University Mohamed Khaider – BISKRA

Faculty of Exact Sciences and Nature

Mater sciences departement (MS)

Academic 2nd year L2 /2023-2024

THÈME

Materials Science and Nanotechnology

Presented by:
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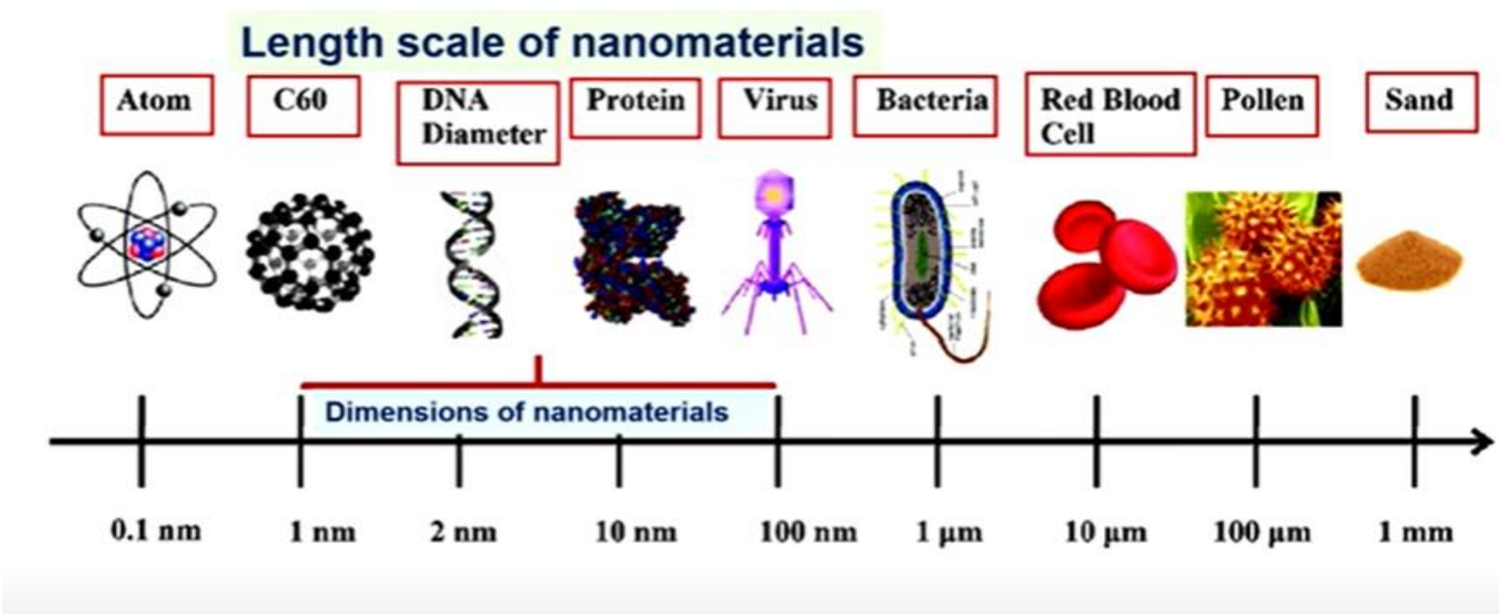
2023-2024

summary

1. Introduction to nanomaterials and nanotechnology
2. Physical chemical of solid surface
3. Types of nanomaterials
4. Synthetesis of nanomaterials methods
5. Properties and Characterization of nanomaterials
6. Applications of nanomaterials

Nano scale

Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. A nanometer is one-millionth of a millimeter - approximately 100,000 times smaller than the diameter of a human hair. Nanomaterials are of interest because, at this scale, unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for significant impacts in electronics, medicine, and other fields.



Nanomaterial:

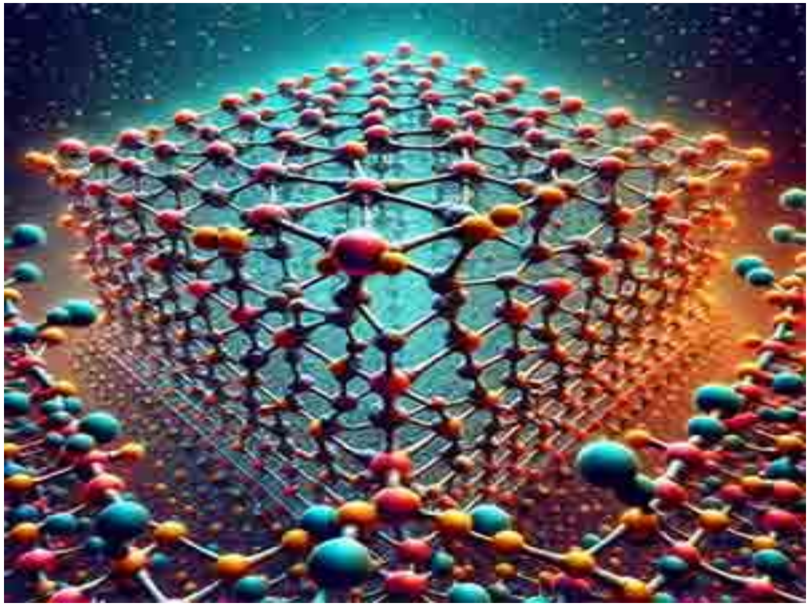
- Material with any external dimension in the nanoscale (1-100 nm) or having internal structure or surface structure in the nanoscale.
- Because of their unique size, the physical and chemical properties of nanomaterials differ from those of their large-scale counterparts.

Nanoscience is the "study" of the fundamental principles of nanomaterials (molecules and structures with at least one dimension between 1 and 100 nm). This includes the physical, chemical, and biological properties of Nano entities.

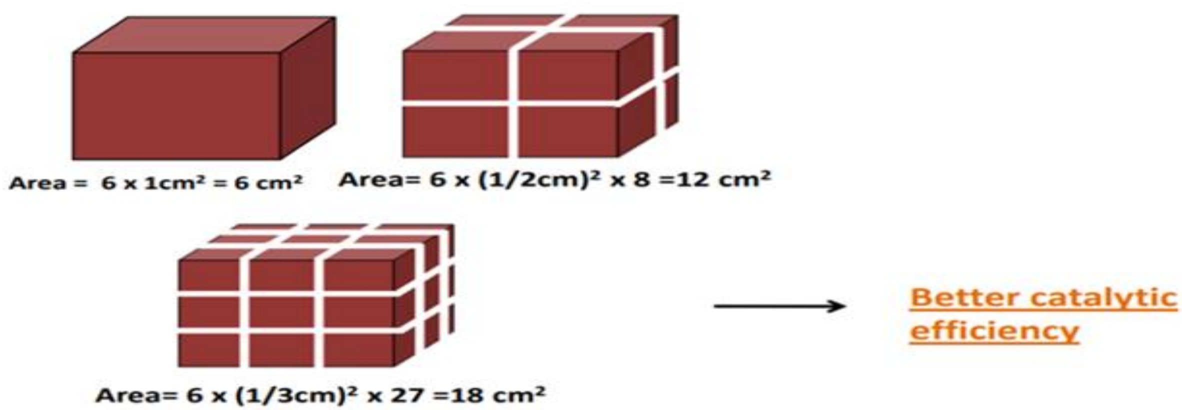
Nanotechnology refers to the fabrication and application of entities whose feature sizes range from less than 1 nm to 100 nm. These entities include films, coatings, dots, lines, wires, tubes, structures, and systems.

What are Nanostructures?

Nanostructures are structures with dimensions on the nanometer scale, typically ranging from 1 to 100 nanometers. They have unique physical, chemical, and electronic properties that differ from those of bulk materials. Nanostructures can be made from various materials, including metals, semiconductors, polymers, and biological materials. They are widely studied for their potential applications in electronics, energy, medicine, and materials science.



- Nanomaterials and nanostructures have a large proportion of surface atoms per unit volume.
- The ratio of surface atoms to interior atoms changes dramatically when a large object is divided into smaller parts.
- For example, in a 1 cm^3 cube of iron, the number of surface atoms is small, but when it is divided into 10 nm cubes, the proportion of surface atoms increases to 10%. In a 1 nm^3 cube, almost all the atoms will be surface.
- As the surface area increases, the total surface energy increases, leading to changes in the physical and chemical properties of the material.
- Table 1 shows how the surface energy varies with particle size in sodium chloride, with the total surface energy increasing as the particle size is reduced to the nanoscale.



The **total surface energy increases with the overall surface area**, which is in turn strongly dependent on the dimension of material.

Table 2.1. Variation of surface energy with particle size.[22]

Side (cm)	*Total surface area* (cm^2)	*Total edge* (cm)	*Surface energy* (J/g)	*Edge energy* (J/g)
0.77	3.6	9.3	7.2×10^{-5}	2.8×10^{-12}
0.1	28	550	5.6×10^{-4}	1.7×10^{-10}
0.01	280	5.5×10^{4}	5.6×10^{-3}	1.7×10^{-8}
0.001	2.8×10^{3}	5.5×10^{6}	5.6×10^{-2}	1.7×10^{-6}
10^{-4} (1 μm)	2.8×10^{4}	5.5×10^{8}	0.56	1.7×10^{-4}
10^{-7} (1 nm)	2.8×10^{7}	5.5×10^{14}	560	170

The specific surface area and total surface energy of a cube of 1 g of sodium chloride vary with particle size dividing it into smaller cubes.

Surface area and the surface energy **increase seven orders of magnitude**.

• Surface energy

A decrease in the energy accompanies the formation of bonds between two atoms in a solid. As the atoms on the surface have fewer bonds than the atoms in the bulk (Figure), the energy of the surface atoms is higher. The extra energy associated with the surface atoms is called surface energy.

A simple estimate of surface energy, γ=ΔG/A, can be made by multiplying the number of bonds broken per unit area, Nb by one-half of bond energy ε

$$\gamma = N_b\left(\frac{1}{2}\varepsilon\right)$$

$$= \frac{1}{2} n_a . n_b\, \varepsilon$$

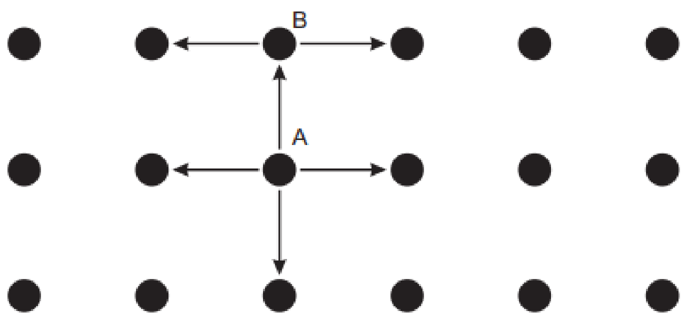


Fig. The atoms on the surface of a solid have fewer bonds as compared to the atoms inside the solid as illustrated for a two dimensional solid here. Thus the atom A has four bonds as compared to the atom B which has only three bonds.

Mechanisms to Reduce the Surface Energy at the Atomic Level

These methods affect individual atoms on the surface to make the material more stable:

A. Surface Relaxation

Surface atoms move inward to reduce unsaturated bonds and reduce surface energy.
This occurs more clearly in less rigid materials or at higher temperatures.

B. Surface Restructuring

Surface atoms rearrange themselves to form new chemical bonds that reduce the number of unsaturated bonds.

Example: In silicon crystals, atoms on the surface are rearranged to form a more stable structure.

C. Chemical and Physical Adsorption

Surface energy is reduced by molecules adsorbing to the surface via chemical bonds (chemisorption) or physical forces such as van der Waals (physisorption).

Example: Covering the surface of a diamond with hydrogen atoms or the surface of silicon with hydroxyl groups.

D. Surface Segregation

Impurities or other elements move to the surface, reducing its energy by reducing the number of unsaturated bonds.

Example: In metal alloys, less chemically active elements can be concentrated at the surface to reduce the surface energy.

Mechanisms to Reduce the Surface Energy at the System Level

These processes occur at the nanoscale level and include:

a. Sintering

- The process of combining small particles at high temperatures to reduce surface area and surface energy.
- Common in ceramic and metallic materials.

b. Ostwald Ripening

- This process occurs when small particles melt and deposit onto larger particles, reducing the overall surface energy.
- This process is used to uniform the particle size in nanomaterials.

c. Agglomeration

- Nanoparticles can aggregate to reduce the overall surface energy.
- This aggregation can be undesirable in some applications, so it is prevented using stabilization techniques.

