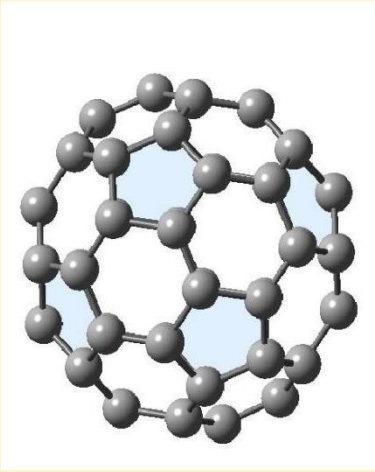


NANO – LECTURE 3



Nano Science and Nanotechnology

Classification of Nanomaterials

Dr. Mervat Kadhem

Classification

- Nanomaterials are usually classified on the basis of their Origin, **dimensionality**, morphology, **composition**, uniformity, physical properties and agglomeration.
- Based on **nanoparticle's dimensionality**, nanomaterials can be classified into :
 - 0-D (dots, 100 nm)
 - 1-D (wires)
 - 2-D (sheets)
 - 3-D (Aggregation of nanomaterials, combinations).

Classification by Origin

1. Natural Nanoparticles

These particles are natural. Volcanic ash , Forest Fire, Pollution, Dust particles etc. Also the nanostructures in butterfly wings , lizard legs and nanoparticles by biological species.

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2. Artificial Nanoparticles

Made by top down or bottom up approach(chemically and Physically) . These may be metal nanoparticles, semiconductor quantum dots, carbon based materials , composites etc.

CLASSIFICATION Based on Dimensionality

0-D

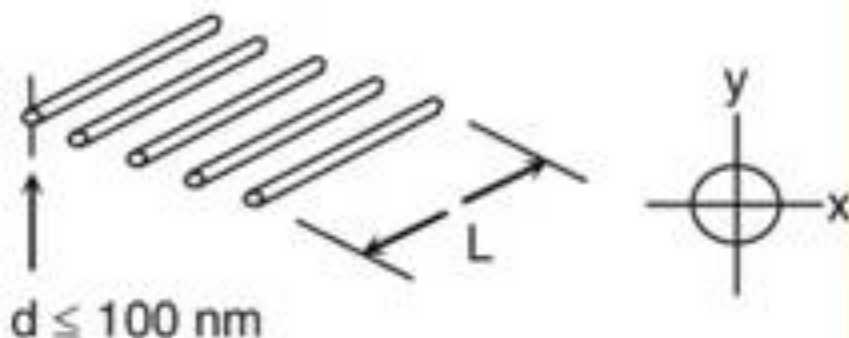
All dimensions (x,y,z) at nanoscale



$$D \leq 100 \text{ nm}$$

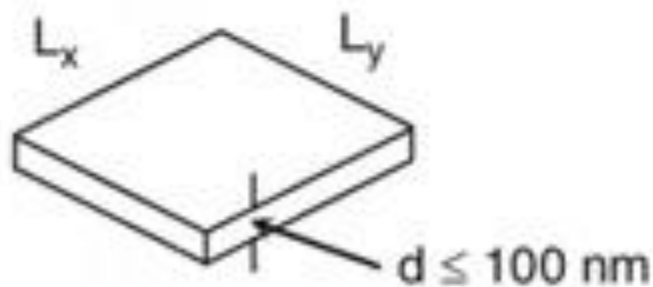
1-D

Two dimensions (x,y) at nanoscale, other dimension (L) is not



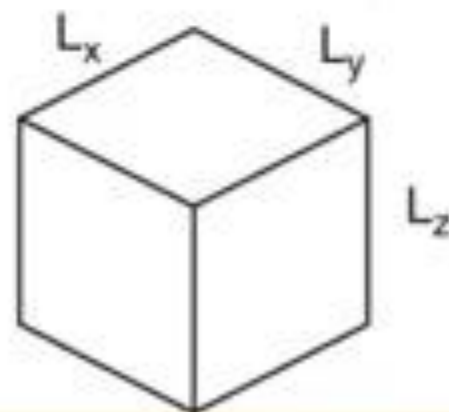
2-D

One dimension (d) at nanoscale, other two dimensions (L_x , L_y) are not



3-D

No bulk dimension at nanoscale



0 -D Nanomaterials

- They have all three dimensions negligibly small. They are also known as artificial atoms (or quantum dots) because their energy levels are discrete.
- Metallic nanoparticles include gold and silver nanoparticles, whereas semiconductor nanoparticles include quantum dots of CdS, CdSe, and CdTe.

0-D Nanomaterials

- They have all three dimensions negligibly small. They are also known as artificial atoms (or quantum dots) because their energy levels are discrete.
- Metallic nanoparticles include gold and silver nanoparticles, whereas semiconductor nanoparticles include quantum dots of CdS, CdSe, and CdTe.
- Nanoparticles may have shapes such as spherical, cubic, or polygonal with size in the range of 1–100 nm.
- The most common example is fullerene, the structure was identified by Kroto and coworkers.

