Nanotechnology

Lecture 4

Types of Nano-materials

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4nd stage

Second Course

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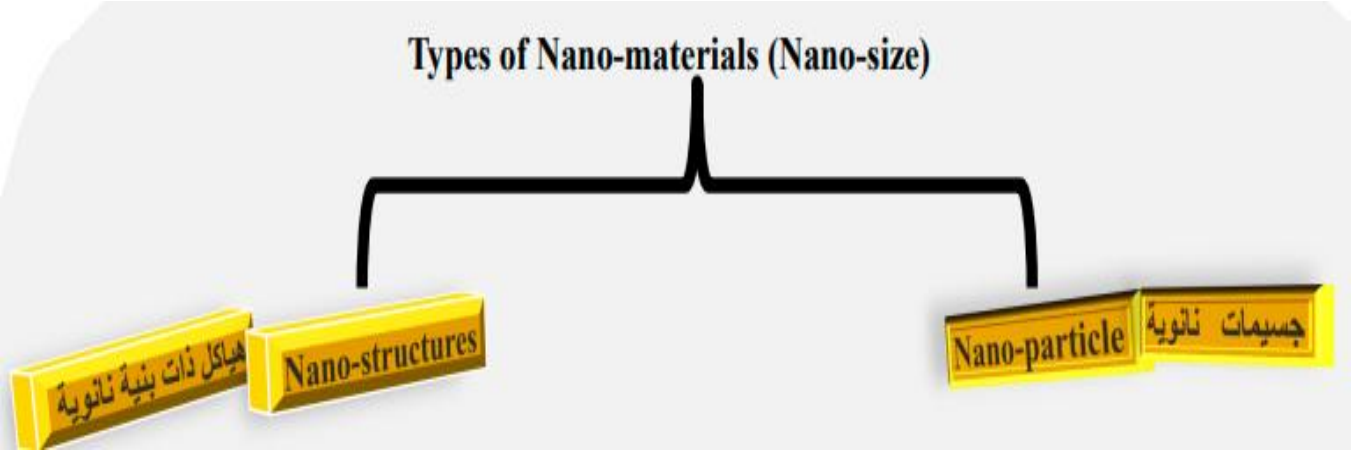
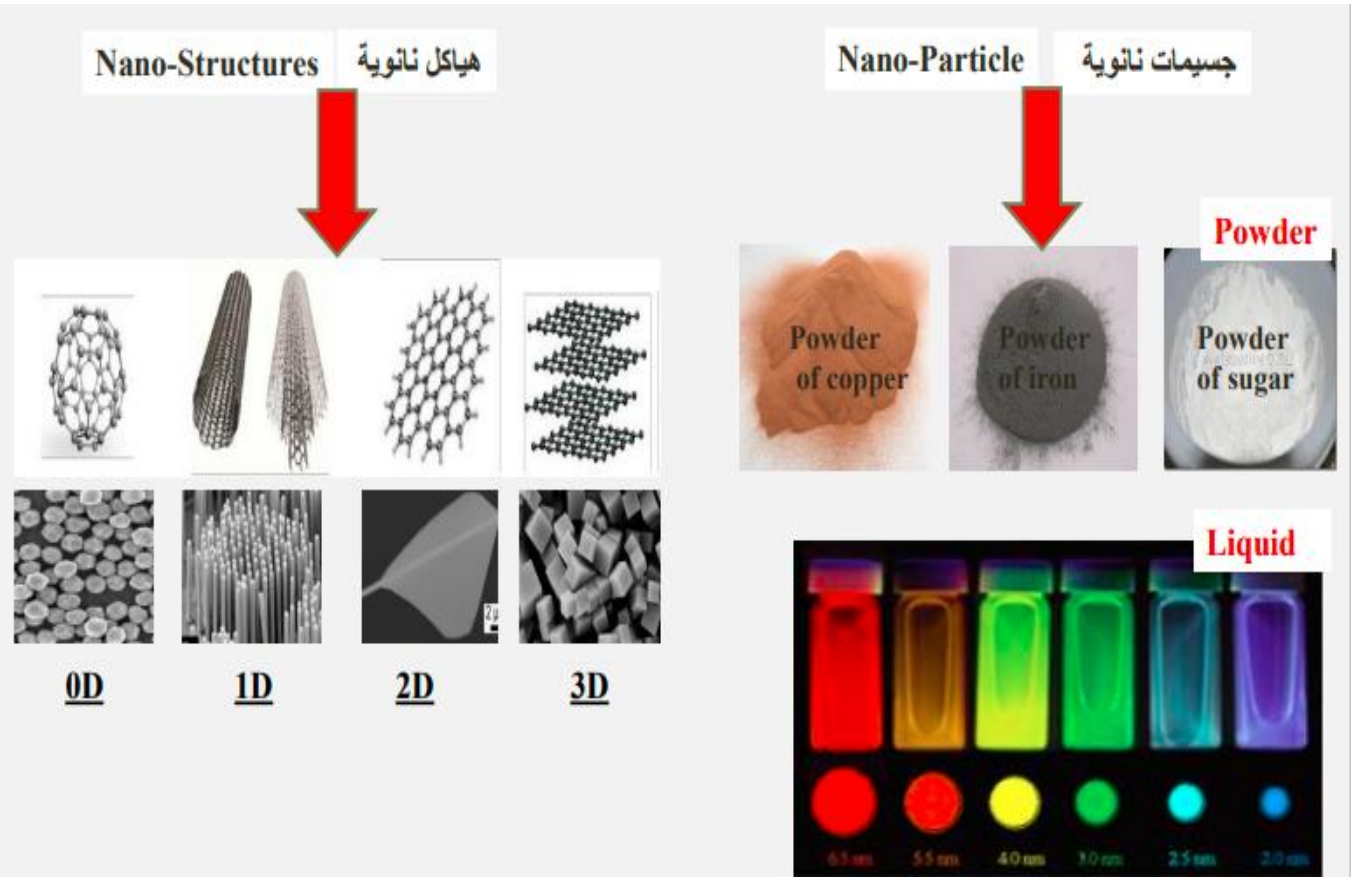
Types of Nano-materials (Nano-size)

