

Reading Project Report
NANOMATERIALS: A QUANTUM PHENOMENON

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I. WHAT ARE NANOMATERIALS?

Nanomaterials are basically the materials having single small unit sized between 1 to 100 nm. The properties of nanometric materials are different from the properties of their bulk materials and their atoms. Nanomaterials can either occur naturally or be created as by-products of combustion reaction or maybe as produced through performing a specialised engineering function. Due to their ability to target the specific regions and their small size, they are widely used in healthcare and cosmetics industries. But, the use of nanomaterials is not only limited to healthcare and medicine industries, they have become a prominent part of most of the industries these days. For example:

- The sports industry has been producing baseball bats that have been made with carbon nanotubes, making the bats lighter therefore improving their performance.[1]
- In military, the use of mobile pigment nanoparticles being used to produce a better form of camouflage, through injection of the particles into the material of soldiers' uniforms[1]

II. DIMENSION-BASED CLASSIFICATION

Nanomaterials can be classified into various categories on basis of chemical constituents, dimension, morphology, uniformity and agglomeration. As far as dimension of nanoscale is concerned, they are classified into zero, one, two and three dimensional nanomaterials.

- In zero dimensional (0-D), nanomaterials that be measured within the nanoscale range (not more than 100 nm) are considered. Examples include: nanoparticles, nanopowders and quantum dots.
- In one dimensional (1-D), any one of the dimension will be in nanoscale range while the remaining two dimensions falls out of nanoscale range. Examples include: nanorodes, nanotubes or nanowires.
- In two dimensional (2-D), any two of the dimension will be in nanoscale range while the remaining one dimension falls out of nanoscale range. Examples include: nanofilms, nanolayers and naocoatings.
- In three dimension (3-D), all the three dimensions fall out of nanoscale range and hence they are greater than the nanoscale range. Examples include: nanocomposites, bundle of nanowires, bundles of nanotubes etc.

III. CONSEQUENCES OF SMALL SIZE OF NANOPARTICLES

Earlier the bulk materials were characterized by the properties such as composition, solubility, boiling point, pH and other properties. But as the decrease in size is observed, the criteria for characterization of nanoparticles also changes. They are then characterized by surface area, melting point and shape of interacting surface. Here are some examples demonstrating the elementary consequences of the same:

A. Surface of Nanoparticles

The first and the most important consequence of the small size is its huge surface area. So assuming the spherical particles the surface "a" with diameter x is

$$a = \pi r^2 \quad (1)$$

so the volume becomes

$$V = \frac{x^3 \pi}{6} \quad (2)$$

Hence the surface by volume ratio becomes:

$$\frac{a}{v} = \frac{6}{x} \quad (3)$$

This ratio is inversely proportional to the particle size and, as a consequence, the surface increases with decreasing particle size.

Therefore, materials made of nanoparticles have a much greater surface area per unit volume ratio compared with the materials made up of bigger particles. This leads to nanoparticles being more chemically reactive. As chemical reactions occur between particles that are on the surface, a given mass of nanomaterial will be much more reactive than the same mass of material made up of large particles. This means that materials that are inert in their bulk form are reactive when produced in their nanoparticle form.

B. Thermal Phenomenon

Let us assume a property of the particle that depends on volume of the particle; the energy of particle maybe $u(v)$, provided that volume is sufficiently small such that the condition

$$u(v) < kT \quad (4)$$

is fulfilled, one may expect thermal instability. In a more generalized manner, thermal instabilities leading to fluctuations may be characterized graphically as shown in Figure 1, provided that the thermal energy kT is greater than E_1 and E_2 , the system fluctuates between both energetically possible states 1 and 2.

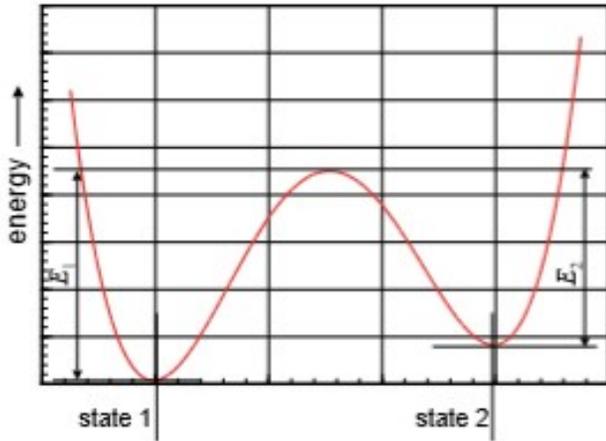


FIG. 1. Graphical representation of Energy Barrier. [2]

C. Diffusion Scaling Law

Fick gave two laws of diffusion:

