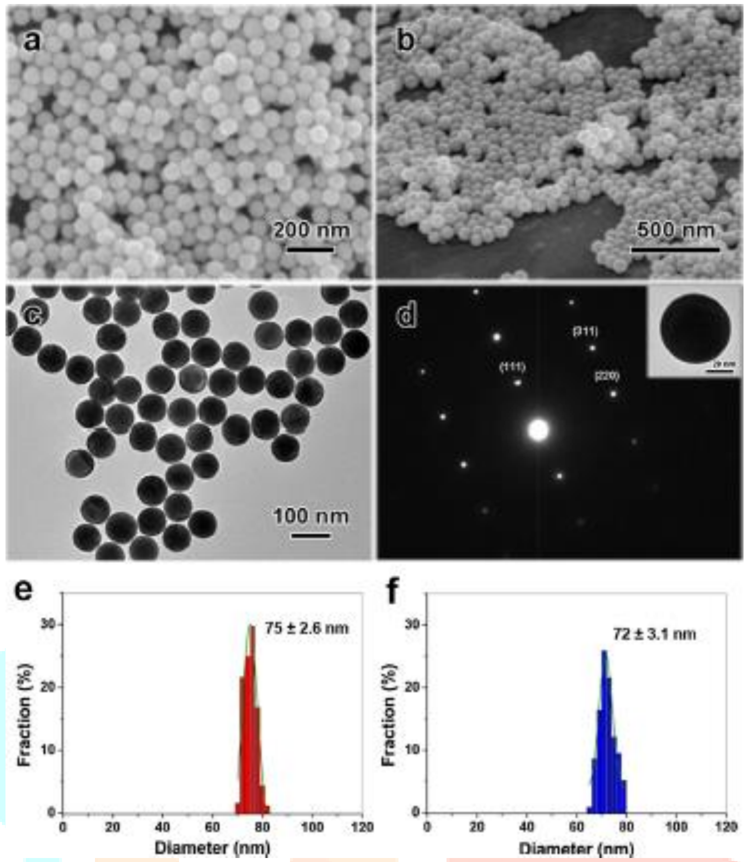


Figure SEM for Au nanospheres (a) top view, (b) tilted view, (c) TEM image of Au nanospheres (d) SAED pattern (inset: TEM of single Au particle), (e) and (f) size distribution spectra of spherical and octahedral Au NP (Liu et al., 2015a, 2015b).

Wang and Xia (Wang and Xia, 2004). The colloidal properties of these NP are excellent. Bismuth acetate was boiled in ethylene glycol in the bottom-up approach, whereas in the top-down approach, bismuth was converted to molten form and then emulsified in boiled diethylene glycol to produce NP. The size of the NP produced by both methods ranged from 100 to 500 nanometers (Wang and Xia, 2004). The details of this research can be found in Scheme 3. The feasibility and less toxic nature of processes are attracting many researchers to green and bionic bottom-up synthesis. These processes are both cost-effective and environmentally friendly, as NP is synthesised using biological systems like plant extracts. For the production of NP, bacteria, yeast, fungi, Aloe vera, tamarind, and even human cells are used. Au NP has been synthesised from wheat and oat biomass using microorganisms and plant extracts as reducing agents (Parveen et al., 2016). (Ahmed et al., 2016). Table 1 summarises the benefits and drawbacks of various top-down and bottom-up techniques, as well as some general observations (Biswas et al., 2012).

3. Applications of NP

Considering the unique properties discussed in Section 5, NP can be used in variety of applications. Some important of these are given below.

3.1. Applications In Drugs and Medications

Nano-sized inorganic particles, whether simplified, have unique physical & chemical properties and are becoming a more important material in the development of new nanodevices for a variety of physical, biological, biomedical, and pharmaceutical applications (Loureiro et al., 2016; Martis et al., 2012; Nikalje, 2015).