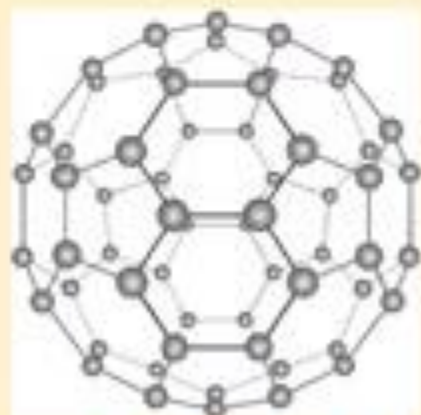
0-D

All dimensions (x,y,z) at nanoscale



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Nanoparticles

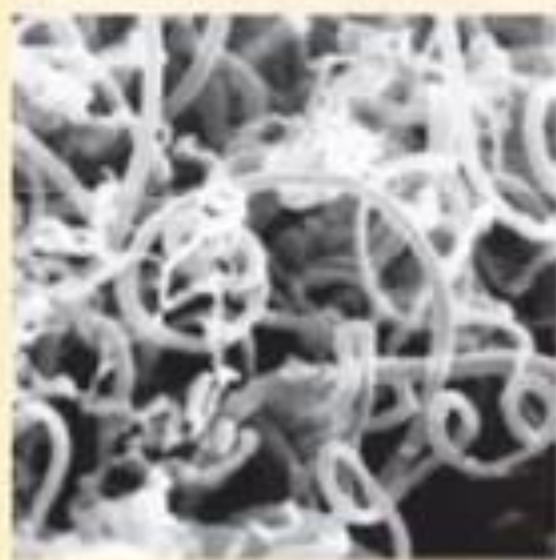


Fullerene (C₆₀)



1 -D Nanomaterials

- They have two dimensions of particulates in the nanometer scale and the third dimension is significant compared to other two dimensions, that is, they have length of several micrometers (or >100 nm) and diameter of only a few nanometers.
- Examples: nanotubes, nanofibers, nanorods, or whiskers of metals or oxides, and carbon nanotubes (CNTs) and carbon nanofibers (CNFs).



1-D

Two dimensions (x, y) at nanoscale,
other dimension (L) is not

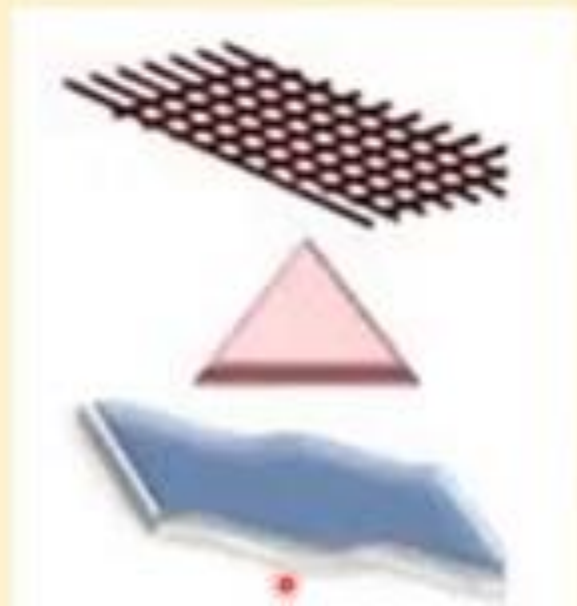


2 -D Nanomaterials

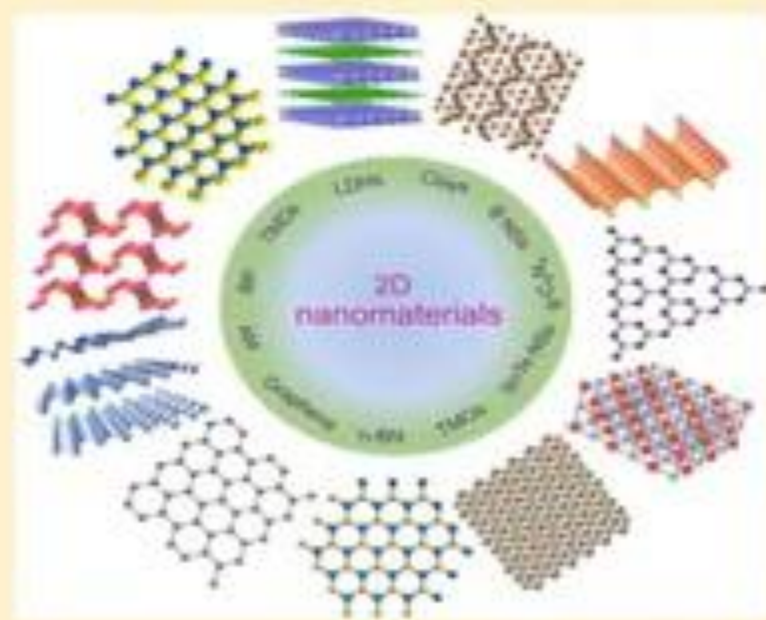
- They have **one dimension in the nanometer scale** and other two dimensions are significantly large compared to third dimension (i.e., thickness).