- The first law states that the flux goes from regions of high concentration to regions of low concentration, with a magnitude that is proportional to the concentration gradient.
- The second law predicts how diffusion causes the concentration to change with respect to time. It is a partial differential equation which in one dimension reads:

$$\frac{\partial^2 \gamma}{\partial t^2} = D \frac{\partial^2 \gamma}{\partial x^2} \quad (5)$$

The solution of these two laws imply that mean square diffusion path of the atoms is proportional to Dt , where D is the diffusion coefficient and t is the time:

$$\langle x^2 \rangle \propto Dt \quad (6)$$

Conventionally, materials usually have around $10 \mu\text{m}$ grain size and at higher temperatures these materials require homogenization of order of many hours. When we consider nanomaterials having grain size of around 10 nm , then according to the Eq. (6) the homogenization time is reduced to one of the millisecond and hence the homogenization occurs instantly.

The possibility of near-instant diffusion through nanoparticles has been exploited technically, the most important example being the gas sensor [2]. It is based on the principle that changes in electric conductivity are result of the changes in the stoichiometry of oxides, variations of which are often observed for transition metals.

The figure 2 shows the comparison between response of gas sensor made up of the conventional

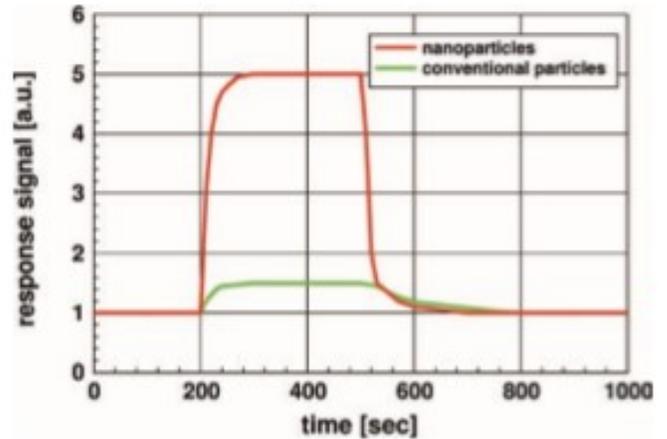


FIG. 2. Comparison between conventional gas sensor and nanoparticle gas sensor. [2]

materials and the newer technology, that is the nanomaterials. In a sensor using nanoparticles (see Figure 2) the time constant depends primarily on the diffusion of the gas molecules in the open-pore network and through the conducting cover layer [1]. Clearly, the gas sensor made of the nanoparticles is faster and also signals better.

IV. MAGNETIC PROPERTIES OF NANOMATERIALS

In response to how materials response to external magnetic properties, they are classified into diamagnetic, paramagnetic or ferromagnetic.

The origin of **diamagnetism** is found in the orbital motion of electrons of the atoms acting like tiny electric current loops, producing magnetic fields. In an external magnetic field, these current loops align in a way so as to oppose the applied field and, therefore, diamagnetic materials are exposed to a force pushing them out of the magnetic field. [2]

Paramagnetism is considered to be stronger than diamagnetism in most of the cases and it produces the magnetization in the direction of applied field. The atoms of such materials act as a tiny magnetic dipoles which can be oriented by external magnetic field.

In **ferromagnetic** materials, the dipoles, represented by the unpaired electron spins of an atom, are interacting. This leads to a long-range ordering phenomenon causing the dipoles to line up parallel [2]. The maximum temperature at which the ferromagnetic property exists is called the Curie temperature.

In case of substances like MnO , FeO and $\alpha - \text{Fe}_2\text{O}_3$ equal number of spins are arranged in antiparallel orientations, thereby cancelling out the magnetic moment. Such substances are known as **antiferromagnetic** materials.

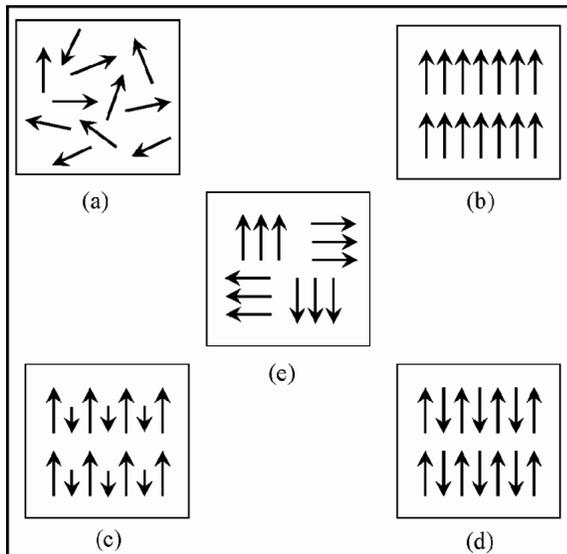


FIG. 3. (a) Paramagnetic materials, (b) Ferromagnetic materials, (c) Ferrimagnetic, (d) Antiferromagnetic, and (e) Superparamagnetic materials.