For their ability to deliver drugs in the optimal dosage range, NP have drawn increasing interest from every branch of medicine, often resulting in increased therapeutic efficiency, weakened side effects, and improved patient compliance (Alexis et al., 2008). Magnetite (Fe_3O_4) and its oxidised form maghemite (Fe_2O_3) are the most commonly used iron oxide particles in biomedical applications (Ali et al., 2016). The optical properties of NP are used to select it for achieving efficient contrast in biological and cell imaging applications, as well as photo thermal therapeutic applications. For the most commonly used classes of NP, such as Au NP, silica-Au NP, and Au nanorods, the Mie theory and discrete dipole approximation method can be used to calculate absorption and scattering efficiencies as well as optical resonance wavelength (Jain et al., 2006). The development of hydrophilic NP as a drug carrier has been a significant challenge in recent years. Polyethylene oxide (PEO) and polylactic acid (PLA) NP have emerged as very promising systems for intravenous drug administration among the various approaches (Calvo et al., 1997). MRI contrast, tissue repair, and immunoassay, as well as detoxification of biological fluids, hyperthermia, drug delivery, and cell separation, are all in vivo applications for superparamagnetic iron oxide NP with appropriate surface chemistry. All of these biomedical applications necessitate a high magnetization value, a particle size of less than 100 nm, and a narrow particle size distribution in the NP (Laurent et al., 2010).The detection of analytes in tissue sections can be accomplished through antigen-antibody inter-actions using antibodies labeled with fluorescent dyes, enzymes, radioactive compounds or colloidal Au (Khlebtsov and Dykman, 2010b).

Over the last few decades, there's been a lot more interest in producing bio NP as effective drug delivery devices (Zhang and Saltzman, 2013). Polymers have been used in drug delivery research because they can efficiently deliver drugs to the target site, increasing therapeutic benefit while reducing side effects.. A major goal in the design of such devices has been the controlled release of pharmacologically active drugs to the precise action site at the therapeutically optimal degree and dose regimen.

Because of their unique benefits, such as the ability to protect drugs from degradation, target to the site of action, and reduce noxiousness and other side effects, liposomes have been used as a potential drug carrier instead of conventional dosage forms. However developmental work on liposome drugs has been restricted due to inherent health issues such as squat encapsulation efficiency, rapid water leakage in the commodity of blood components and very poor storage, and stability. On the other hand, polymeric NP promise some critical advantages over these materials i.e. liposomes. For instance, NP help to increase the rat ability of drugs or problems and possess convenient controlled drug release properties.Because of their enhanced surface plasmon resonance (SPR) light scattering and absorption, most semiconductor and metallic NPs have enormous potential for cancer diagnosis and therapy. The strong absorbed light is efficiently converted into localised heat by Au NP, which can be used for cancer photothermal therapy (Prashant et al., 2007). Beside this the antineoplastic effect of NP is also effectively employed to inhibit the tumor growth. The multihy-droxylated [Gd@C82(OH)22]n NP showed antineoplastic activity with good efficiency and lower toxicity (Chen et al., 2005). Ag NP are being used increasingly in wound dressings, catheters and various households' products due to their antimicrobial activity (AshaRani et al., 2009). Antimicrobial agents are extremely vital in textile, medicine, water disinfection and food packaging. Therefore, the antimicrobial characteristics of inorganic NP add more potency to this important aspect, as compared to organic compounds, which are relatively toxic to the biological systems (Hajaipour et al., 2012). These NP are functionalized with various groups to overcome the microbial species selectively. TiO2, ZnO, BiVO4, Cu- and Ni-based NP have been utilized for this purpose due to their suitable antibacterial efficacies (Akhavan et al., 2011; Pant et al., 2013; Qu et al., 2016; Yin et al., 2016).

3.2. Applications In Manufacturing and Materials

Nanocrystalline materials are fascinating materials for material science because their properties differ in size from those of their bulk counterparts. Manufacture NP display physicochemical characteristics that induce unique electrical, mechanical, optical and imaging properties that are extremely looked-for in certain applications within the medical, commercial, and ecological sectors (Dong et al., 2014; Ma, 2003; Todescato et al., 2016). NP focus on the characterization, designing and engineering of biological as well as non-biological structures < than 100 nm, which show unique and novel functional properties. Many companies have documented the high and low-level benefits of nanotechnology, and marketable products are already being mass-produced in industries like microelectronics, aerospace, and pharmaceuticals (Weiss et al., 2006). To date, the largest category of nanotechnology consumer products has been health and fitness products, followed by electronic and computer products, as well as home and garden products. Nanotechnology has been touted as the next revolution in many industries including food processing and packing. Resonant energy transfer (RET) system consisting of organic dye molecules and noble metals NP have recently gamed considerable interest in bio photonics as well as in material science (Lei et al., 2015). The presence of NP in commercially avail-able products is becoming more common.