Classification of nanomaterials

2.1. Classification based on the dimensions

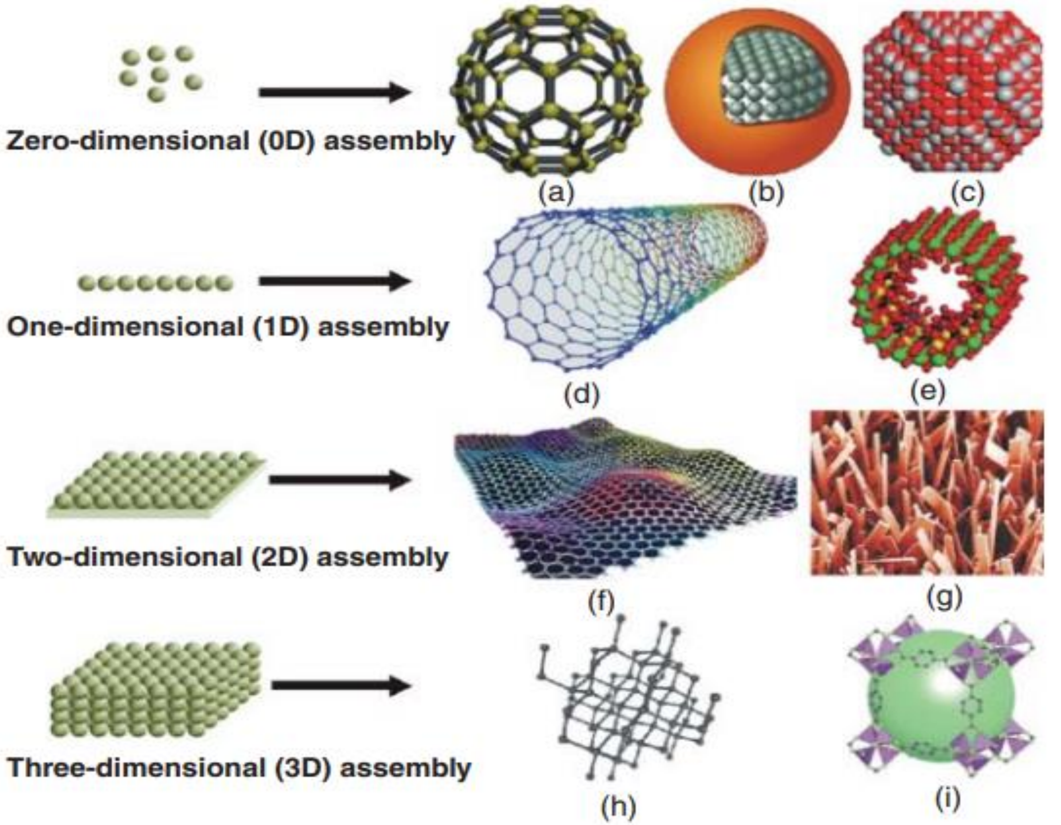
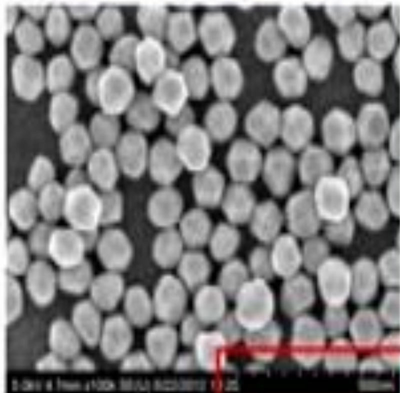


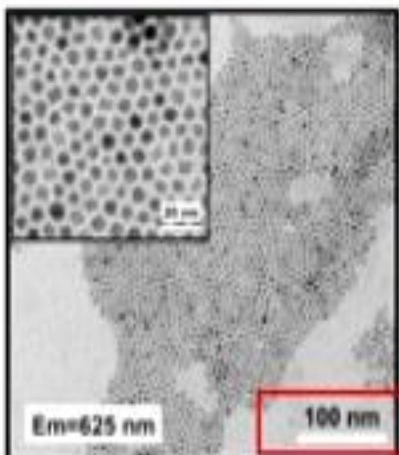
Figure 1.10 Typical examples showing varied dimensionality in nanomaterials: (a) fullerene; (b) quantum dot; (c) metal cluster; (d) carbon nanotube; (e) metal oxide nanotube; (f) graphene; (g) metal oxide nanobelts; (h) nanodiamond; (i) metal organic frameworks (MOFs).

Zero- dimensional (0D)

: (Nanoparticles, Nanodots)



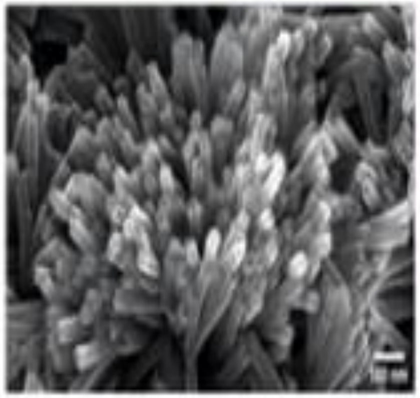
SEM of gold nanoparticles.
www.cytodiagnostic.com



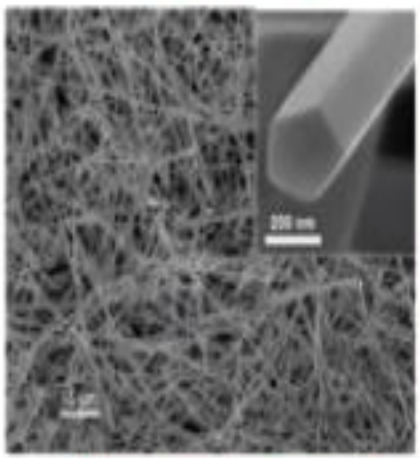
SEM images of CdSe/ZnS quantum dots
H. Zhang, Analytical Letters, 51(6), 921-934, 2017

One- dimensional (1D)

: (Nanotubes, Nanowires)



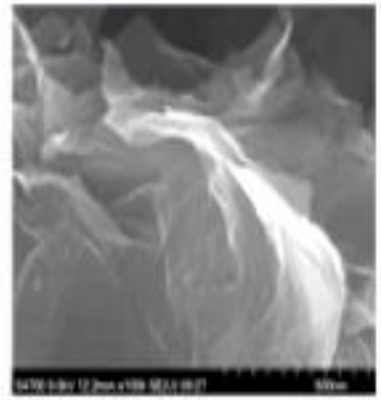
SEM of Polydiacetylene Nanotube
www.sigmaaldrich.com



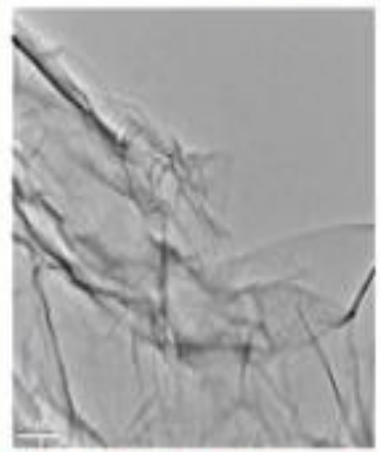
SEM image of silver nanowires
J. R. Gasga, et. al., Journal of Crystal Growth 286, 162-172, 2006

Two- dimensional (2D)

: (Nanofilms, Nanolayers)



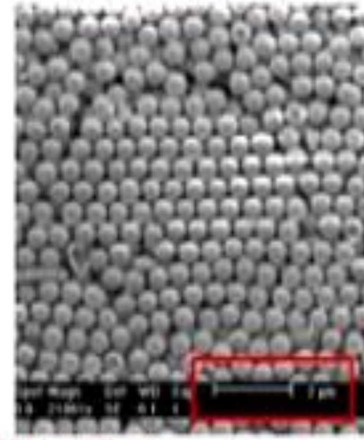
SEM for graphene oxide
International Nano Letters, 5, 187-190, 2015



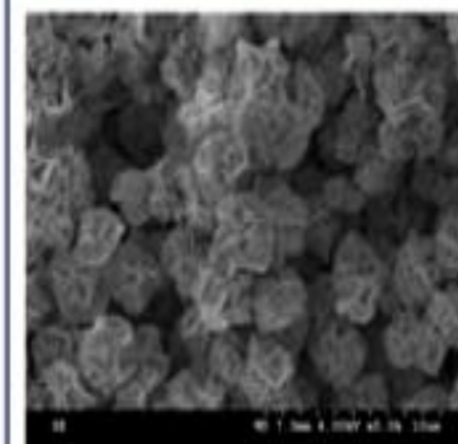
TEM of Single Layer Graphene
ACS Material-Graphene Factory, USA

Three- dimensional (3D)

: (Core-shell, Flowers)

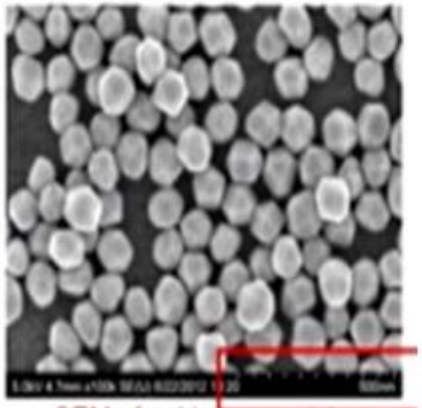


SEM of 3D silica- gold core-shell
D.A. Mazurenko, et al. Proc. of SPIE, 5450, 2015

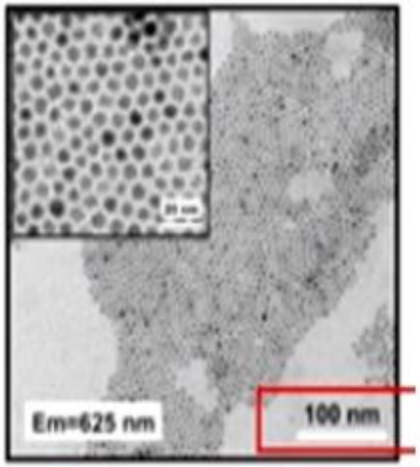


SEM of nano-flowers nanomaterial
M. B. Bazbouz, J. APPL. POLYM. SCI. 136 (10), 47153- 47167, 2019

a) Zero dimensional (0-D) (nanoparticles and nanodots): These nanomaterials have not any-dimensions. Metallic nanoparticles including gold and silver nanoparticles and semiconductor such as quantam dots are the perfect example of this kind of nanoparticles. Most of these nanoparticles are spherical in size and the diameter of these particles will be in the 2-10 nm range. Zero dimensional Nanoparticles can be amorphous or crystalline, single crystalline or polycrystalline, composed of single or multi-chemical elements, exhibit various shapes and forms, exist individually or incorporated in a matrix, be metallic, ceramic, or polymeric.

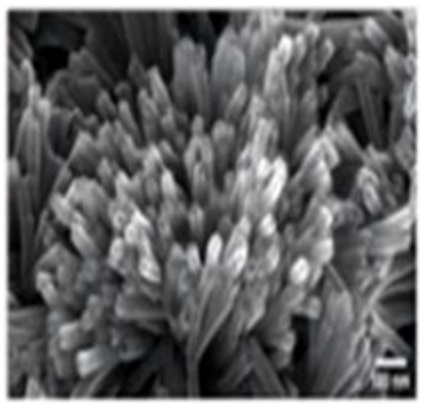


SEM of gold nanoparticles.
www.cytodiagnostic.com

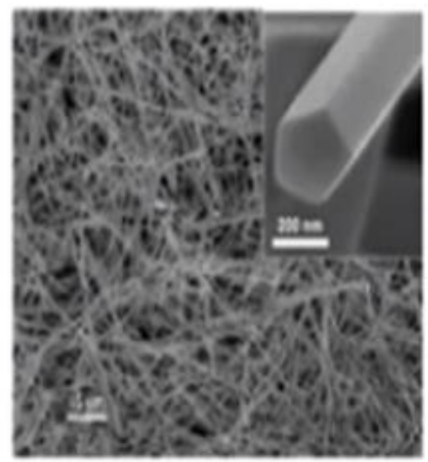


SEM images of CdSe/ZnS quantum dots
H. Zhang, Analytical Letters, 51(6), 921-934, 2017

b) One dimensional (1-D) (Nanotubes and nanowires): In these nanostructures, one dimension of the nanostructure will be outside the nanometer range. These include nanowires, nanorods, and nanotubes. These materials are long (several micrometer in length), but with diameter of only a few nanometer. Nanowire and nanotubes of metals, oxides and other materials are few examples of this kind of materials. One dimensional nanoparticles can be amorphous or crystalline, single crystalline or polycrystalline, chemically pure or impure, standalone materials or embedded in within another medium, metallic, ceramic, or polymeric

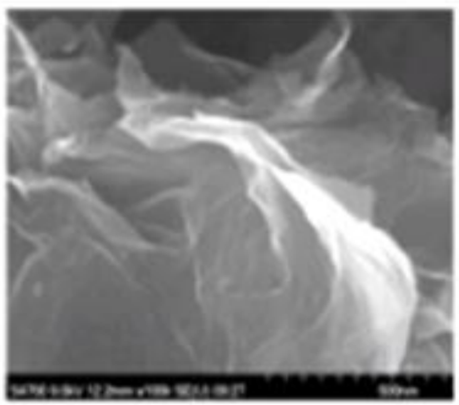


SEM of Polydiacetylene Nanotube
www.sigmaaldrich.com



SEM image of silver nanowires
J. R. Gasga, et. al., Journal of Crystal Growth 286, 162-172, 2006

c) Two dimensional (2-D) (nanofilms and nanolayers): In this type of nanomaterials, two dimensions are outside the nanometer range. These include different kind of nano films such as coatings and thinfilm-multilayers, nano sheets or nano-walls. The area of the nano films can be large (several square micrometer), but the thickness is always in nano scale range. Two dimensional nanoparticles can be amorphous or crystalline, made up of various chemical compositions, used as a single layer or as multilayer structures, deposited on a substrate, integrated in a surrounding matrix material, metallic, ceramic, or polymeric.