Whereas in case of substances like $MnFe_2O_4 = MnO.Fe_2O_3$ magnetic moments of the two magnetic sublattices are not equal hence a magnetic net moment is observed. These substances are termed as **ferrimagnetic** materials.

The domain structure of a ferromagnetic material determines the size dependence of its magnetic behavior. When the size of a ferromagnetic material is reduced below a critical value, it becomes a single domain. Size effect based on the magnetic domain structure of ferromagnetic materials results in fine particle magnetism. It assumes that the state of lowest free energy of ferromagnetic particles has uniform magnetization for particles smaller than a certain critical size and has nonuniform magnetization for larger particles [3]. The reaction of ferromagnetic materials on an applied field is characterized by a hysteresis loop, which is effected by two main parameters: remanence and coercivity. As the particle size reduces, the coercivity increases to a maximum value and then decreases towards zero.

V. OPTICAL PROPERTIES OF NANOPARTICLES

Due to small size of nanoparticles, they exhibit significant difference from properties of bulk materials. A wide range of optical effects can be generated by controlling the size, shape of different nanoparticles. Here are some of the optical properties being discussed below:

A. Scattering, Absorption and Extinction

When light falls on nanoparticle, it can be either absorbed or scattered and the sum of scattered and absorbed is called extinction. Nanoparticles are of size where only fraction of light that is scattered or absorbed can vary greatly depending on the diameter of the particle size. For the sizes around or less than 20 nm the major factor contributing in extinction is due to absorption, whereas at the diameter size of 100 nm scattering plays a major role. By varying the size of the nanoparticle, the optimal amount of scattering and absorption can be achieved. Due to this relationship between size and light absorption/scattering, it can be concluded that the aggregation can significantly increase the size thereby resulting in scattering of light. This is why 20 nm diameter silica particles are clear in solution but re-suspensions of dried 20 nm silica particles (aggregated) will be a milky white color.[4]

B. Plasmonic Nanomaterials

Nanoscale structures made of gold, silver and aluminum exhibit surface plasmon modes where the free electrons in the material resonate naturally at a frequency depending on the composition, size and shape of the particle. When the wavelength of incident light matches the oscillation frequency, the particles can strongly absorb or scatter the light resulting in a strongly colored particle [4]. By varying the size and shape, the peak resonance wavelength is shifted across the visible and into the infrared region of the spectrum. This allows a wide range of color tunability. Recently, not only metal nanoparticles but also when metal oxide nanoparticles are doped with other metal atoms, they show strong and tunable plasmon resonances. By changing the particle size, dopant and dopant concentration, plasmon resonances in the near-infrared (NIR) and short-wavelength infrared (SWIR) have been fabricated[4].

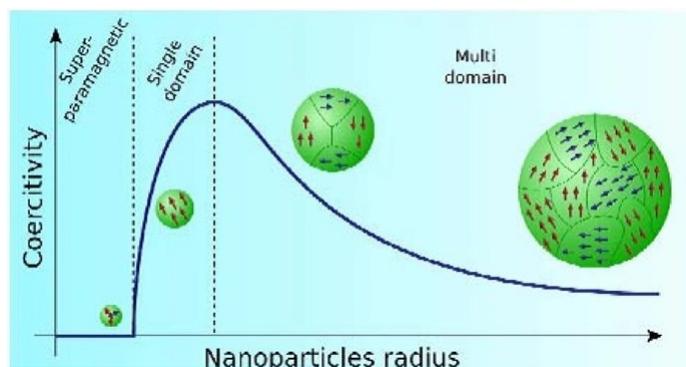


FIG. 4. Illustration of coercivity-size relations of nanoparticles. [3]

C. Quantum Dots

Quantum dots (QD) are nanoparticles made of semiconductor materials that can absorb and emit light at certain wavelengths depending strongly on particle size and shape due to quantum confinement effects. The emission wavelengths of quantum dots can be tuned by changing the size and composition from the UV through the visible to the near infrared regions of the spectrum. For example, by tuning the size of CdSe QDs from 2 nm to 8 nm in diameter, the emission wavelength can be shifted across the visible spectrum, with the smaller particles emitting in the blue and the larger particles emitting red light.[4]

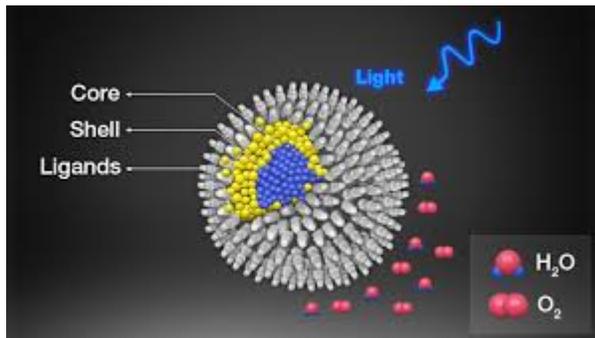


FIG. 5. Illustration of Quantum Dot.