Examples: graphene, nanolayers, nanoclays, nanosheets, nanofilms, platelet-like structure, nanoflakes, or nanoplatelets and silicate nanoplatelets.

- The area of the nanofilms or coating is of the order of several square centimeters, but the thickness is in the range of 1–100 nm.



Layered
Structures



3 -D Nanomaterials



- All dimensions of these materials are outside the nanometer range. The best example is the **nanostructured bulk**, which consists of individual blocks with the size in the range of 1–100 nm.

3 -D Nanomaterials



- All dimensions of these materials are outside the nanometer range. The best example is the **nanostuctured bulk**, which consists of individual blocks with the size in the range of 1–100 nm.
- These materials have all three dimensions >100 nm.
- Bulk nanomaterials consist of a multiple arrangement of nanosized crystals typically in different orientations.
- In other words, 3-D nanomaterials can contain dispersions of nanoparticles, nanowires, nanotubes, or multilayers, etc. in the matrix.

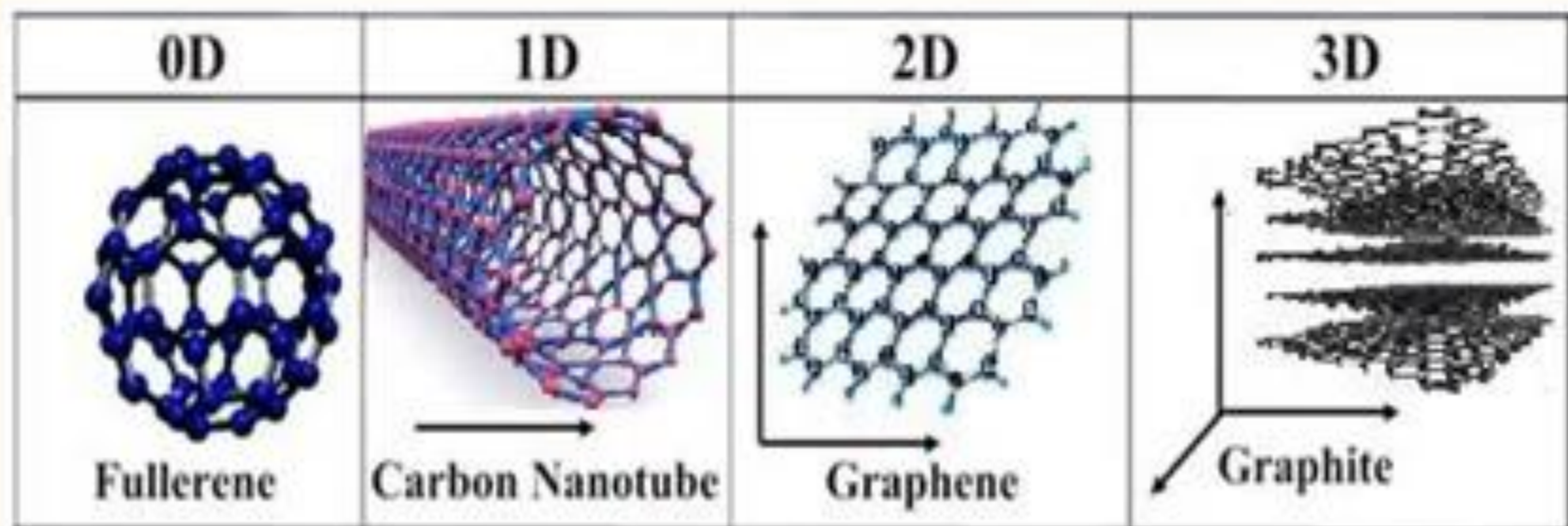
Classification of nanomaterials based on type of Material or Composition

- **(i) Carbon based materials**
- **(ii) Metal or metal oxide based materials**
- **(iii) Dendrimers or polymer based**
- **(iv) Composites or mixture**

(i) Carbon based materials: These are composed of carbon, taking the form of hollow spheres, or tubes.