SEM for graphene oxide

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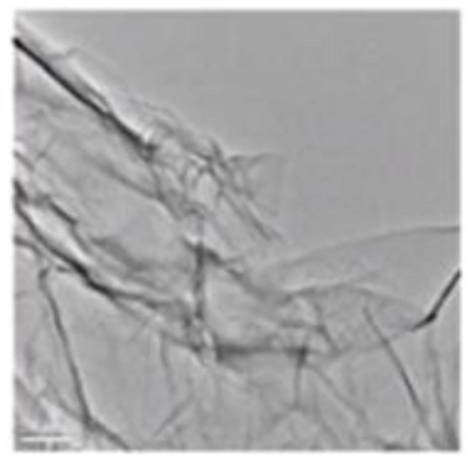
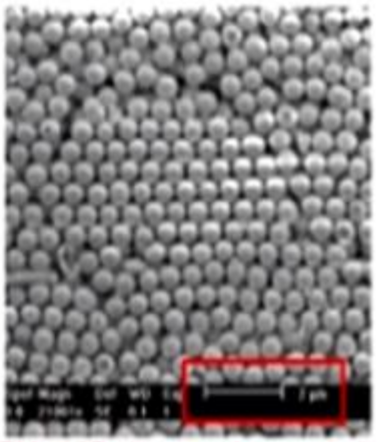


TEM of Single Layer Graphene

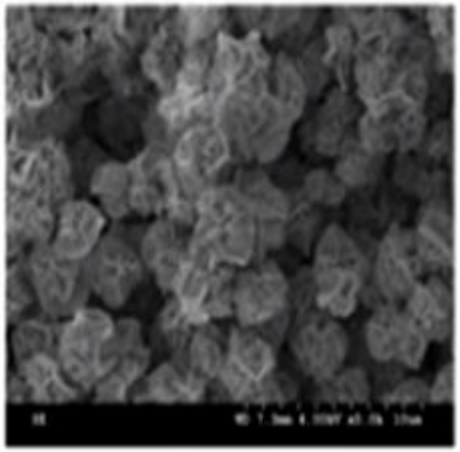
ACS Material-Graphene Factory, USA

d) Three Dimensional (3-D) (Core-shell and flowers): All dimensions of a three dimensional material are outside the nano meter range. These include bulk materials composed of the individual blocks which are in the nanometer scale (1-100 nm). Three dimensional nanoparticles can contain dispersions of nanoparticle, bundles of nanowires, and nanotubes as well as multinanolayers.



SEM of 3D silica- gold core–shell

D.A. Mazurenko, et al, Proc. of SPIE, 5450, 2015



SEM of nano-flowers nanomaterial

M. B. Bazbouz, J. APPL. POLYM . SCI. 136 (10), 47153- 47167 2019

2.2. Classification based on their nature

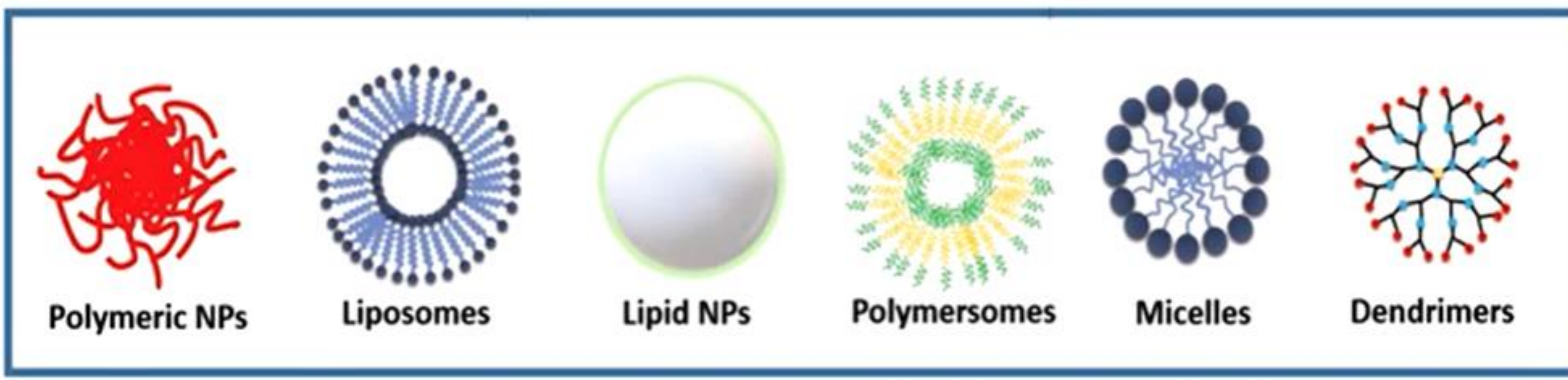
1- Organic

2- Inorganic (Metals, Metal Oxide, Metal Chalcogenides)

3- Carbon based(Organic) (CNTs, Graphene, Fullerenes)

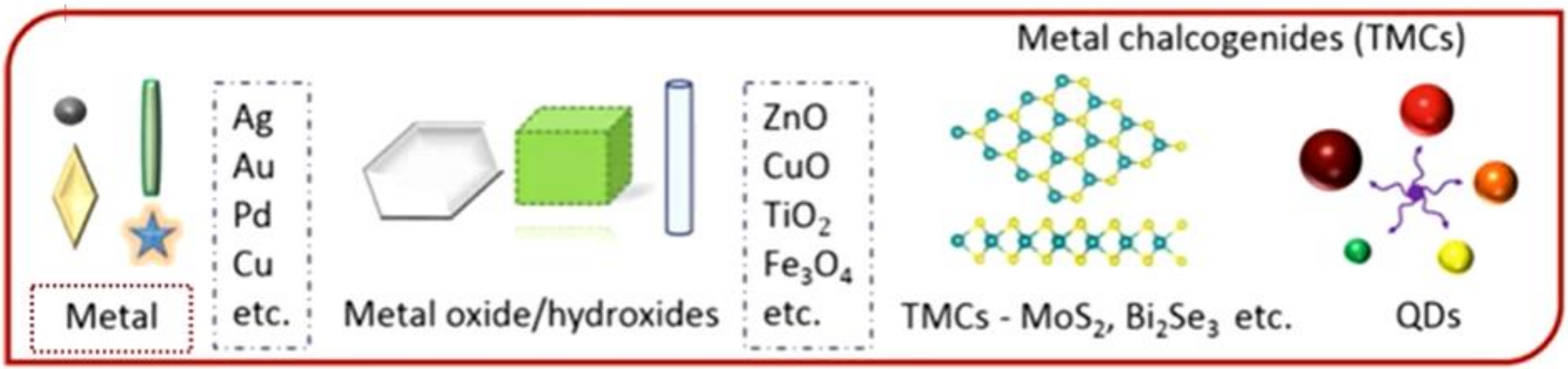
4- Nanocomposite (Metals-Metal oxide-Oxy acids)

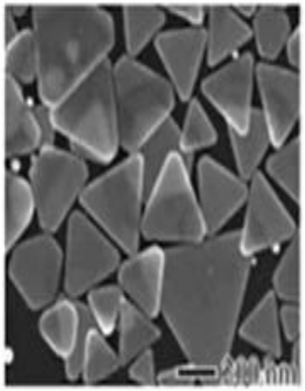
a) **Organic nanoparticles:** these nanomaterials are considered environmentally friendly as they biodegradable and non toxic. They are edeal for drug delivery applications due to their high stability, biocompatibility, surface morphology, drug carring capacity and delivery efficiency.



b) Inorganic nanmaterials: these nanomaterials are synthesized :

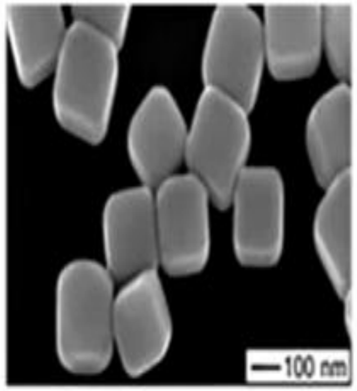
- metals also include Pt, Zn, Cu, Co, Al, Cd, Pb, Fe and Ni (Fe and Ni are highly reactive an explosive.
- Biometallic nanoparticles (e.g., Pt-Pb, Cu-Ni) which often exist as core-shell and alloy structures.
- Metal-oxide (ZnO, TiO2, CuO...) and hydroxide (α-Cu(OH)2, β6Ni(OH)2, ...