1. Advantages over organic fluorescent dyes

- Easily tune optical properties by varying particle size.
- Less prone to photobleaching under high intensity illumination.
- Comparable or larger quantum yields than organic dyes.
- Can be excited much further away from their emission peak hence giving large effective Stokes shift.
- Allows more flexibility with imaging or choosing excitation sources.

D. Photonic Crystals

When nanoparticles are organized into ordered structures, with structural elements similar in size to the wavelength of light, they can selectively reflect certain portions of the spectrum, producing films with optical responses that can be tuned by selecting the size of the component particles. Such structures are called **Photonic Crystals**.

For example, the blue appearance of a morpho butterfly wing is due to nanoscale periodic structures that reflect only blue wavelengths of light. Structural color assemblies can also be created dynamically in solution using magnetically-responsive particles, such as the particles shown below which align into ordered structures in the presence of a magnetic field [4].

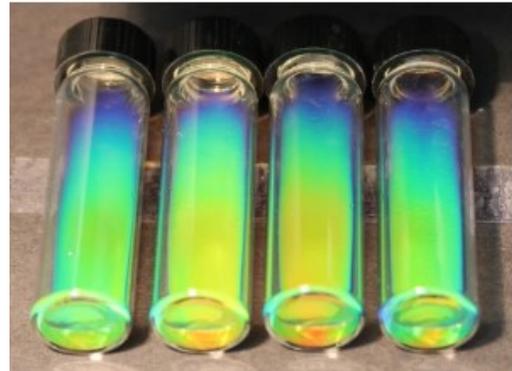


FIG. 6. Particles in ordered structures in presence of magnetic field. [4]

VI. SYNTHESIS OF NANOPARTICLES

There are various types of techniques that can be used to synthesize the nanoparticles. There are two main approaches that are followed basically for the synthesis of the nanoparticles. These are described as under:

- **TOP DOWN APPROACH:** In this approach a larger metal is leached out systematically bit after bit which leads to the generation of fine nanoparticles. Several methods fall under this approach such as photolithography, electron beam lithography, milling techniques, anodization, and ion and plasma etching.
- **BOTTOM DOWN APPROACH:** Here, the atoms and molecules are assembled together to form a wide range of nanoparticles. Examples of the bottom-up approach include self-assembly of monomer/polymer molecules, chemical or electrochemical nanostructural precipitation, sol-gel processing, laser pyrolysis, chemical vapor deposition (CVD), plasma or flame spraying synthesis, and bio-assisted synthesis [5]

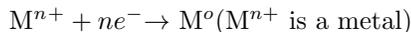
Below we will discuss the different processes to synthesize:

A. Co-precipitation

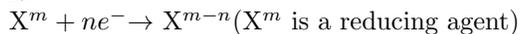
Co-precipitation is a process which involves the occurrence of nucleation, growth, agglomeration process and coarsening. It requires the aqueous medium for precipitation [6]. In a nutshell, this process involves mixing of two or more divalent and trivalent metal ions generally in which mostly the trivalent ions are soluble salts. Even though the nanoparticles formed by this method are uniform in nature but they show less particle nature. Hence, to boost up the crystallinity. To make the alkaline nature of the solution, common reducing agents like ammonia solution, sodium hydroxide are added. The water soluble trivalent metal ions to form insoluble metal ions which gets precipitated. By filtering or centrifuging, the solvent is separated and further purified and dried. The products under going co-precipitation are generally insoluble species formed under high supersaturation.

The nucleation process which is the occurrence of smallest particle of new thermodynamic phase and the growth process in which the larger particles consume the smaller particles to reduce the surface energy are considered to be the main steps of the co-precipitation method. Ostwald ripening and aggregation which are the secondary processes, affect the properties of the products like size and morphology. If coarsening and agglomeration of particles is not controlled, they may continue to grow beyond the nanorange. Some capping or stabilizing agents are helpful to cease the growth of nanomaterials. The capping agents bind to the nanoparticle surface through chemisorption of charged species and produce the electrostatic (vander Waals) repulsion on its surface. If the repulsive forces are strong then the stable nanoparticles will form or else the coagulation will occur [6].