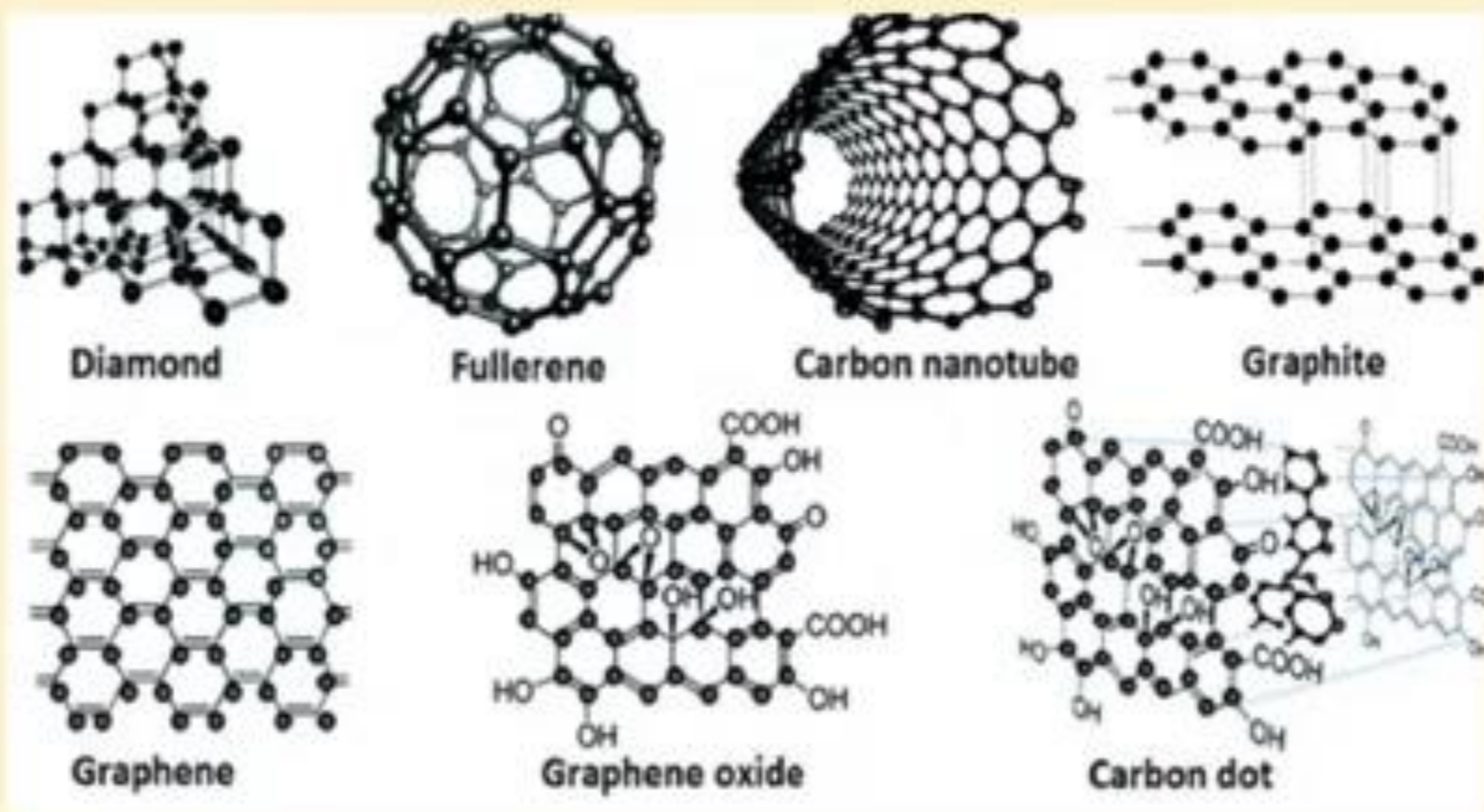
Carbon materials can be divided into :

- zero-dimensional (0D) carbon based materials such as fullerenes (C_{60})
- one-dimensional (1D) carbon based materials such as carbon nanotubes and carbon fibers,
- two-dimensional (2D) carbon based materials such as graphene
- three-dimensional (3D) carbon based materials such as graphite, Diamond etc.