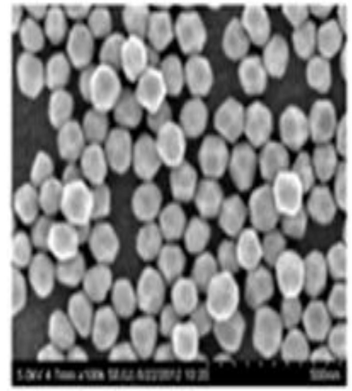
SEM of Ag nano-prisms

Y. Yang, et. al. Small 10, 1430–1437, 2014.



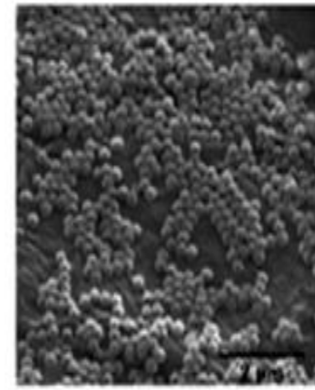
SEM of Ag nano-cubes

Y. Sun, et. al. Science, 298, 2176–2179, 2002.



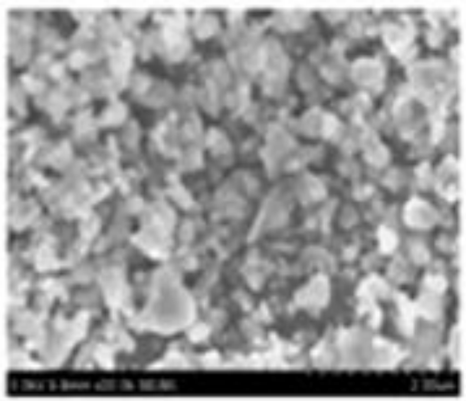
SEM of gold nanoparticles

www.cytodiagnostic.com



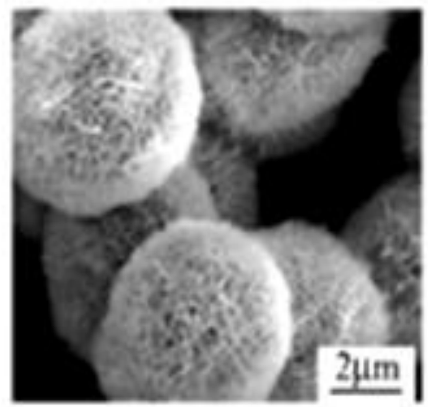
SEM of a Au@SiO2-cellulose

R. J. B. Pinto, et. al. Colloid Interface Sci.,312, 506–512, 2007.



SEM of SiO2 Nanoparticles

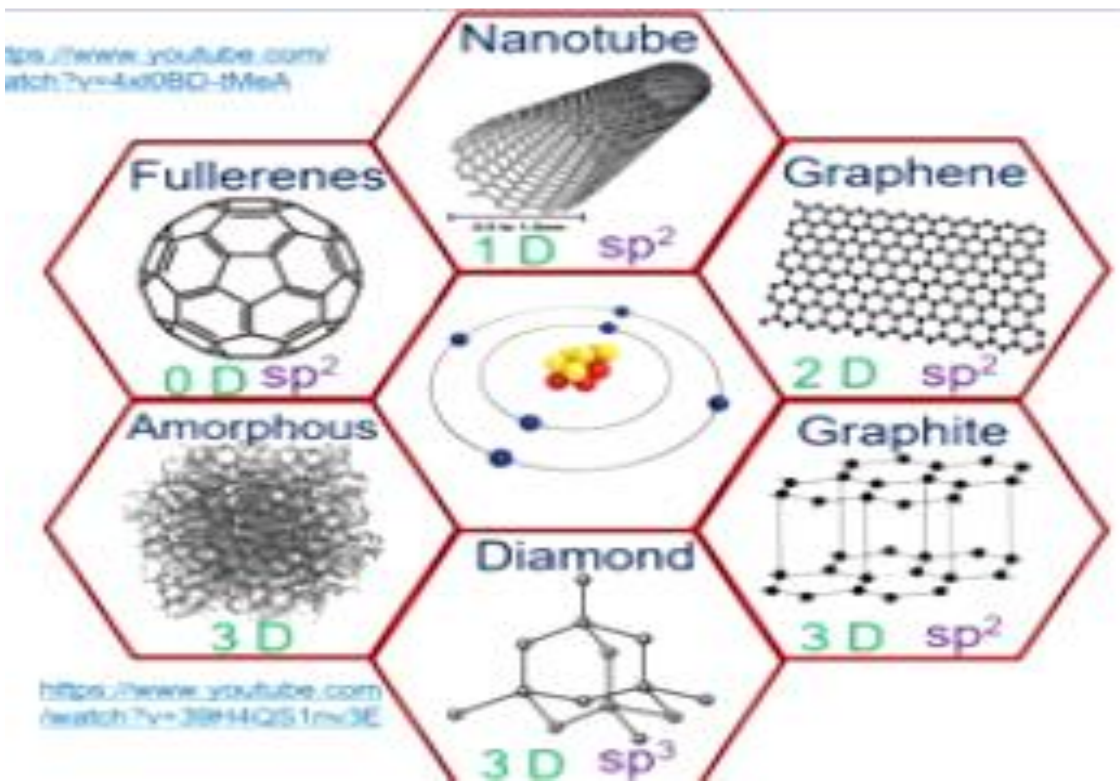
https://www.ssnano.com/



SEM of the α-Ni(OH)2 sphere

Y. Luo, et. al. Nanotechnology 17, 4278–428

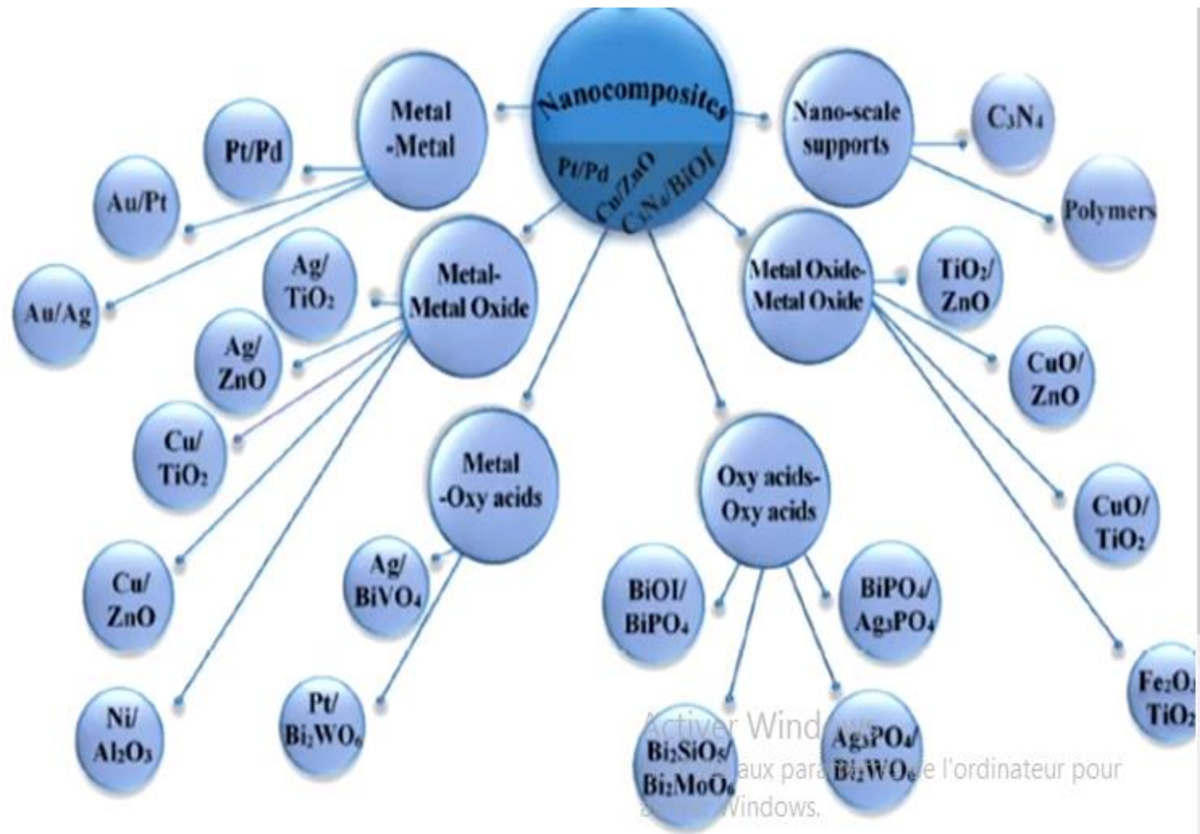
c) Carbon based nano-materials: The nanomaterials which contain carbon are called carbon nanomaterial, and these carbon nanomaterial can be synthetized in different shapes such as hollow tubes or spheres. In addition, carbon nanofibers, graphene, fullerenes, carbon black, carbon nanotubes, and carbon onions are also classified as carbon nanomaterials



d) Nanocomposite: The combination of one type of nanomaterials with another type of nanomaterials is called as nanocomposites. The nanomaterials either combine with other types of nanowires, nanofibers, or can be combined with larger size materials. These nanocomposites may be any combinations of metal-based, carbon-based, or organic-based nanowires, nanofibers, with any form of ceramic, metal, polymer bulk materials

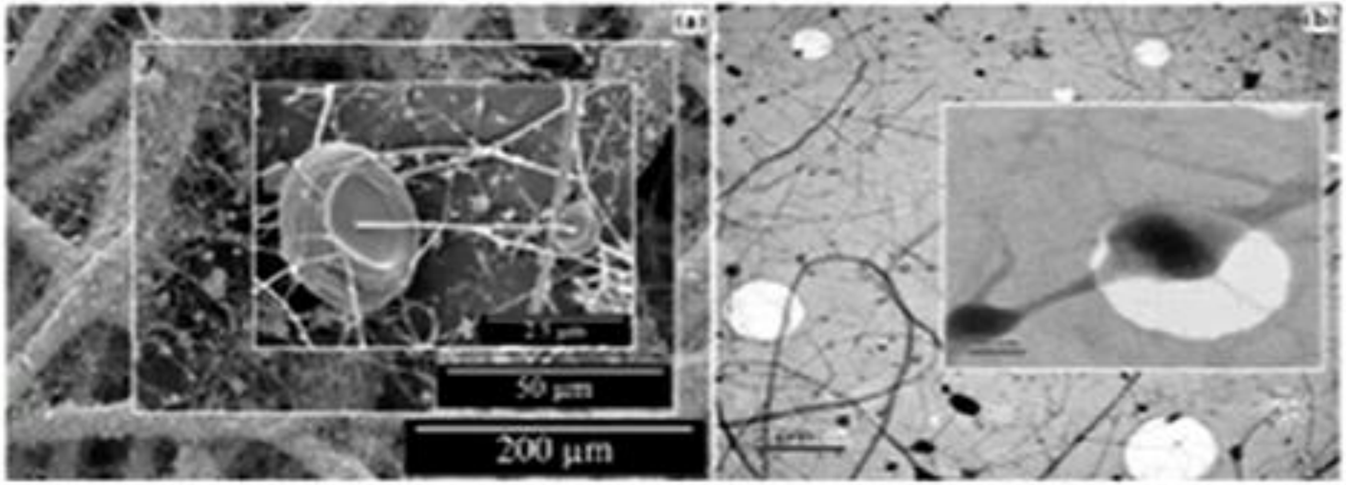
Nanocomposites are mainly formed by merging metals, metal oxides and oxyacids as follows:

(I) metal–metal,
(II) metal–metal oxide,
(III) metal oxides–metal oxides,
(IV) metal oxides–oxyacids
(V) oxyacids–oxyacids



2.3. **Classification based** on structural configuration

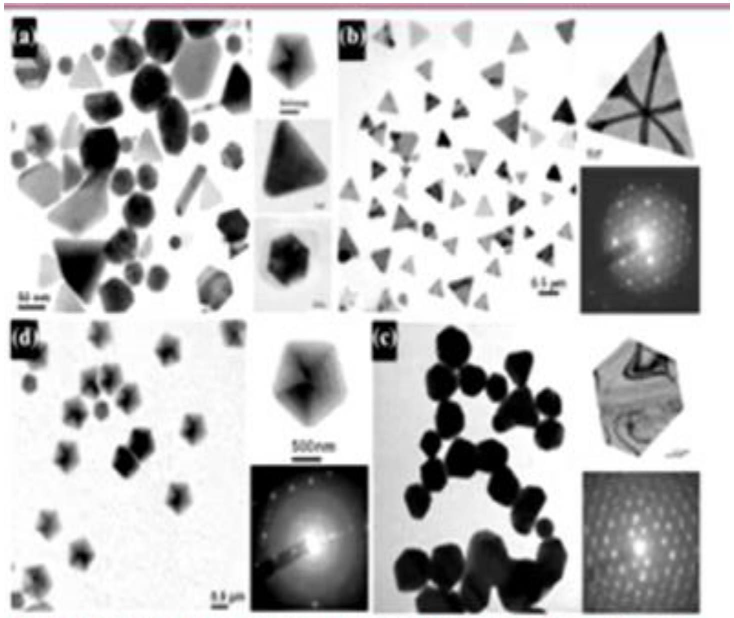
a) **Composite:** Nanomaterial can be classified as a signal or composite material. Signale materials consist individual nanoparticles that can be hollow (CNTs) or compact (silver nanowires). Composite materials consist of two or more materials



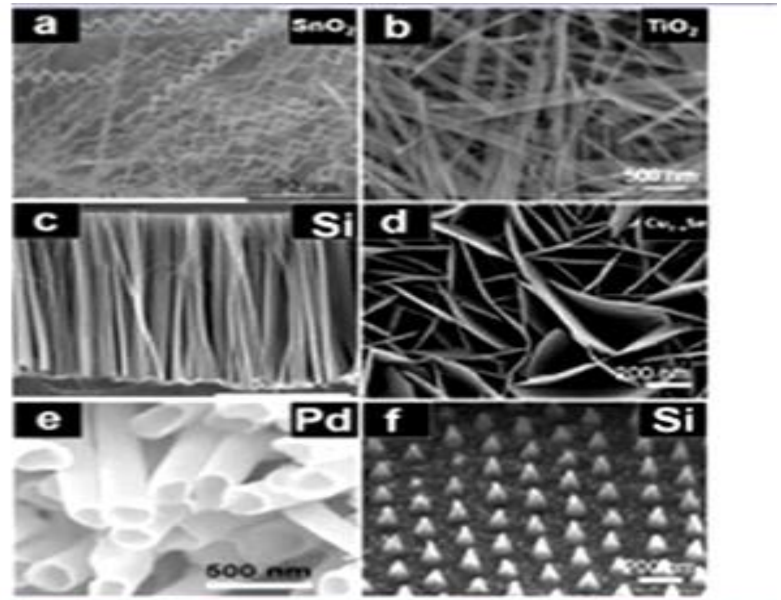
SEM (a) and TEM (b) images of CA/BC nanofibres

M. B. Bazbouz, et. Al. J Mater Sci, 53:10891–10909, 2018

b) Morphological shape: Nanomaterial can be classified as a signal or composite material. Signale materials consist individual nanoparticles that can be hollow (CNTs) or compact (silver nanowires). Composite materials consist of two or more materials