Metals NP such as noble metals, including Au and Ag have many colors in the visible region based on plasmon reso-nance, which is due to collective oscillations of the electrons at the surface of NP (Khlebtsov and Dykman, 2010a, 2010b; Unser et al., 2015). The size and shape of the NP, the inter particle distance, and the dielectric property of the surrounding medium all influence the resonance wavelength. The noble metals NP's unique plasmon absorbance properties have been used in a variety of applications, including chemical sensors and biosensors (Unser et al., 2015).

3.3. Applications in the environment

Engineered NP is becoming more widely used in industrial and household applications, resulting in the release of these materials into the environment. Understanding the mobility, reactivity, Eco toxicity, and persistence of these NP in the environment is necessary for assessing their risk in the environment (Ripp and Henry, 2011; Zhuang and Gentry, 2011).Engineering material applications can raise NP concentrations in groundwater and soil, providing the most important exposure avenues for assessing environmental risks (Golobic et al., 2012; Masciangioli and Zhang, 2003). Natural NP play an important role in solid/water partitioning due to their high surface to mass ratio. Contaminants can be absorbed to the surface of NP, co-precipitated during the formation of natural NP, or trapped by aggregation of NP with contaminants adsorbed to their surface. The interaction of contaminants with NP is dependent on the NP characteristics, such as size, composition, morphology, porosity, aggregation/dis-aggregation and aggregate structure. When luminophores are doped inside the silica network, they are protected from environmental oxygen and are not harmful to the environment (Swadeshmukul et al., 2001).

Most of environmental applications of nanotechnology fall under three categories:

1.Environmentally benign sustainable products (e.g. green chemistry or pollution prevention).

2.Remediation of materials contaminated with hazardous substances and

3.Sensors for environmental stages (Tratnyek and Johnson, 2006).

Because of their negative effects on the environment and human health, heavy metals such as mercury, lead, thallium, cadmium, and arsenic have been removed from natural water. For this toxic soft material, super paramagnetic iron oxide NP is an effective sorbent material. As a result of the lack of analytical methods capable of quantifying trace concentrations of NP in the environment, no measurements of engineered NP in the environment have been available (Mueller and Nowack, 2008). Photodegradation by NP is also very common practice and many nanomaterials are utilized for this purpose. Rogozea et al. used NiO/ZnO NP modified sil-ica in the tandem fashion for photo degradation purpose. The high surface area of NP due to very small size (<10 nm), facilitated the efficient photo degradation reaction (Rogozea et al., 2017). The same group has reported the synthesis of variety of NP and reported their optical, florescence and degradation applications (Olteanu et al., 2016a, 2016b; Rogozea et al., 2016).

3.4. Applications in electronics

In recent years, there has been a surge in interest in the development of printed electronics, owing to its advantages over traditional silicon techniques, as well as the potential for low-cost, large-area electronics for flexible displays & sensors. Printed electronics using diverse operational inks containing NP, such as metallic NP, organic electronic molecules, CNTs, and ceramics NP, are expected to become a mass production process for new types of electronic equipment quickly (Kosmala et al., 2011).

One-dimensional semiconductors and metals have unique structural, optical, and electrical properties, making them a key structural component in a new generation of electronic, sensor, and photonic materials (Holzinger et al., 2014; Millstone et al., 2010; Shaalan et al., 2016).

The good example of the synergism between scientific discovery and technological development is the electronic industry, where discoveries of new semiconducting materials resulted in the revolution from vacuumed tubes to diodes and transistors, and eventually to miniature chips (Cushing et al., 2004).

The important characteristics of NP are facile manipula-tion and reversible assembly which allow for the possibility of incorporation of NP in electric, electronic or optical devices such as ‘‘bottom up” or ‘‘self-assembly” approaches are the bench mark of nanotechnology (O’Brien et al., 2001).

3.5. Applications In Energy Harvesting

Due to their nonrenewable nature, recent studies have warned us about the limitations and scarcity of fossil fuels in the coming years. As a result, scientists are refocusing their research efforts to develop low-cost renewable energy sources from readily available resources. Because of their large surface area, optical behaviour, and catalytic nature, they discovered that NP are the best candidate for this purpose.NPs are widely used in photocatalytic applications to produce energy from photoelectrochemical (PEC) and electrochemical water splitting (Avasare et al., 2015; Mueller and Nowack, 2008; Ning et al., 2016). Advanced energy generation options included solar cells and piezoelectric generators, in addition to water splitting and electrochemical CO2 reduction to fuel precursors (Fang et al., 2013; Gawande et al., 2016; Lei et al., 2015; Li et al., 2016; Nagarajan et al., 2014; Sagadevan, 2015; Young et al., 2012; Zhou et al., 2016).NP also use in energy storage applications to reserve the energy into different forms at nanoscale level (Greeley and Markovic, 2012; Liu et al., 2015a, 2015b; Sagadevan, 2015; Wang and Su, 2014). Recently, nanogenerators are created, which can convert the mechanical energy into electricity using piezoelectric, which is an unconventional approach to generate energy (Wang et al., 2015). Fig. 13 shows some energy generating devices, and uses NP.