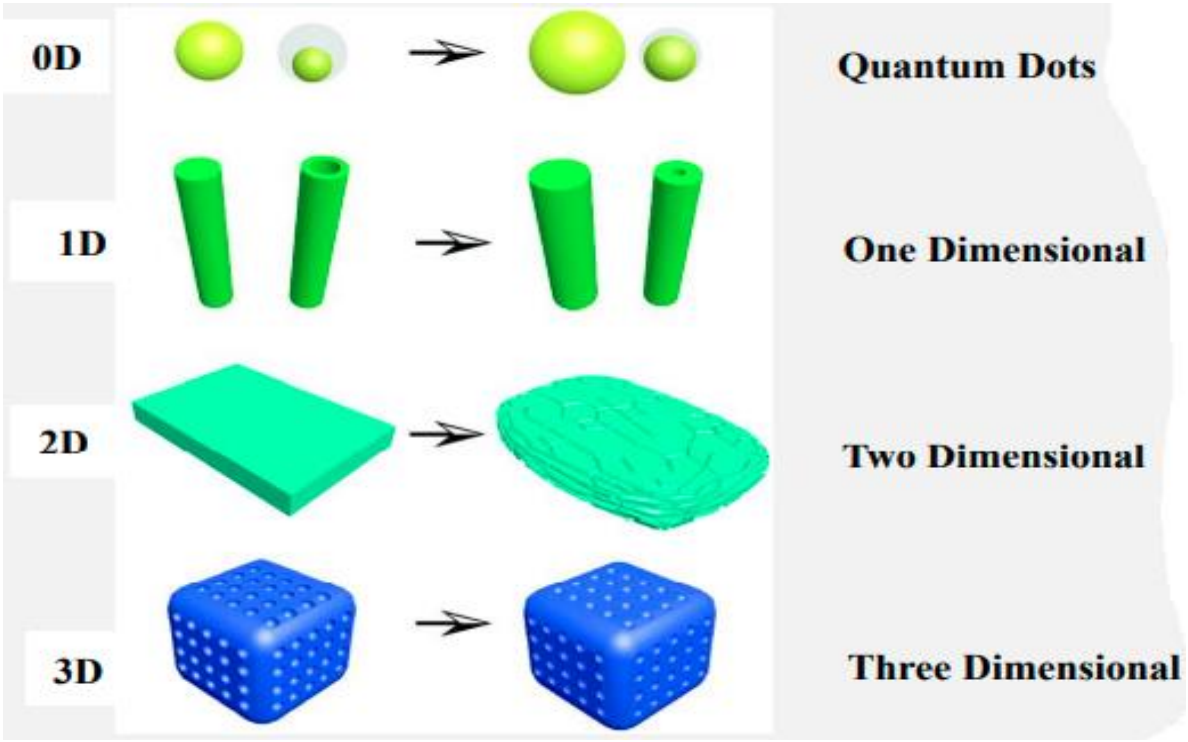
Nano-scale materials can be found in multiple situations and different shapes and dimensions. In general the nano-materials can be divided into:

(i) **Nano-particle** (powder and liquid).
(ii) **Nano-structures** (semiconductor, oxide semiconductor).