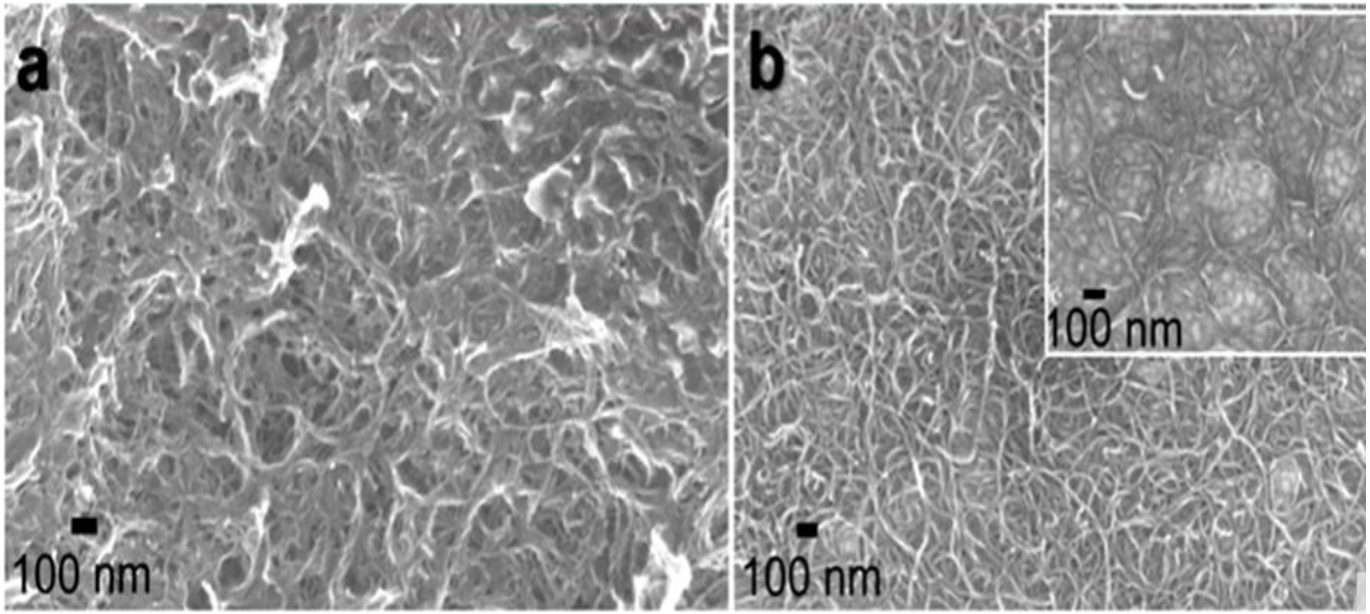
TEM images of synthesized Au nanoparticles with different shapes under different conditions: (a) nanoplates with triangle, hexagon, pentagon, star, shapes; (b) triangle; (c) hexagon; (d) pentagon. S. K. Das, et. al. Small 6, 1012–1021, 2010



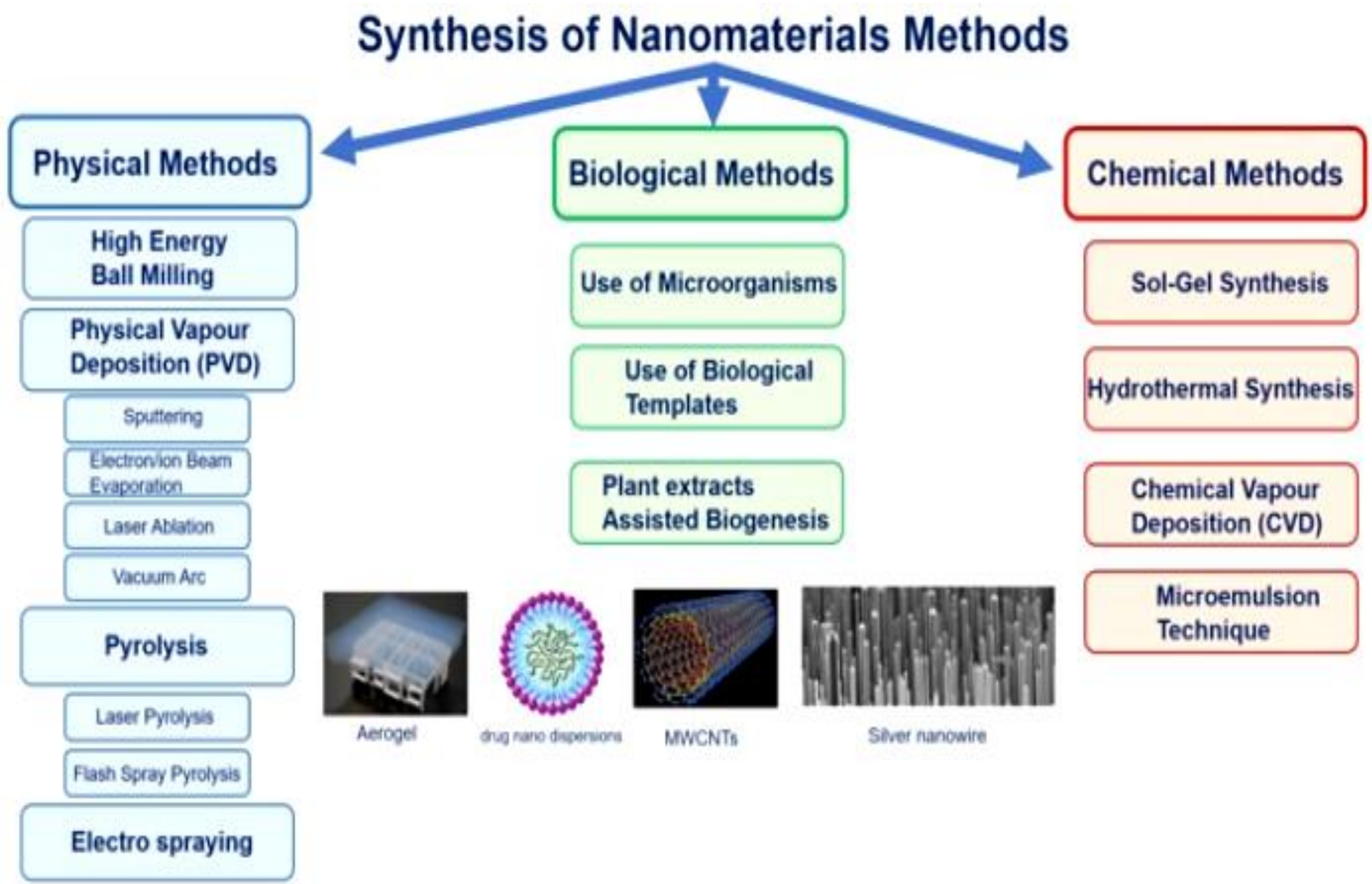
SEM images of long aspect ratio nanomaterials. (a) zigzag SnO_2 nanobelts. (b) TiO2 nanobelts. (C) nanowires of Si attached on a substrate. (d) $Cu_{2-x}Se$ nanosheets. (e) nanotubes of Pd. (f) Silico top of a layer of polyimide.

c) Agglomeration state and uniformity: Nanomaterial can be categorized based on:

- uniformity of their size distribution (homogenous or inhomogenous).
- Degree of agglomeration depends on the surface charge (nanoparticles can be as dispersed or agglomerated particles).



Synthesis of nanomaterials methodsion



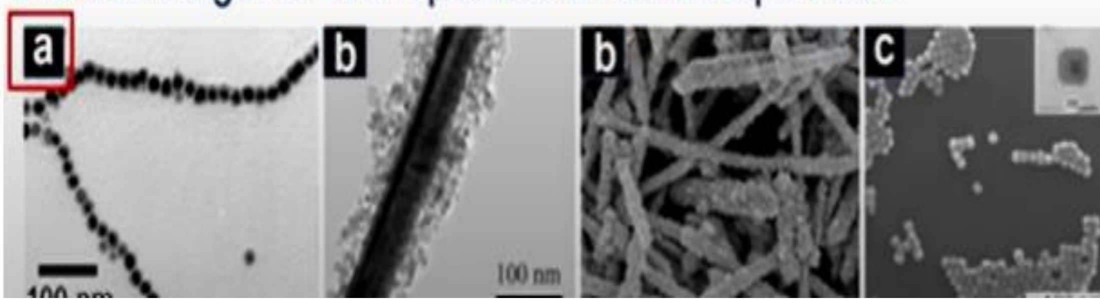
Properties and characterizations of nanomaterials

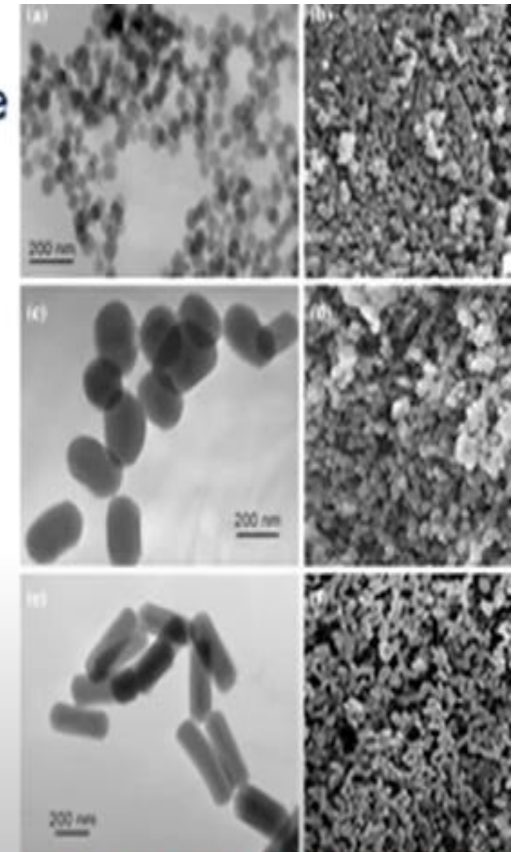
1- Surface Composition

Nanomaterial particles can be made of a single material or composite materials.

Examples of nanomaterials particles are metal oxide nanoparticles: Al, Sb, Bi, Co, Cr, Fe, In, La, Mn, Ni, Si, Sn, Ti, W, V, Y, Zn, and Zr with sphere, rod and long rod-shaped nanoparticles.

Nanocomposites can be fabricated in different shapes, such as nanosphere core-shell, nanocubes core-shell and long aspect ratio materials together with spherical small nanoparticles.

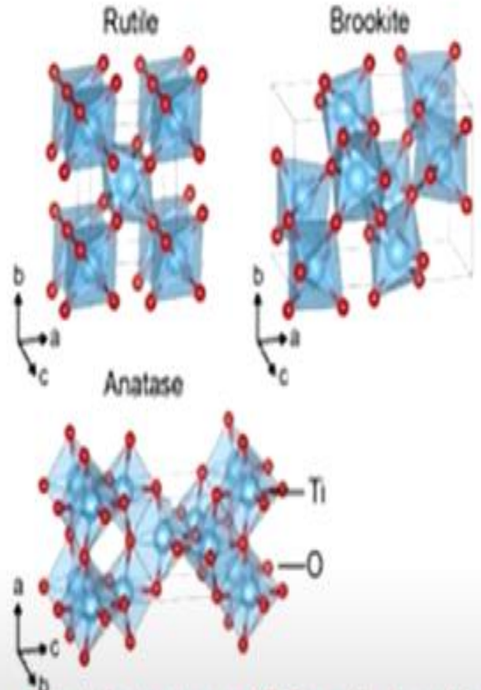




2- Crystalline Structure

Crystalline structure is of major importance in deciding a nanoparticle's mechanical, chemical, and physical properties.

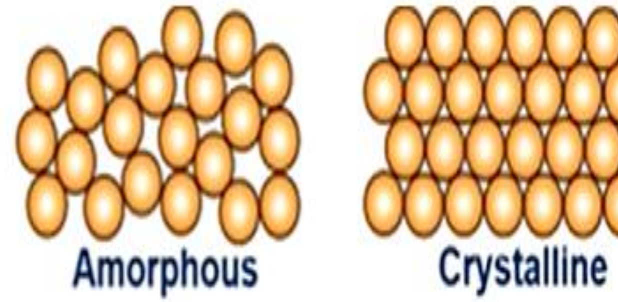
The same material in a different crystalline form can have very different properties and applications.



Crystal structures of TiO_2 rutile, brookite and anatase.

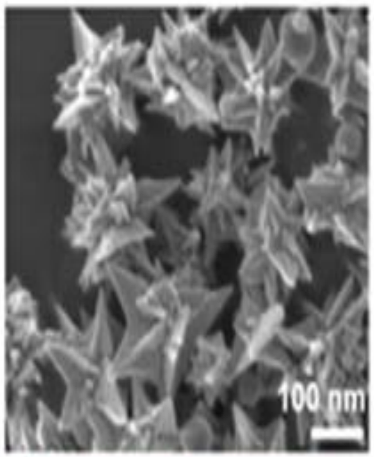
TiO_2 has applications in paint pigments to transparent conductors and photocatalysts

J. E. S. Haggerty, et al. Sci Rep 7, 15232, 2017

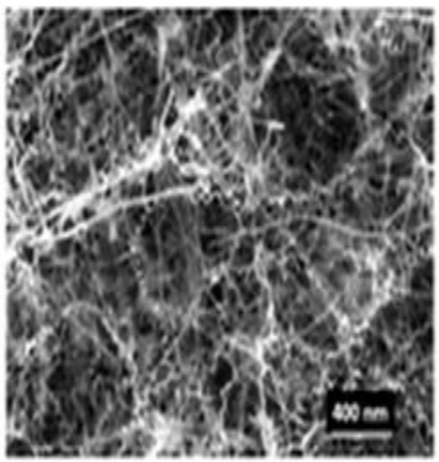


3- Morphology

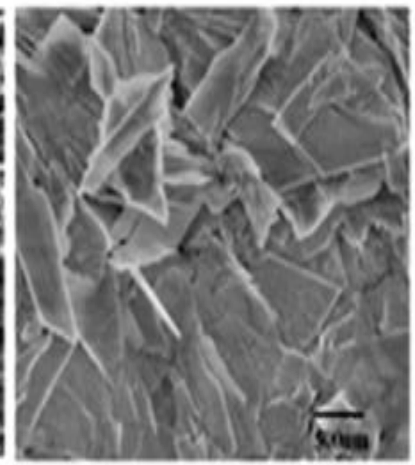
Nanomaterials particles can be fabricated in almost any **shape** and containing various combinations of composites materials. Different morphologies such as: **Nanorods, nanozigzags, nanocubes, nanostars, nanohelices, nanoplates**, and more **complex morphologies** such as **core-shell nanoparticles** (e. g. spherical **CdSe/CdS** and **Pd–Cu**) and **hollow $BaTiO_3$** nanoparticles (supercages).