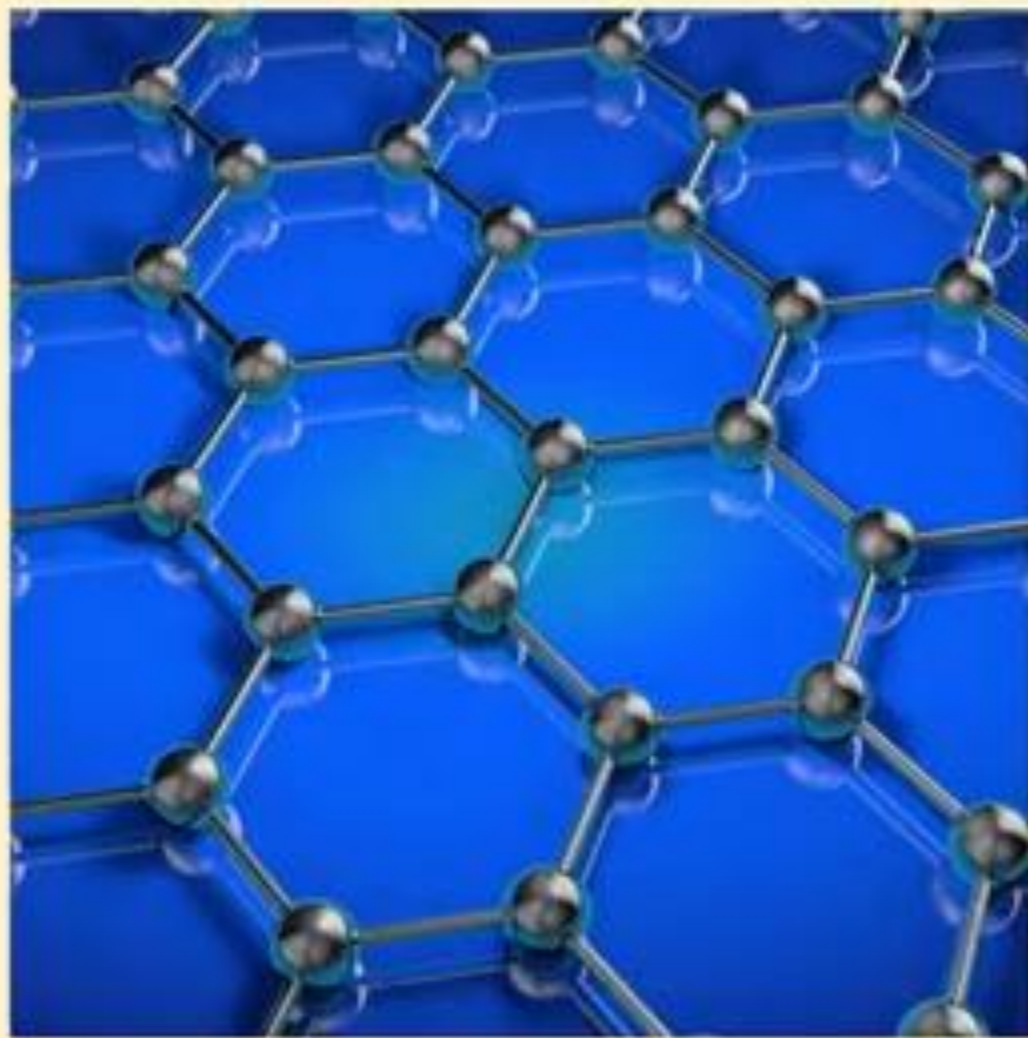
CARBON BASED MATERIALS

Spherical and ellipsoidal carbon nanomaterials are referred to as fullerenes, while cylindrical ones are called nanotubes.



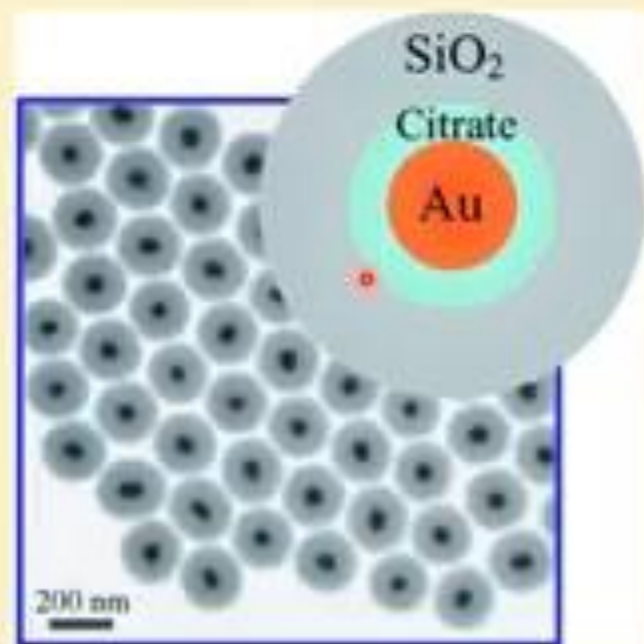
GRAPHENE – HEXAGON-SHAPED PLANE OF CARBON ATOMS IN SHEET FORM

Graphene is a single layer (monolayer) of carbon atoms, tightly bound in a hexagonal honeycomb lattice. It is an allotrope of carbon in the form of a plane sheet.