The reaction is as follows:



The oxidation reaction which takes place simultaneously is:



The reactants taken here are in aqueous form, but the end product so formed is in solid phase.

B. Laser Ablation

It is the process by which material with the help of laser beam is removed from the solid surface. At low laser flux, the material is heated by the absorbed laser energy and evaporates whereas at high laser flux, the material is converted to plasma. In this method, a laser beam is irradiated to vaporize a graphite target held in a controlled environment oven having the temperature approximately 1200C. The condensed material is then collected on a cool target (water cooled Cu collector) and is found to have a significant amount of nanotubes and nanoparticles. In improved laser ablation method, cobalt and nickel catalyst were used either to dope the graphite targets or to coat the silica plate in order to align the

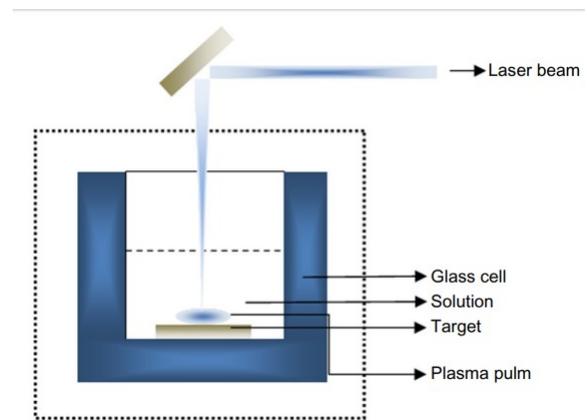


FIG. 7. Preparation of nanoparticles by laser in solution.[7]

growth of the carbon nanotubes. [7]

C. Hydrothermal Method

Hydrothermal synthesis refers to the synthesis by chemical reactions of substances in a sealed heated solution above the ambient temperature and pressure [8]. The main advantage of this method is that the good quality crystals are obtained with controlled composition. In this method, the divalent and trivalent transition metal salts are mixed in 1:2 mol ratios and the organic solvent is mixed with constant stirring to get the homogenous mixture. Then the solution is brought into the sealed vessel which is known as autoclave and on further heating the solution, the autogenous increase of pressure takes place raises the solvents above their boiling points. It is considered to be the preferred method for preparing least size nanoparticles which are mostly used in biological field.

D. Sol-Gel Method

Sol-gel is a method for producing solid materials from small molecules. In this method, the raw materials are uniformly mixed in the liquid phase. Then, to form a stable and transparent sol system, hydrolysis and polycondensation reactions are carried out. Due to polycondensation, the liquid phase was changed into the gel phase by the removal of the water molecules in the solution and it also increases the viscosity of the solution [6]. After various processes, such as drying and sintering, materials with microstructures and even nanostructures can be prepared. Even though it is the simplest method of synthesizing the nanoparticles, the purity of crystals so obtained is less due to formation of composites in it. Hence, we require post treatment for its purity.

E. Inert Gas Condensation

The inert gas condensation is the most common method for synthesis of metal nanoparticles. In this method, metals are evaporated in an ultrahigh vacuum chamber filled with helium or argon gas at very high pressure. The evaporated metal atoms lose their kinetic energy by collisions with the gas, and condense into small particles. These particles then grow by Brownian coagulation and coalescence and finally form nanocrystals [8]. The Clusters are formed in the vicinity of the source in gas phase by homogenous nucleation and then they grow by coalescence and incorporation of atoms. The size of the particle or cluster depends on the residence time of the particles in the growth regime and the size can be influenced by the gas pressure, the kind of inert gas (He, Ar, or Kr) and evaporation rate/vapor pressure of the evaporating material. If the gas pressure, vapor pressure, and mass of the inert gas is increased, the average particle size of the nanoparticles increases. For the collection of particles, we use a rotating cylindrical device cooled with liquid. The nanoparticles which are extracted from it are in the size range from 2 to 50 nm. They get deposited on the surface of the collection device as a powder of low density and no agglomeration. Subsequently, we remove the crystals with the help of scrapper. This method can only be used in a system designed for gas flow, that is, a dynamic vacuum is generated by means of both continuous pumping and gas inlet via a mass flow controller [8].

F. Sputtering

Sputtering is a process in which the metal surface is bombarded with energetic particles which results in ejection of atoms from the material surface. When the plasma ions strike the material target, their electrical charge is neutralized and they return to the process as atoms. The neutralization process results in a positive charge on the target surface if the surface is an insulator [8]. This charge may reach a level at which bombarding ions are repelled and the sputtering process stops and the polarity must be reversed to attract enough electrons from the plasma to eliminate surface charge and continue the process. When radio-frequency (RF) is applied, a periodic reversal of polarity takes place automatically. Thus, this type of sputtering is known as "RF sputtering."