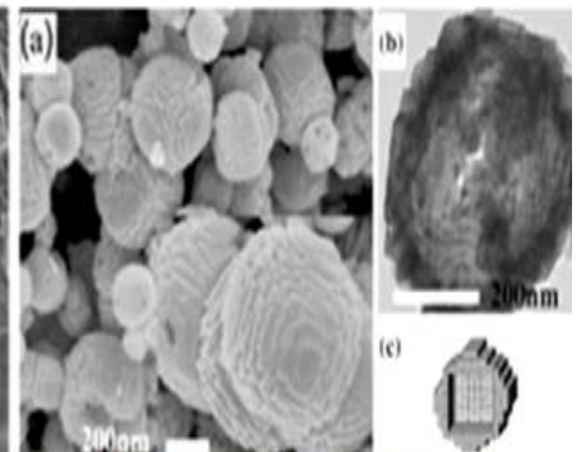
SEM of gold (Au) nanostars



SEM of nanohelices of ZnO nanofibres



SEM of ZnO nanoplates

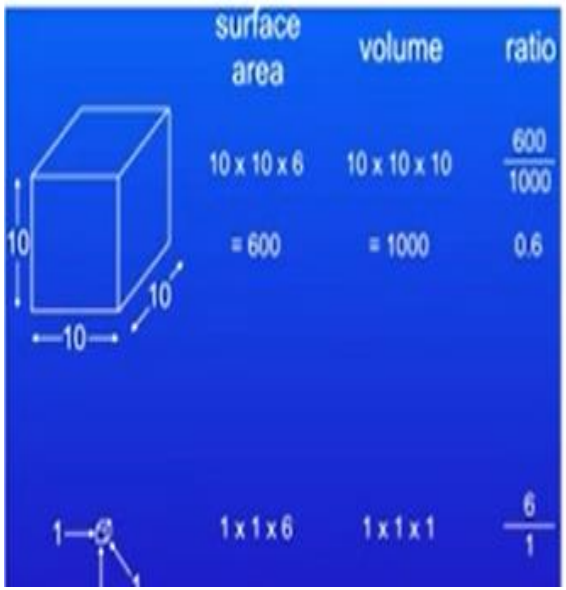


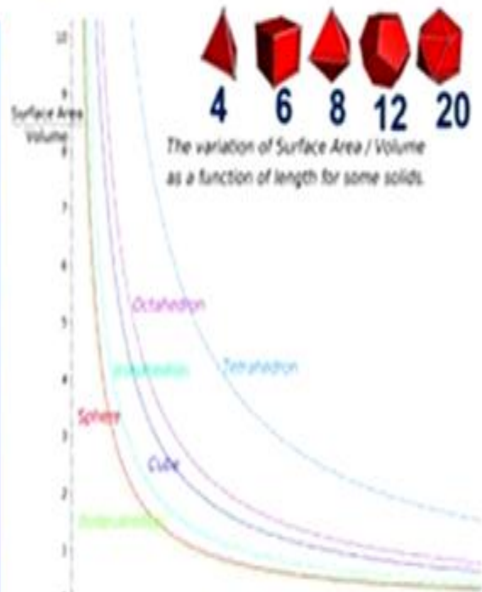
BaTiO3 meso-crystalline nanostructured

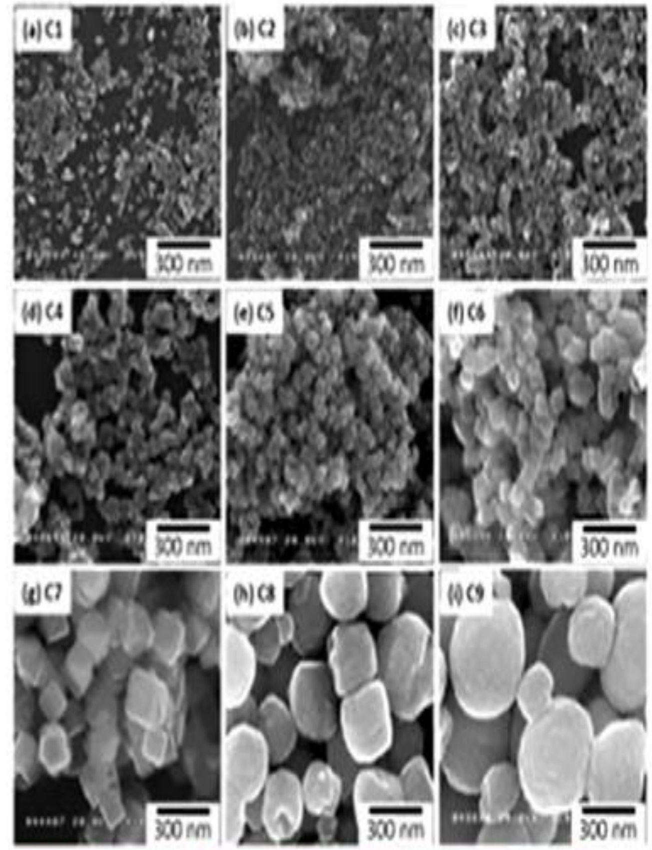
4- Surface Area

Particle size and surface area are important parameters that play a major role in interaction of nanomaterials with the exterior.

Decreasing the size of the nanoparticle leads to an exponential increase in surface area relative to volume, resulting in an enhanced reactivity.



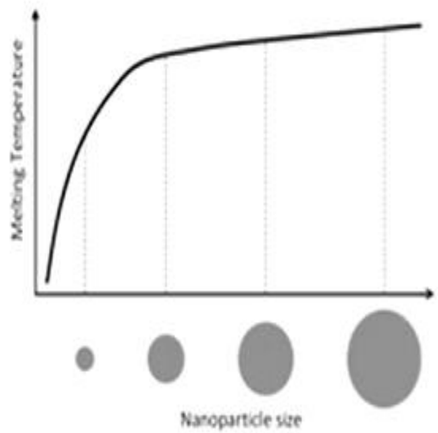




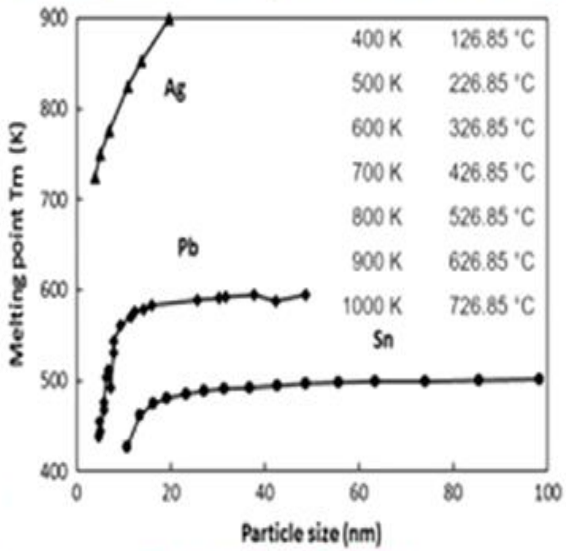
SEM images of cube-like Fe_3O_4 nanoparticles with various particle sizes. (a) 9.6, (b) 19.6, (c) 24.4, (d)

5- Mechanical Properties (Melting Temperature)

The melting temperature decrease with decreasing particle size. e.g. gold nanoparticles of 3.8 nm (1,700 atoms) is about 727 C, while for 2.5 nm (500 atoms) is around 227 C, and the bulk melting point is 1064 C.



Schematic of size dependent melting temperature of nanoparticles



The melting point, Tm, versus

6- Magnetic Properties: There are two types of materials that exhibit magnetism in nanoform.

1- Magnetic nanomaterials that are magnetic in bulk form.

2- Nanoparticles that show magnetic behavior only in nanoform, while in bulk are nonmagnetic.

Diamagnetic (bulk Cu, Ag, Au, and most of the rest of the elements)

Paramagnetic (Mg, Li, Ta) Magnetic response in an external magnetic field

Ferromagnetic (Fe, Ni, Co, Gd) Spin moment Orbit moment

Ferrimagnetic (Magnetite Fe3O4) Magnetic moment of single domain

Antiferromagnetic (MnO, CoO, NiO)

Compared to bulk materials nanomaterials show a variety of unusual magnetic behavior due to the surface or interface effects, including symmetry breaking, electronic environment, or charge transfer and magnetic interaction. Thus the nanomaterials may become superparamagnetic, even though their corresponding bulk materials are not magnetic. For example, Fe3O4 nanoparticles showed superparamagnetic-like behavior, even though bulk iron oxide (Fe3O4) is ferromagnetic. Superparamagnetic nanoparticles are not magnetic when located in a zero magnetic field, but they quickly become magnetized after an external magnetic field is applied. When they are below the superparamagnetic diameter, the nanoparticles can revert quickly to a nonmagnetized state after an external magnet is removed. There are various crystalline materials that exhibit ferromagnetism, such as Fe, Co, or Ni. Among them, ferrite oxide-magnetite (Fe3O4) is the most widely used in the form of superparamagnetic nanoparticles for all sorts of biological applications.

7- Optical Properties

The optical properties of nanoparticles vary with their **composition**, **morphology**, and **size**

Absorption of light

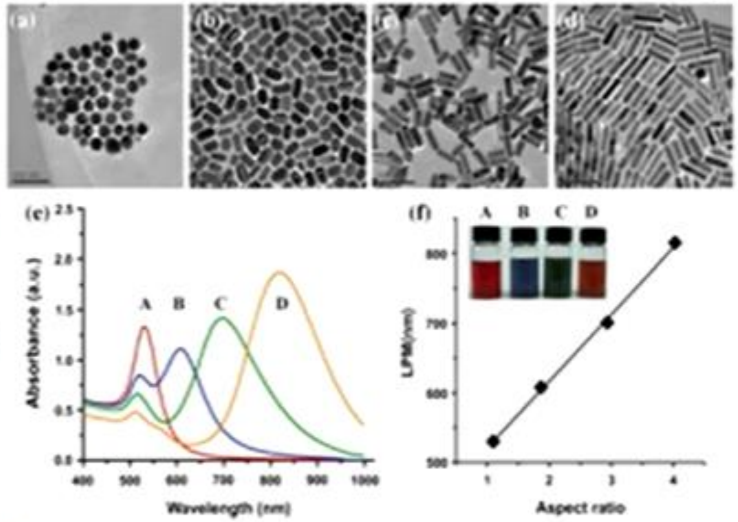
Optical properties of nanoparticles pertain to the way that they interact with light

Scattering of light

Reemission of the absorbed light (fluorescence)

Nanoparticles

Nanoparticles exhibit an enhancement of all the above-mentioned processes due to a unique interaction of the nanoparticle-free electrons and light.



TEM images of Au nanoparticles with different aspect ratio
(e) FT-IR absorption spectra. (f) the Au NRs suspensions.