The nano-structures could be classified depending on the dimension and shape into:



Quantum Dots (0D)

ONE : Types and Shapes of 0D

- **Spheres (Nanospheres)**

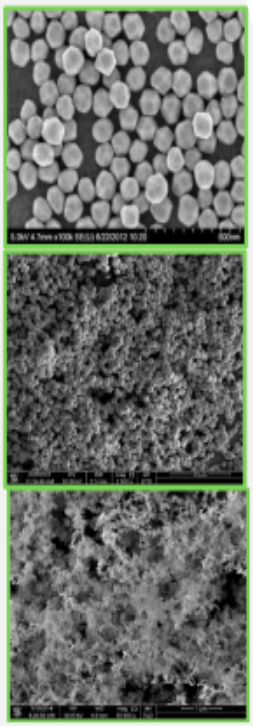
This is the **most common** shape. Most nanoparticles, like those found in **gold or sunscreens**, are **roughly spherical**.

- **Clusters (Nanoclusters)**

These are **smaller than standard nanomaterials** and **consist** of a specific, **small number of atoms**

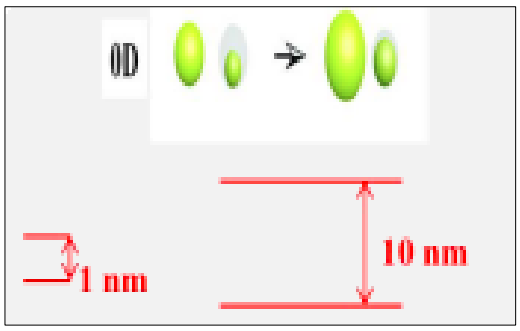
- **Nano-Hollow Spheres**

These are 0D nanomaterials **made of a "shell" with an empty center.**



Shapes of 0D (Quantum Dots)

TWO : Properties of 0D



1-0D diameters can range from about 1-10 nm.

2- 0D represent the smallest type of nano-structures.

3-0D represents the best in properties compared to other types.

4- 0D can used for various applications.

5- One application of 0D is : Tiny semiconductors that emit specific colors of light when hit by electricity. You'll find these in high-end TV displays.

THREE : Applications of 0D

➢ **Next-Generation Display Technology**

If you've seen a **QLED TV**, you've seen **0D nanomaterials in action**.

➢ **Targeted Medicine and Bio-imaging**

0D nanoparticles are **the perfect size** to navigate the **human bloodstream and enter cells.**

➢ **Catalysis and Chemical Processing**

Because 0D materials are basically "**all surface**," they are **incredibly (highly)reactive.**

One Dimensional (1D)

ONE : Types and Shapes of 1D

• **Nanowires:** Solid, wires-like structures with a high length-to-width. They are typically metallic or semiconducting.

• **Nanotubes:** Hollow, cylindrical structures. The most famous example is the Carbon Nanotube (CNT), which can be single-walled or multi-walled.

• **Nanobelts** : These have a rectangular cross-section, looking more like a flat ribbon than a round wire. This shape offers unique mechanical flexibility.

• **Nanorods**: Similar to nanowires but much shorter.

• **Nanoneedles**: Structures that taper to a sharp point at one end, often used in scanning probe microscopy or targeted drug delivery.

TWO : Properties of 1D

1- 1D represents a high surface-to-volume ratio

2- It has **electron confinement properties**

3- This 1D nanostructures is **characterized by its polar nature**

4- 1D have **larger useful for electron transport**

THREE : Applications of 1D

1. Electronics and Optoelectronics

➢ **Field-Effect Transistors (FETs):** Carbon nanotubes and silicon nanowires are used to create transistors that are smaller, faster, and more energy-efficient than traditional silicon chips

➢ **Flexible Displays:** Silver nanowires (Ag-NWs) are used to create flexible display with transparent, conductive films

➢ **Nano lasers:** Cadmium sulfide (CdS) nanowires can act as tiny optical cavities, creating small-sized lasers for high-speed data processing.

2. Energy

➢ **Lithium-Ion Batteries:** Using silicon nanowires in battery allows the material to expand and contract as it absorbs lithium without cracking, which significantly increases battery life and capacity.

➢ **Solar Cells:** Titanium dioxide (TiO2) or Zinc Oxide (ZnO) nanorods help "guide" electrons directly to the electrodes in solar panels, reducing the amount of energy lost as heat.

3- Chemical and Biological Sensors

➢ **Gas Sensing: Tin oxide (SnO_2) nanowires can detect toxic gases at concentrations as low as a few parts per billion.**

➢ **Disease Detection: Nanowires coated with specific antibodies can detect cancer or viruses in a single drop of blood.**

4. Environmental Remediation

➢ **Water Filtration**: **Carbon nanotube membranes** can filter out bacteria and salt ions **while** allowing water molecules to flow through with very little friction, **making desalination process more cost-effective**.