G. Biological Synthesis

Biological synthesis of nanoparticles is a green chemistry approach interconnecting nanotechnology and biotechnology. The biological nanoparticles are not monodispersed and the rate of synthesis is slow. The

concentration of synthesized macromolecules or components involved in the nucleation of particles varies with time and prolongs the nucleation period, which causes the polydispersity of nanoparticles and subsequent decreased rate of synthesis [8]. Microbial cultivation methods and the extraction techniques need to be optimized so as to overcome this problem.

VII. CHARACTERIZATION OF NANOPARTICLES

The nanoparticles exhibit different physicochemical properties. To examine their properties characterization of nanoparticles wants to be done with different instruments. They are UV Spectrophotometer, Fourier Transform Infrared (FT-IR) Spectroscopy, Atomic Force Microscopy (AFM), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Vibrating Sample Magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), Energy Dispersive X-ray Spectroscopy (EDS), X-ray Photoelectron Spectroscopy (XPS).

A. Transmission Electron Microscopy (TEM)

Transmission electron microscopy (TEM) is a high magnification measurement technique that images the transmission of a beam of electrons through a sample. TEM imaging has significantly higher resolution than light-based imaging techniques because instead of using light based imaging techniques it uses electrons to illuminate the sample. Materials with electron densities that are significantly higher than amorphous carbon are easily imaged [5]. The main advantage of using TEM is that it can determine the morphology, crystal structure, and size and the qualitative and quantitative analysis of the prepared nanoparticles. Despite having this advantage, the main limitation of TEM is that only limited areas samples >300 nm thick are screened. Also low magnification is achieved for particle size >100 nm.

B. Spectroscopic Analysis (UV-Visible Spectroscopy)

With the help of UV/Visible spectroscopy the light that is absorbed and scattered by a sample can be identified. In this, a sample is placed between a light source and a photodetector, and the intensity of a beam of UV/visible light is measured before and after passing through the sample. and then they are compared at each wavelength to quantify the sample's wavelength dependent extinction spectrum. The data so collected is then plotted as extinction (sum of absorbed and scattered light) as a function of wavelength. To ensure that

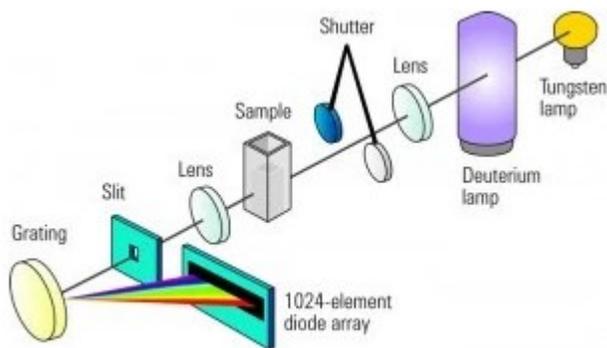


FIG. 8. Set-Up of UV Visible Spectroscopy. [9]

the spectral features from buffer are not included in sample spectrum, each spectrum is background corrected. Since gold and silver plasmonic nanoparticles have optical properties that are sensitive to size, shape, concentration, agglomeration state, and refractive index near the nanoparticle surface, this makes UV/Vis spectroscopy a valuable tool for identifying, characterizing, and studying nanomaterials [9]. Even though, non-plasmonic nanoparticles also have size and concentration dependent optical properties, but their spectrum is not as sensitive to the dispersion properties as plasmonic nanoparticles.

C. Atomic Absorption Spectroscopy (AAS)

Atomic absorption spectroscopy (AAS) is a method which is used to determine the mass concentration of an element in a liquid or solid sample. It is based on the principle of atomic absorption where ground state electrons of the atoms due to absorption of light of a specific wavelength are elevated to an excited state. Since the amount of energy absorbed is directly proportional to the number of atoms in the light path, the sample mass concentration can be quantified by comparing the signal to calibration standards at known concentrations. To measure the concentration of nanoparticles to 0.1 parts per million (ppm), generally Flame Atomic Absorption Spectrum (FAAS) is used. For this, the sample is atomized and then aerosol is introduced into an air-acetylene or nitrous-acetylene flame. The light source is aligned to pass through the flame where the particle is vaporized. A monochromator isolates the specific wavelength for the element of interest, and a detector measures the signal [9].