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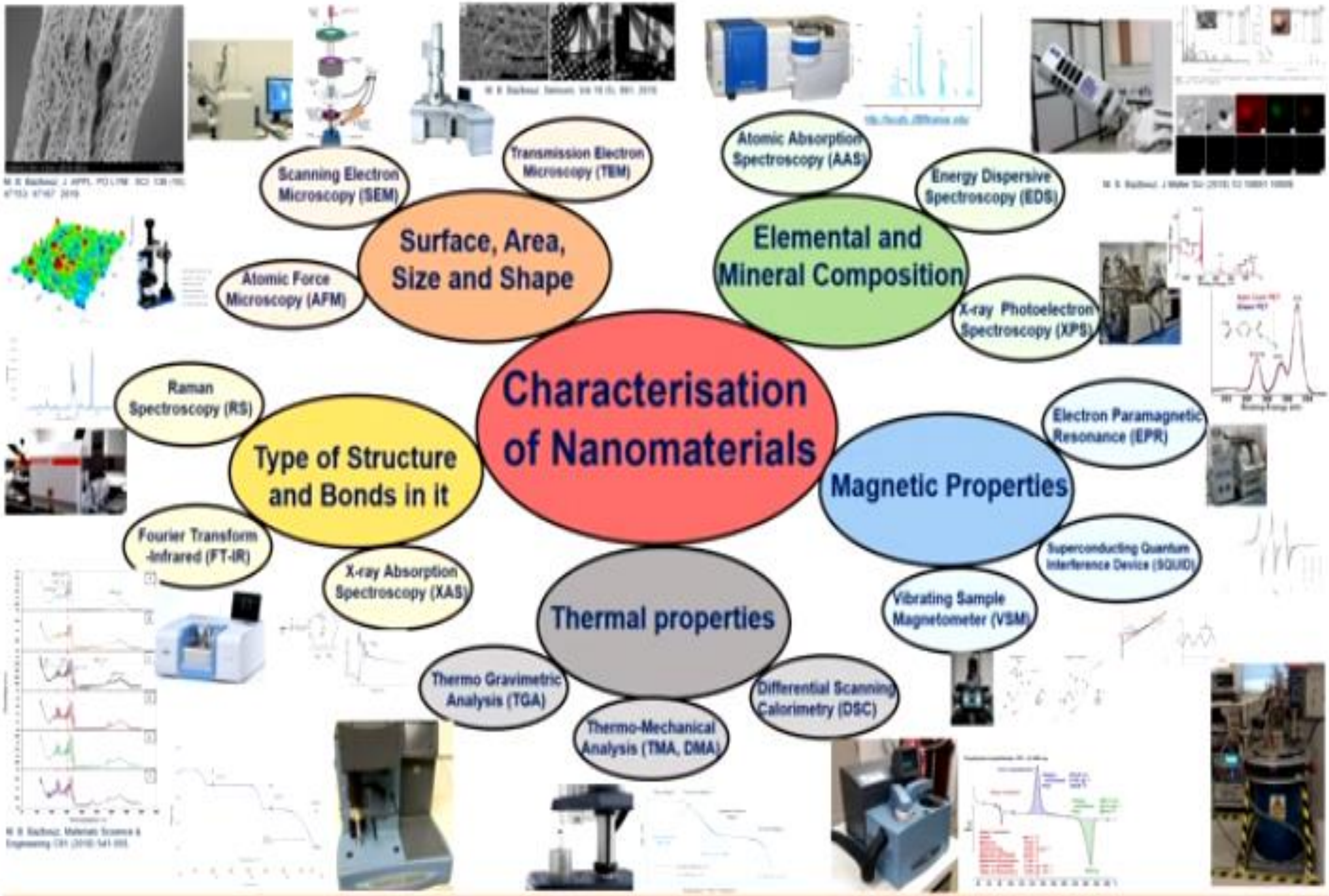
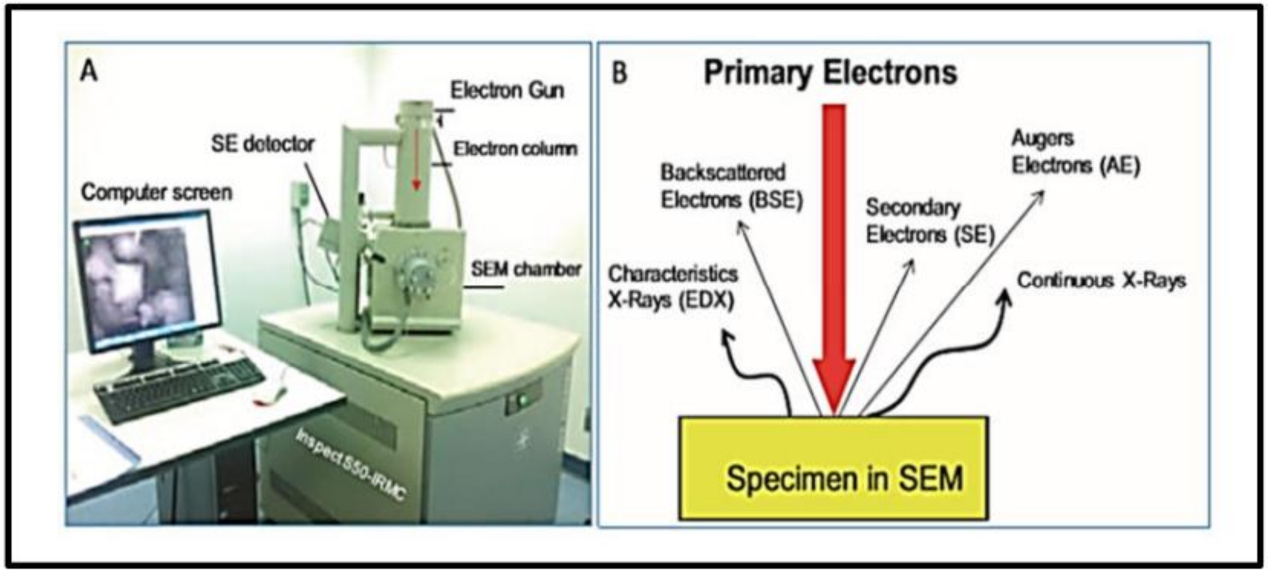
The optical properties such as reflection, transmission, absorption, and light emission of the nanomaterials are completely dependent on their electronic structure that significantly differs for various morphologies since electronic structure of the nanomaterials are very much dependent on surface atoms.
Optical properties such as emission and adsorption occur when electron transition occurs between these two bands. This optical bandgap increases with the decrease in particle size, especially for the semiconductor nanomaterials. When an electron drops from higher energy state to lower energy state a quantum of light (photon) with wavelength $\lambda=hc/\Delta E$ will be emitted where h, c, ΔE are Plank's constant, speed of light, and energy difference between allowed electron energy levels, respectively.

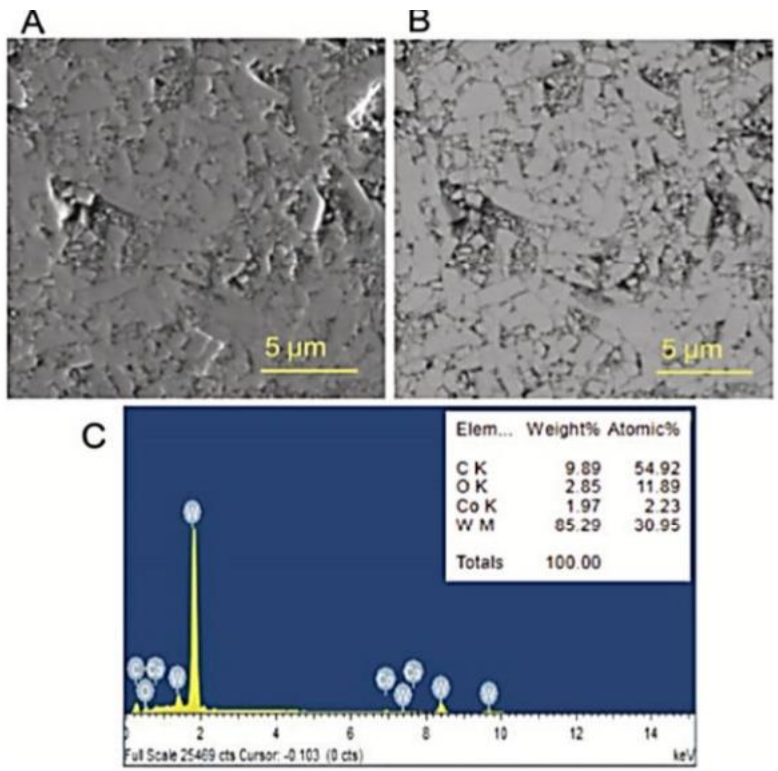

Characterisation of Nanomaterials
Surface, Area, Size and Shape
Scanning Electron Microscopy (SEM)
Transmission Electron Microscopy (TEM)
Atomic Force Microscopy (AFM)
Elemental and Mineral Composition
Atomic Absorption Spectroscopy (AAS)
Energy Dispersive Spectroscopy (EDS)
X-ray Photoelectron Spectroscopy (XPS)
Type of Structure and Bonds in it
Raman Spectroscopy (RS)
Fourier Transform -Infrared (FT-IR)
X-ray Absorption Spectroscopy (XAS)
Magnetic Properties
Electron Paramagnetic Resonance (EPR)
Superconducting Quantum Interference Device (SQUID)
Vibrating Sample Magnetometer (VSM)
Thermal properties
Thermo Gravimetric Analysis (TGA)
Thermo-Mechanical Analysis (TMA, DMA)
Differential Scanning Calorimetry (DSC)

- ## Scanning Electron Microscopy (SEM)

From the name, it is clear that the electron microscopes use electrons for the formation of images instead of light as the case for optical microscopes. The electronic image has often better image quality in terms of resolution than optical microscopy, thanks to their small wavelengths. Scanning electron microscope (**SEM**). SEM is a very useful technique to obtain the surface topography and chemical composition of the specimens with a wide view [43]. SEM instrument along with a schematic of basic signals produced in SEM are shown in (Figure).



Different kinds of signals such as secondary electrons (SE), backscattered electrons (BSE), Auger electrons (AE), X-rays, etc. are generated as energetic beam of electrons is subjected to the specimen. These signals are then detected by the dedicated detectors and produce electronic images or spectra as shown on the computer screen. The SE signals are utilized to generate surface morphological images while BSE and **EDX** signals are used to obtain chemical and structural information of the specimen (see Figure)



- **Transmission Electron Microscopy (TEM)**

Transmission electron microscopy (TEM) is a powerful tool to attain a high-quality data of the nanomaterials. The main difference in SEM and TEM is that in TEM, the electron beam is transmitted through a thin specimen, while in SEM, the beam of electrons scans the surface of the sample instead of passing through. Another important difference is the power of the microscope (accelerating voltage; V). Typically, TEM is operated at 80–300 kV, this power is much higher than SEM (maximum: 30 kV).

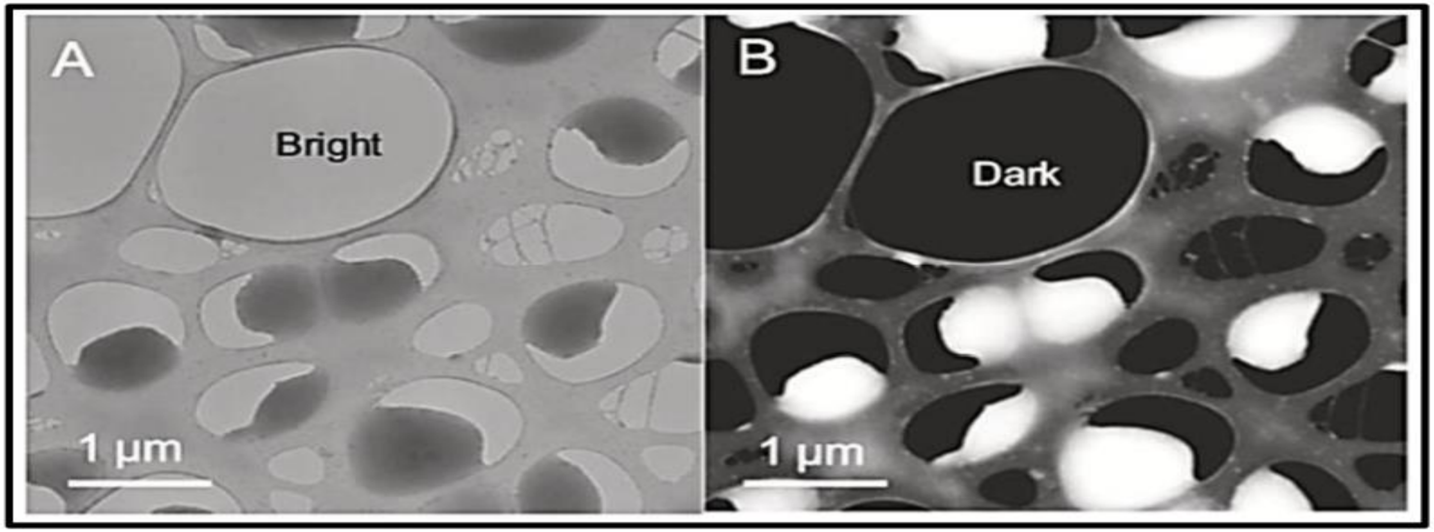
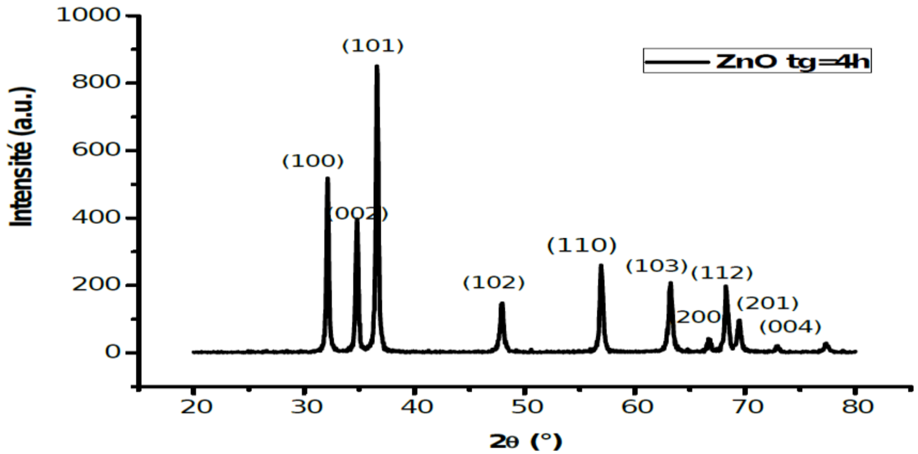


Figure (3.3): Two imaging modes of TEM: (a) BF and (b) DF imaging. The carbon hole that has bright contrast in BF turned to dark (inverse) in DF (working voltage: 200 kV). The scale bars are 1 µm [44].