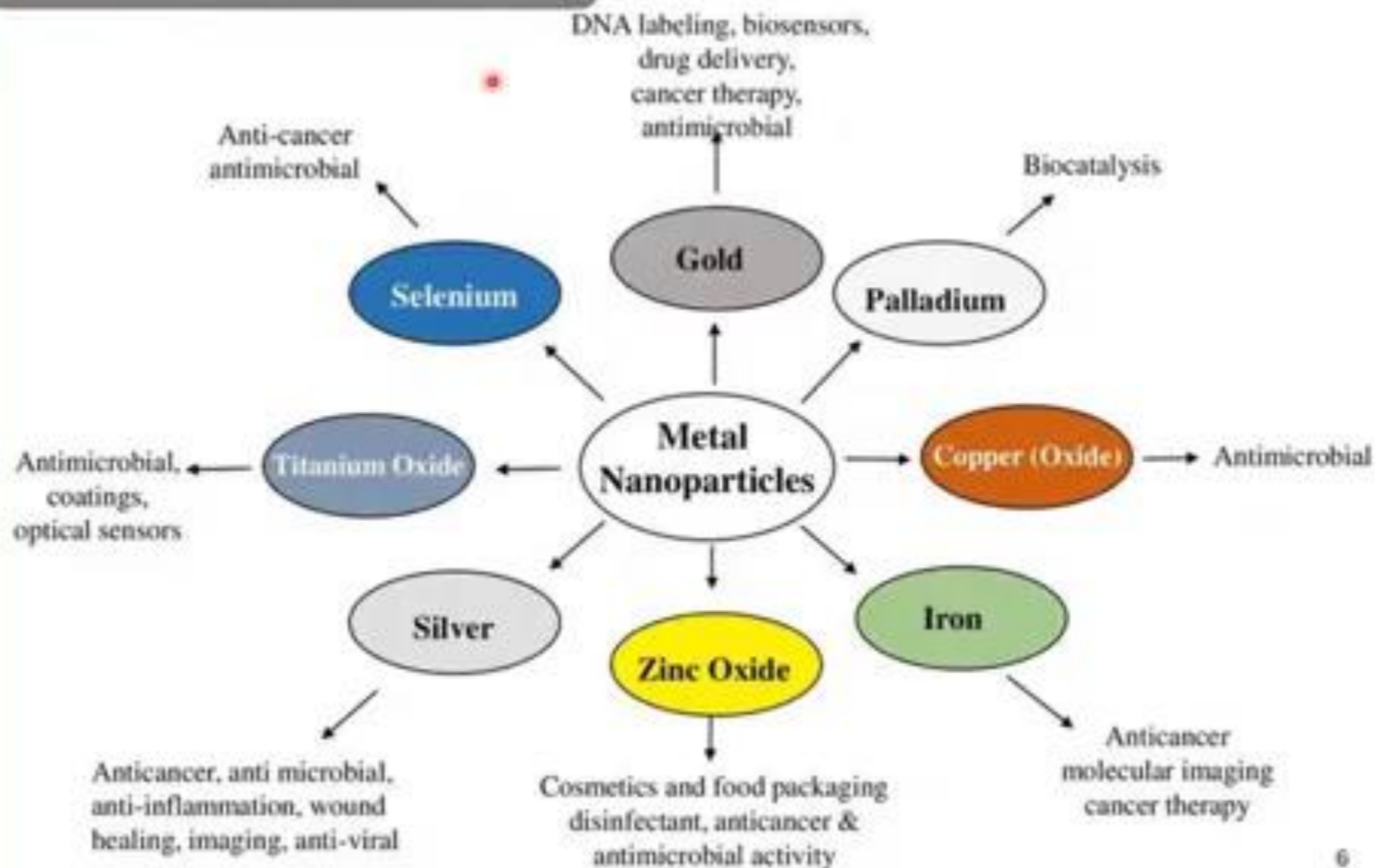


(ii) Metal based materials

- These include quantum dots, nano gold, nano silver and metal oxides like ZnO or TiO₂.
- A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, whose size is on the order of a few nanometers to a few hundred nanometers.