D. X-ray powder diffraction (XRD)

XRD is one of the best methods for characterization of the crystalline form of organic and inorganic materials. Using this, the cubic and crystalline nature and purity of the nanoparticles can be measured. XRD is nondestructive,

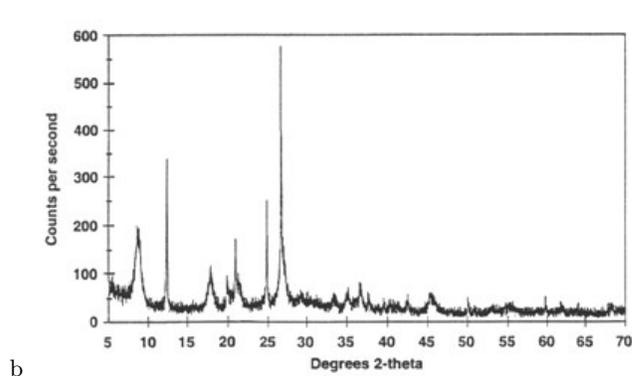


FIG. 9. X-ray powder diffractogram

and user friendly containing several application aspects such as pharmaceutical, glass, polymer, geological, and forensic. It has been used to analyze the chemical composition by quantitative and qualitative measurements by measuring the degree of crystallinity and providing accurate information on the atomic arrangements at interfaces [5]. The crystal structure describes the atomic arrangement, position, and intensity of the diffraction peaks. Therefore, it is mainly used for probing the structure of nanomaterials. A single beam of X-rays is scattered by each atom in the powder sample. The scattered beams reflected by any crystal form many diffraction patterns. The peak where the X-rays are scattered maximum at a particular angle reflects the structural and physicochemical characters of the crystal. Bragg's Law is the working principle of XRD.

E. Scanning Electron Microscopy (SEM)

SEM is a versatile, nondestructive analytical method involving a microscope with a large specimen chamber, with a working distance of 8.5 mm, owing to a combination of inclined detectors and the sharp conical objective lens. This instrument is used for surface and dimensional measurements of nano and micro structure analysis of samples. It is a type of imaging technique mainly used for the evaluation of material structure. The main advantage of this technique is that it is fast and easy to operate and provides reliable data. In addition, SEM is applied in numerous fields such as biological science, biomolecules, biomedical fields, and material sciences. In biomedical sciences, it is primarily used to characterize cells and organ and tissues surfaces based on 3D images [5]. It provides more information about the cell surfaces. The working principle of SEM is based on generation of electron beams having magnetic properties. Their magnetic field interacts with the sample producing secondary and backscattered electron used for detection. This detection of transmitted electrons is useful for study of nanomaterials.

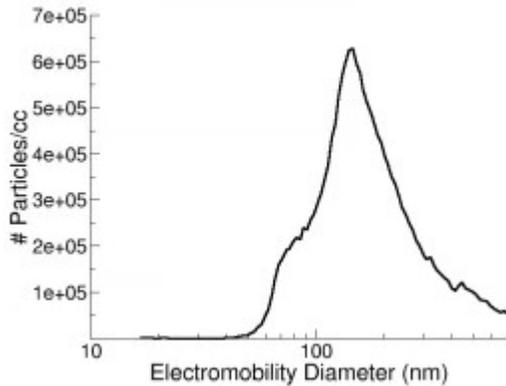


FIG. 10. The data collected from SMPS aerosol chamber. [9]

F. Scanning Mobility Particle Sizer (SMPS)

The majority of aerosol particle sizing instruments use light scattering to determine the size of the particle. When the particle size is below 500 nm, the particle scatters small amount of light making it difficult to detect. For more accurate measurement, a Scanning Mobility Particle Sizer (SMPS) is used. It consists of two complementary instruments: a Differential Mobility Analyzer (DMA) and Condensation Particle Counter (CPC) to measure the electromobility diameter of aerosolized nanoparticles. The DMA determines the particle size by measuring the electrical mobility of particles in response to high voltage electric field. Particles flow down a tube with a center electrode at high voltage and outer tube at ground [9]. Those particles with a particular electrical mobility to pass are allowed to pass through the small orifice. A very narrow range of particle diameters passes through the exit port by changing the voltages. Since these particles are too small to be accurately counted by light scattering, the particle size is increased by a CPC that condenses butanol on the surface [9]. After condensation, the particles are individually counted. After counting the number of particles at each voltage, a particle size distribution between 10 and 500 nm can be obtained.

VIII. APPLICATIONS OF NANOMATERIALS

Nanomaterials exhibit very attractive and useful properties, which can be used for a range of structural and non-structural applications. They can be applied in a host of applications including, but not limited to those listed below.