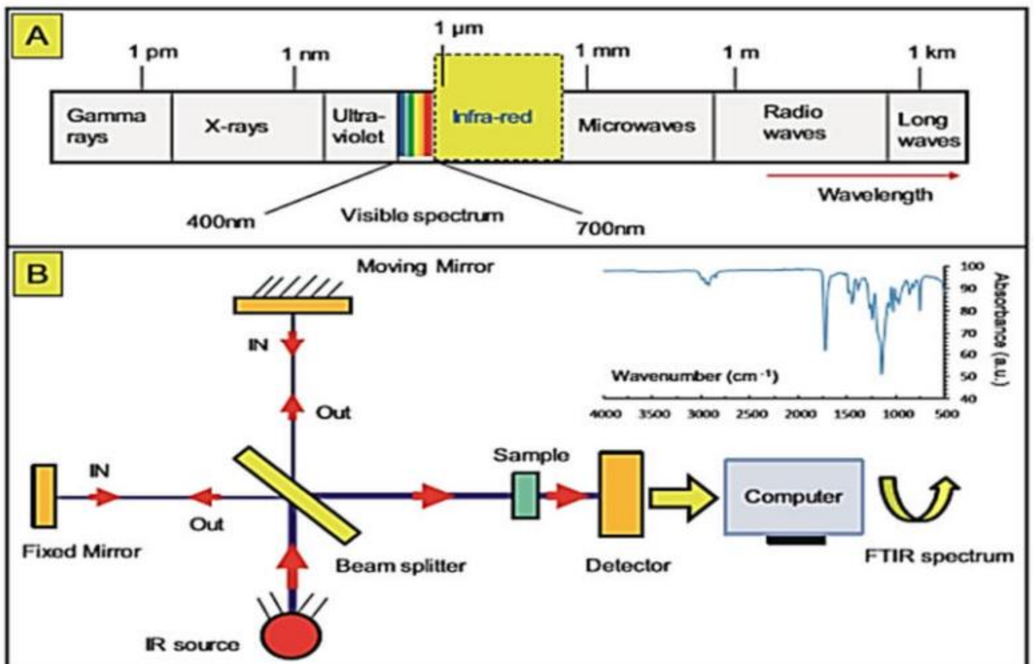
- **X-Ray Diffraction (XRD)**

X-ray diffraction (XRD) is a non-destructive method to study the material's structure at the molecular and atomic level. XRD is the best method to investigate the crystalline, polycrystalline, and non-crystalline (amorphous) materials. The wavelengths (λ) of the X-rays (used in the XRD) are in the range of nanometers. XRD analyzer plotted the x–y plot (XRD pattern) between intensity (in arbitrary units) and scattering angle, 2θ (degrees). The XRD pattern is analyzed by a mathematical formulation, known as Bragg's law and the following information can be obtained such as nature of material, atomic arrangement, crystallite size, chemical composition, etc. The XRD line patterns of more than 60,000 different crystallographic phases are available in the electronic database: JCPDS (Joint Committee on Powder Diffraction Standards).

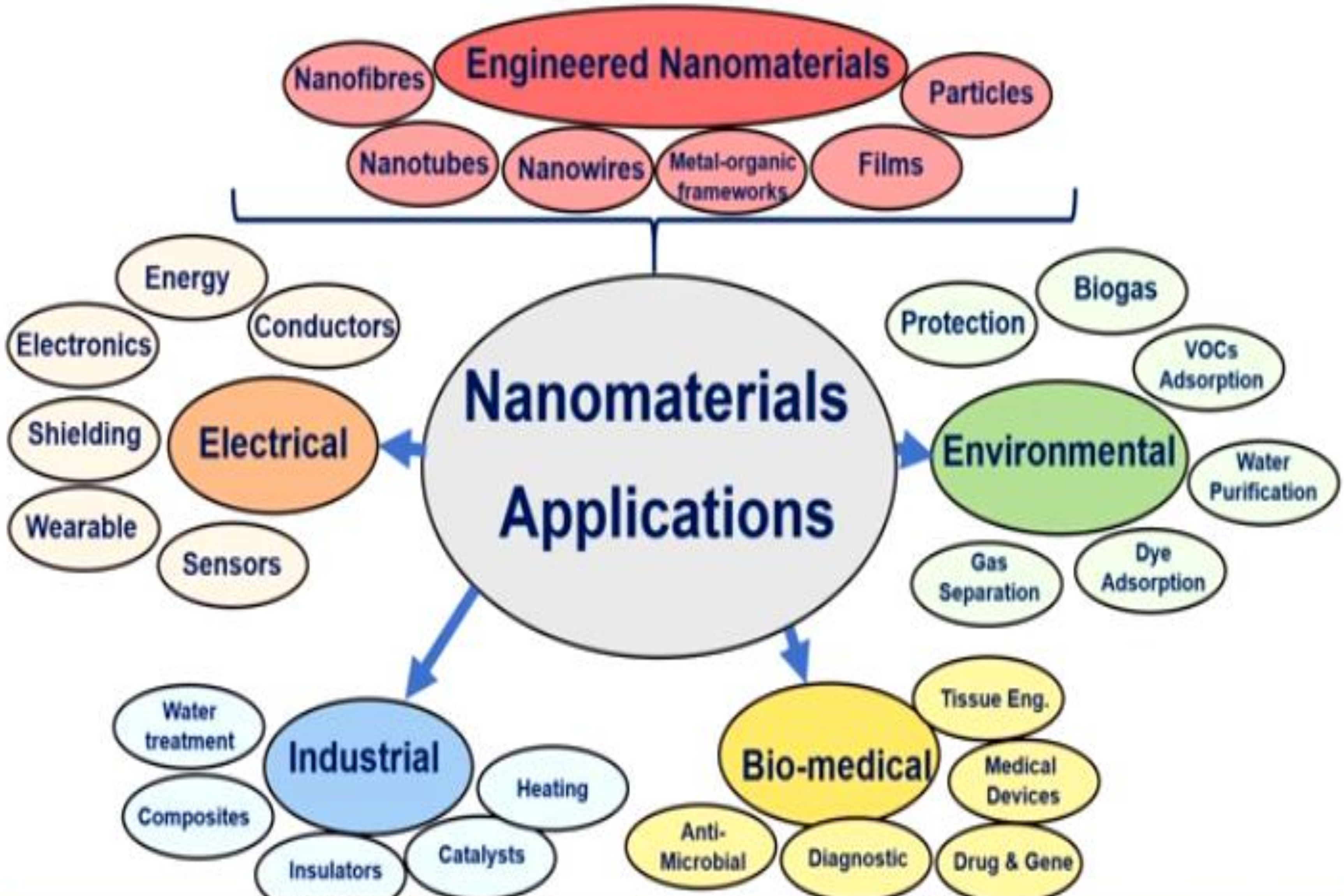


- **Fourier Transform Infrared (FTIR) Spectroscopy**

Fourier transform infrared (FTIR) is an infrared spectroscopy technique to study the molecular bonding of the organic/inorganic materials. IR is a region of electromagnetic radiations at a wavelength of 700 nm to 1 mm. During FTIR, a specimen is exposed to IR radiations in order to create a spectrum of the specimen [45]. A portion of the radiations is transmitted, while the rest of the radiations are absorbed by the specimen depending on the nature of bonding in the material. A molecular fingerprint of the specimen is created as a result of transmission and absorption at a molecular level. A wide range of information, such as identifying the material properties, quality of the specimen, and number/ratio of the individual ingredients in a mixture can be extracted by FTIR spectra [45].



Applications of nanomaterials



a) Sunscreens and Cosmetics: The traditional chemical UV protection approach suffers from its poor long-term stability. A sunscreen based on mineral nanoparticles such as titanium dioxide offer several advantages. Titanium oxide nanoparticles have a comparable UV protection property. Nanosized titanium dioxide and zinc oxide are currently used in some sunscreens, as they absorb and reflect ultraviolet (UV) rays and yet are transparent to visible light and so are more appealing to the consumer. Nanosized iron oxide is present in some lipsticks as a pigment. The use of nanoparticles in cosmetics has raised a number of concerns about consumer safety.

b) Paints: Incorporating nanoparticles in paints could improve their performance, for example by making them lighter and giving them different properties. Thinner paint coatings ('lightweighting'), used for example on aircraft, would reduce their weight, which could be beneficial to the environment.

c) Displays: The huge market for large area, high brightness, flat-panel displays, as used in television screens and computer monitors, is driving the development of some nanomaterials. Nanocrystalline zinc selenide, zinc sulphide, cadmium sulphide and lead telluride synthesized by sol gel techniques are candidates for the next generation of light-emitting phosphors.

d) Batteries: With the growth in portable electronic equipment (mobile phones, laptop computers, remote sensors), there is great demand for lightweight, highenergy density batteries. Nanocrystalline materials synthesized by sol–gel techniques are candidates for separator plates in batteries because of their foam-like (aerogel) structure, which can hold considerably more energy than conventional ones. Nickel–metal hydride batteries made of nanocrystalline nickel and metal hydrides are envisioned to require less frequent recharging and to last longer because of their large surface area.

e) Catalysis In general, nanoparticles have a high surface area, and hence provide higher catalytic activity. Catalysis is important for the production of chemicals. Nanoparticles serve as an efficient catalyst for some chemical reaction, due to the extremely large surface to volume ratio. Platinum nanoparticles are now being considered in the next generation of automotive catalytic converters because the very high surface area of nanoparticles could reduce the amount of platinum required. Some chemical reactions are also carried out using nanomaterials. For example, reduction of nickel oxide to the base metal Ni.

f) Medecine: Nanomedicine is an application of nanotechnology which works in the field of health and medicine. Nano-medicine makes use of nanomaterials, and nanoelectronic biosensors. In the future, nanomedicine will benefit molecular nanotechnology.
With the help of nanomedicine early detection and prevention, improved diagnosis, proper treatment and follow-up of diseases is possible. Certain nano-scale particles are used as tags and labels, biological can be performed quickly, the testing has become more sensitive and more flexible. Gene sequencing has become more efficient with the invention of nano-devices like gold nanoparticles, these gold particles when tagged with short segments of DNA can be used for detection of genetic sequence in a sample.

g) Sensors of gases The gases like NO2 and NH3 can be detected on the basis of increase in electrical conductivity of nanomaterials. This is attributed to increase in hole concentration in nanomaterials due to charge transfer from nanomaterials to NO2 as the gas molecules bind the nanomaterials.

h) Energy The most advanced nanotechnology projects related to energy are: storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving and enhanced renewable energy sources. Today's best solar cells have layers of several different semiconductors stacked together to absorb light at different energies but they still only manage to use 40 percent of the Sun's energy. Commercially available solar cells have much lower efficiencies (15-20%). Nanotechnology could help increase the efficiency of light conversion by using nanostructures.

i) Catalysis Higher surface are available with the nanomaterial counterparts, nano-catalysts tend to have exceptional surface activity. For example, reaction rate at nano-aluminum can go so high, that it is utilized as a solid-fuel in rocket propulsion, whereas the bulk aluminum is widely used in utensils. Nano-aluminum becomes highly reactive and supplies the required thrust to send off pay loads in space. Similarly, catalysts assisting or retarding the reaction rates are dependent on the surface activity, and can very well be utilized in manipulating the rate-controlling step.

j) Water treatment The application of nanomaterials in water and wastewater treatment has drawn wide attention. Due to their small sizes and thus large specific surface areas, nanomaterials have strong adsorption capacities and reactivity. Heavy metals [17], organic pollutants [18], inorganic anions [19], and bacteria [20] have been reported to be successfully removed by various kinds of nanomaterials [21]. In recent years, photocatalytic degradation by metal oxide nanoparticles such as TiO_2 has been successfully applied in the contaminant degradation in water and wastewater.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