➢ **Photocatalysis**: 1D nanostructures are used **to analyze organic pollutants in wastewater** using **sunlight as the only energy source.**

Two Dimensional (2D)

ONE : Types and Shapes of 2D

• **Nanosheets / Nanoflakes**: The most common form; free-layers with high lateral dimensions.

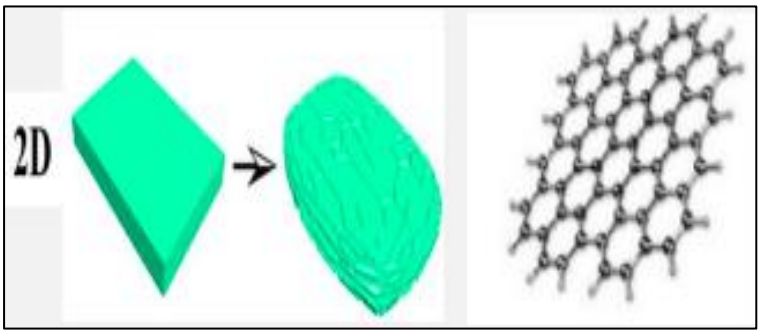
• Nanoleaves: It consist of structures like tree leaves, and is often single layer

• **Nano coatings / Nanofilms**: 2D layers that are deposited directly onto a surface

• **Nano walls:** 2D sheets that grow vertically (standing up) from a substrates walls

• **Nanoplatelets**: Thicker than a single atom but still under 100nm

TWO : Properties of 2D



1- 2D represent single layer materials

2- 2D consisting of a single layer of atoms

3- 2D facilitates tuning of the molecular in the crystal.

4- Can be found as nano-leaves, nano-flags, and nano-sheet.

THREE : Applications of 2D

1. Next-Generation Electronics & Computing

➢ **Ultra-Thin Transistors**: its much thinner and more energy-efficient than silicon, reducing heat in high-performance processors.

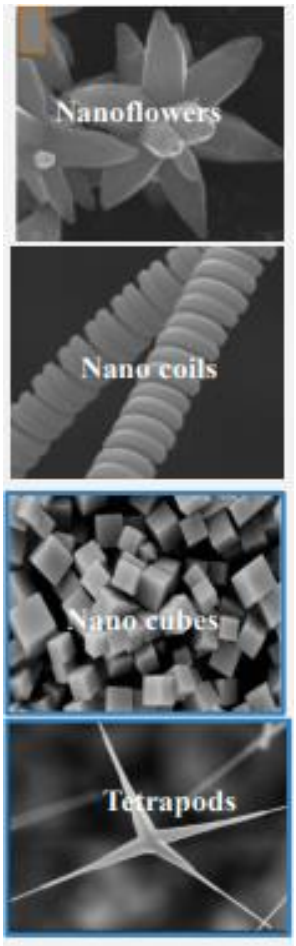
➢ **Flexible & Wearable Techs**: Graphene-based conductive inks are used to print circuits directly onto flexible plastics. This enables "skin sensors" that monitor health without the need for bulky hardware.

➢ **Optoelectronics**: 2D sheets are used in ultra-fast photodetectors and LEDs. Because they are nearly transparent, they are perfect for the next generation of "smart windows" and foldable smartphone screens

2- Energy Storage

2D materials are solving the biggest problems in green energy: how to store and move power quickly.

Two Dimensional (3D)



ONE : Types and Shapes of 3D

▪ **Nano flowers**: These consist **a mixture of 1D** or **2D** "petals" (like nanowires or nanosheets), **that create from a central point**. This shape **provides an high surface area for chemical reactions**.

▪ **Nano coils** : These are 3D **spiral structures**. They are particularly **useful in creating "nanosprings" for microscopic mechanical devices**

▪ **Nano cubes** : Its **represents a specialized class of 0-dimensional (0D)** nanomaterials because they are **confined to the nanoscale in all three spatial dimensions.**

▪ **Tetrapods**: Tetrapod's **appear four arms at 109.5° angle with**

each other. The **sensors based on tetrapods** can give **multiple responses to a single signal at the same time with four arms.** The **junctions in the arms** of tetrapods **play a critical role in the electrical properties. The leges of tetrapods can be designed as multi-terminal sensors**.

TWO : Applications of 3D

➢ **Environmental & Energy Solutions**: 3D nanomaterials are the **leaders in clean energy and reduce pollution** because of their **large internal surface areas.**

➢ **Atmospheric Water** : 3D porous nanomaterials are now **used in desert regions to pull drinkable water from relatively dry air**

➢ **In biology : 3D shapes like "nanoflowers" interact with cells in ways flat materials cannot.**