A. Diagnosis and Drug Delivery

Nanoparticles have high penetration character and show less disturbance to the normal healthy tissues, so the nanomaterials are used to protect the normal cells. In the targeted pharmaceuticals area the nanoparticles are used to treat the diseases especially the cancer tumors. For this application of releasing the drug at the targeted site through the blood circulation, the drug so released must be in the least size. Since the nanoparticles have the smaller radii hence they are used for this job. For drug delivering and targeting mainly gold, titanium, magnetic nanoparticles and quantum dots are used [5]. On combining these nanoparticles with polymers good and improved output will observe. Among all the nanoparticles the gold nanoparticles are the most efficient ones in drug targeting.

B. Nanoparticles as catalysts

By adding catalyst to a chemical reaction, the activation energy reduces, and binds to reagents to polarize the bonds and getting effective collisions by bringing the reactive species to approach each other closely resulting in higher yield of the product. Catalysts are useful in lowering the temperature of the reaction, by reducing the formation of side reactions also [5]. The least size of the nanoparticles enhances the surface area per unit mass. This provides the more surface area to the catalytic chemical reactions. This increases the reactivity in the case of nanocatalytic reactions than that of normal catalytic reactions composing of bulk materials. Nanocatalysts are basically type of quantum dots, carbon-based nanocatalysts, thin layer nano catalysts, core-shell nano catalysts, ceramic nanocatalysts.

C. Fuel Cell Application

The chemical energy is converted into electrical energy with the help of electrochemical cell. In a fuelcell, oxygen and hydrogen react and generate electricity without emitting the harmful carbon oxide. The different types of fuel cells are Proton Exchange Membrane Fuel Cell (PEMFC), Direct Methanol Fuel Cell (DMFC), Alkaline Fuel Cell (AFC), Phosphoric acid Fuel Cell (PAFC), molten carbonate fuel cells (MCFC), and solid oxide fuel cells (SOFC) [5]. Platinum (Pt) depended catalysts are expensive which is a main drawback for the fuel cells application. Researchers are still searching for a substitute of the Pt nanoparticles. Some of the platinum dependent catalysts are Pt-Mn, Pt-Fe, Pt-Ir, Pt-Co, Pt-Ru, Pt-Cu etc [5]. The other type of catalysts like transition metal oxides, iron-based catalysts carbon-based catalysts. The research is still continuing in this area.

D. In electronic devices

Since the nanoparticles have different magnetical, electrical, optical and chemical properties, the researchers are attracted towards it in finding various applications of nanoparticles. Due to their small size, they are widely using in electronic devices like memory devices, sensors, and biosensors, computer units, antenna cores, high-density storage, in recording media and transformer cores. For example, the ferrite nanoparticles with high Hs can be applicable in magnetic recording [5]. In transformers, lose Hs is preferable [5]. In recording media, such as audio and video tapes they must show high MS and HS and low residual magnetization. Magnetic fluids, data processing circuits, digital computers, digital recordings the nanoparticles are widely useful [5]. The magnetic ferrites show high magnetic permeability and electrical resistivity so they can be applicable in magnetic recording media, biomedical fields [5]. Cobalt ferrites show good magnetic and electrical properties [10]. By adding ferrites into the polymers their electronic and magnetic properties improved.

E. Longer-Lasting Satellites

Satellites are used for both civilian and defense applications. These satellites make use of thruster rockets to stay in or alter their orbits because of various factors, such as the impact of gravitational forces applied by the earth [10]. Hence, to reposition the satellites, thrusters are required. To a great extent, the life of these satellites is governed by the amount of fuel they can take on board. For repositioning, these thrusters waste over one-third of the fuel carried by the satellites, caused by partial and inefficient burning of the fuel, such as hydrazine. This in turn decreases the efficiency of satellites. The partial and

inefficient combustion occurs due to rapid wearing out of onboard ignitors that stop performing effectively as a result [10]. Nanomaterials like nanocrystalline tungsten-titanium diboride-copper composite improve the performance features and life of these ignitors, thereby making the life of these satellites more efficient.

IX. CONCLUSION

Day to day the synthesis of novel nanomaterials is increasing. The nanomaterials having mixed compositions are also being synthesized so that they can be used in different fields. The facile synthesis methods can produce the nanoparticles of desired size, shape and property. Nowadays wide research is being undertaken in the fields of biomedicine, electronic storage devices, and sensors since nanomaterials due to their small size have a huge scope for the development of research in these areas. Integration of nanomaterials, especially nanoparticles, could extend the construction of the theragnostic platform, which combines therapeutics with diagnostics, to make the diagnosis processes more simple and rapid and less invasive [7]. From the examples provided in the report, it is quite clear that nanocrystalline materials produced gel can be used in an extensive range of unique, new, and existing applications. It is also obvious that nanomaterials outclass their traditional counterparts by virtue of their excellent physical, chemical, and mechanical properties, and by their outstanding formability.

X. ACKNOWLEDGEMENT

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