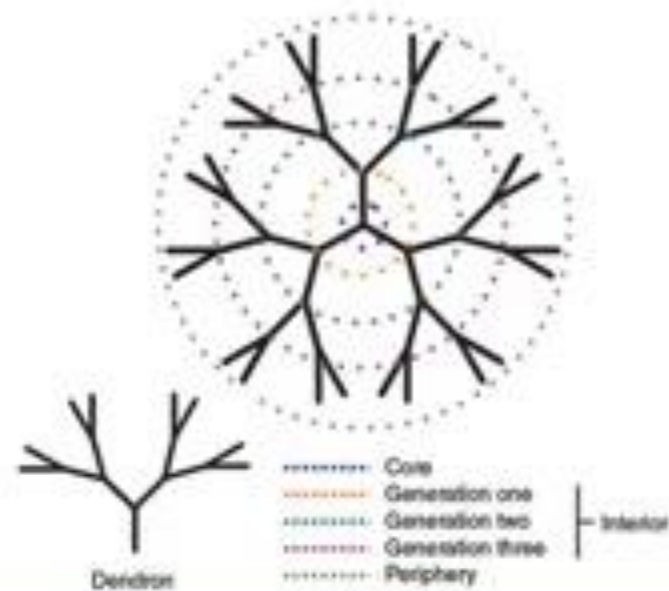


Types of Metal Nanoparticles



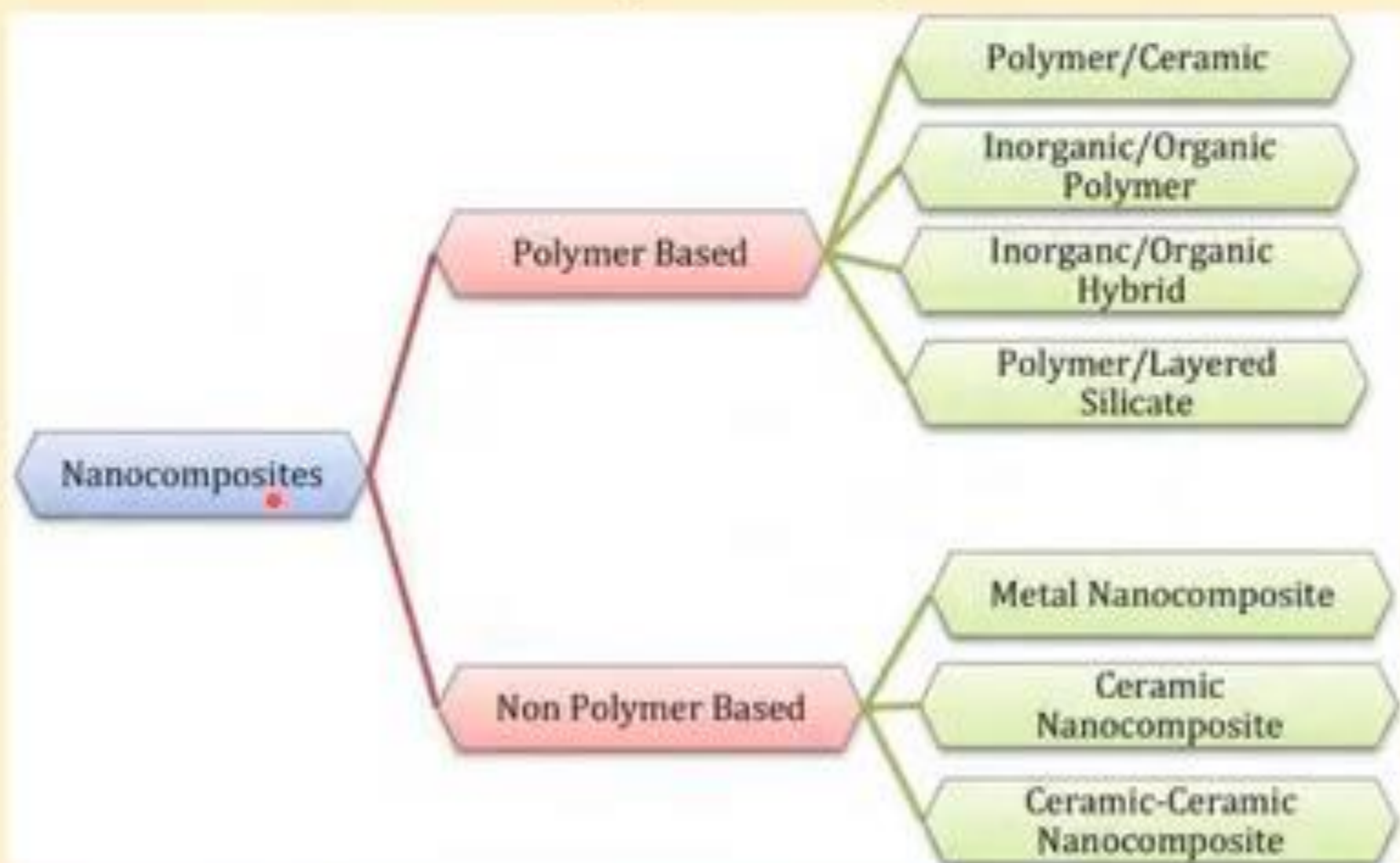
(iii) Dendrimers:

- Dendrimers are repetitively branched molecules.
- The name comes from the Greek word 'dendron' (tree).
- These nanomaterials are nanosized polymers built from branched units.
- The surface of a dendrimer has numerous chain ends, which can perform specific chemical functions.
- Dendrimers are used in molecular recognition, nanosensing, light harvesting, and opto-electrochemical devices.