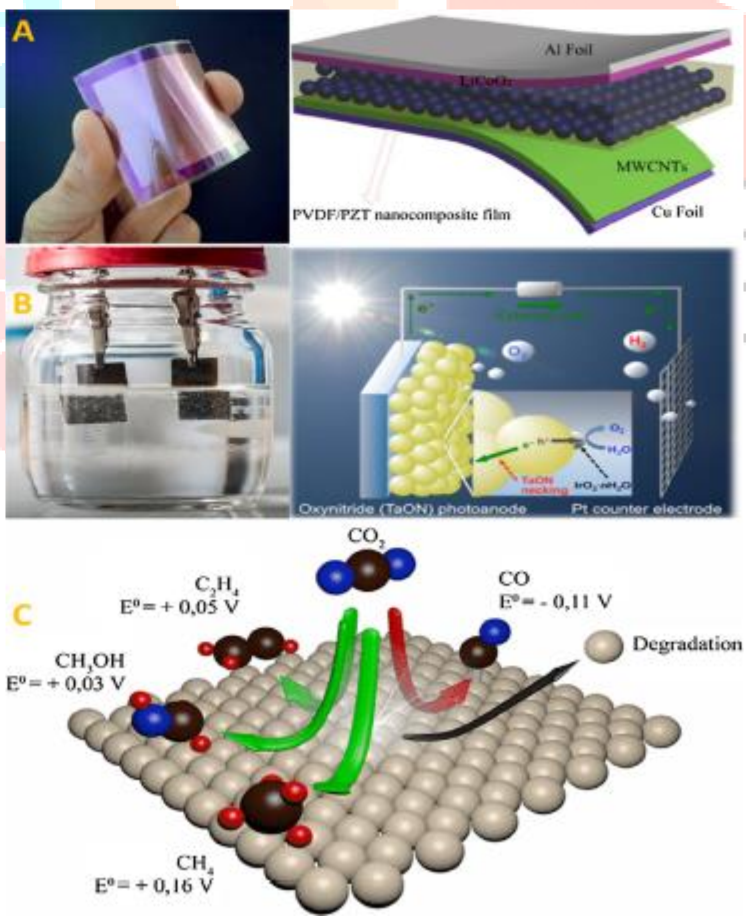


Figure Energy generation approaches from (A) Piezoelectrics actuators (B) Water splitting (C) CO2 reduction.

3.6. Applications in Mechanical Industries

As revealed from their mechanical properties through excellent young modulus, stress and strain properties, NP can offer many applications in mechanical industries especially in coating, lubricants and adhesive applications. Besides, this property can be useful to achieve mechanically stronger nanodevices for various purposes. Tribological properties can be controlled at nanoscale level by embedding NP in the metal and polymer matrix to increase their mechanical strengths. It is because, the rolling mode of NP in the lubri-cated contact area could provide very low friction and wear. Furthermore, NP has good sliding and delamination properties, which may reduce friction and wear while also increasing lubrication effect (Guo et al., 2014). Coating increases toughness and wear resistance, resulting in a wide range of mechanically strong properties. Coatings made of alumina, titania, and carbon-based NP have all achieved the desired mechanical properties (Kot et al., 2016; Mallakpour and Sirous, 2015; Shao et al., 2012).

4. Conclusion

We presented a detailed overview of NP, their types, synthesis, and applications in this NP review. It was discovered that NPs range in size from a few nanometers to 500 nanometers using various characterization techniques such as SEM, TEM, and XRD. The morphology, on the other hand, can be controlled. Because of their small size, NPs have a large surface area, making them a good candidate for a variety of applications. Furthermore, optical properties dominate at that size, emphasising the importance of these materials in photocatalytic applications. Synthetic techniques can be used to control the morphology, size, and magnetic properties of NP. Though NP are useful for a wide range of applications, their unchecked use and discharge into the natural surroundings pose some health risks, which should be considered in order to make NP use more useful and environmentally friendly.

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