(iv) Composites:

- Composites are combination of nanoparticles with other nanoparticles or with larger, bulk-type materials.
- Nanoparticles like nanosized clays are added to products (auto parts, packaging materials, etc.) to enhance mechanical, thermal, and flame-retardant properties



Gleiter's Classifications

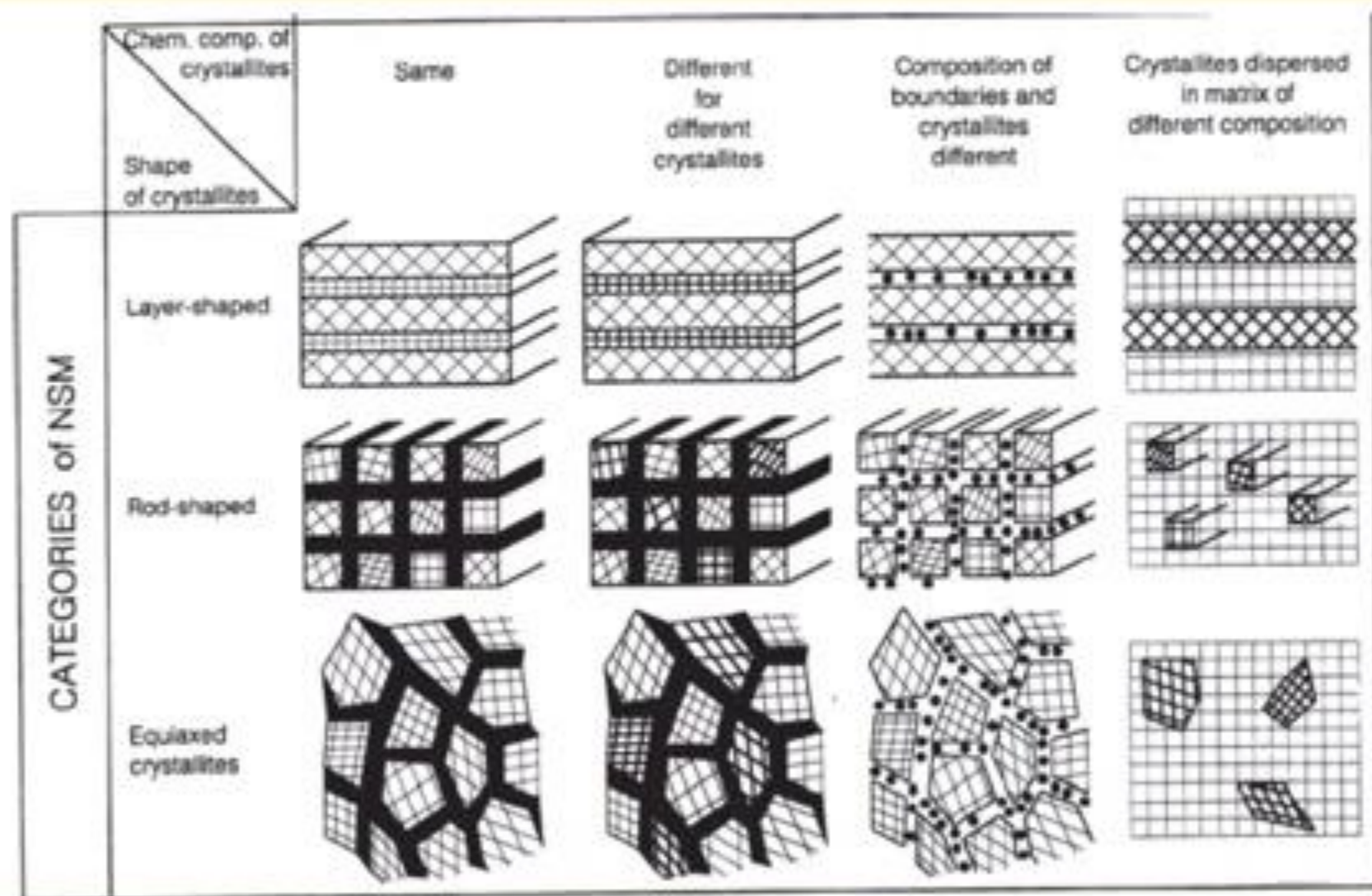


Gleiter's classification of nanostructured materials

First classification scheme of NSMs was proposed by H. Gleiter in 1995 and further was extended by V. Pokropivny and V. Skorokhod in 2005.

Crystalline forms and chemical composition was assumed by Gleiter as a basis of a classification scheme of NSMs where both **inter-crystalline grain boundaries and crystallites were regarded as building blocks**. Therefore in this scheme there are actually 3 classes and 4 types in each of them rather than 12 classes. However this scheme seems to be incomplete because of zero- and one-dimensional (0D, 1D) structures such as fullerenes and nanotubes were not considered.

Gleiter's classification scheme for NSM according to their chemical composition and the dimensionality (shape) of the crystallites (structural elements) forming the NSM.



12 classes

(Classified in year 1995)

SUMMARY

- Nanomaterials refer to the class of materials with at least one of their dimensions in the nanometric range. They can be metals, ceramics, polymers or composites.
- Nanostructured materials may occur in several different geometric configurations including wires, tubes, rods, shells, etc.

Thanks for Watching