Fundamentals of nanotechnology

Assit. Prof. Dr. Niveen Jamal Abdulkader

Materials Engineering Department/ University of Technology

3rd Grade/ General Materials Branch

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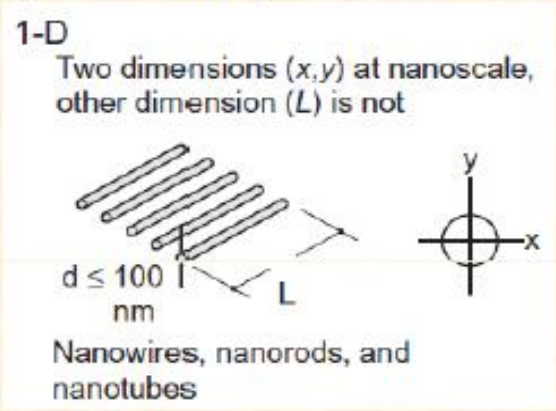
Fundamentals of nanotechnology

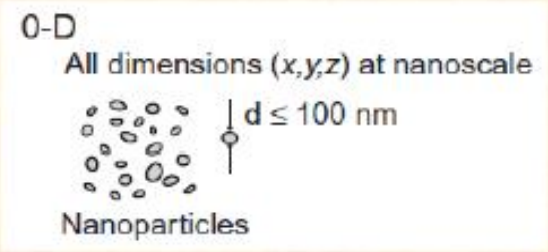
- **Classification of nanostructures by dimensionality**
- Zero-Dimensional Nanostructures
- One-Dimensional Nanostructures:
- Two-Dimensional Nanostructures:
-Three-Dimensional Nanostructures

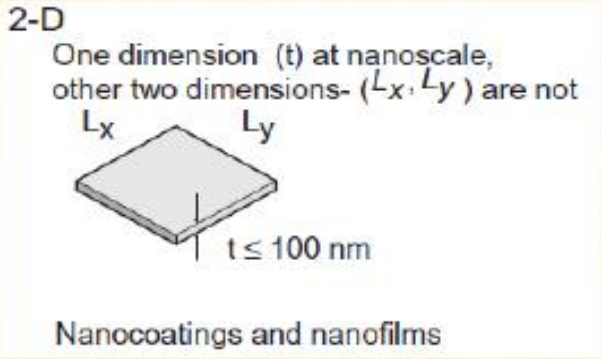
Classification of Nanomaterials

Classification

- Classification is based on the number of dimensions, which are not confined to the nanoscale range (<100 nm).
- (1) zero-dimensional (0-D),
- (2) one-dimensional (1-D),
- (3) two-dimensional (2-D), and
- (4) three-dimensional (3-D).







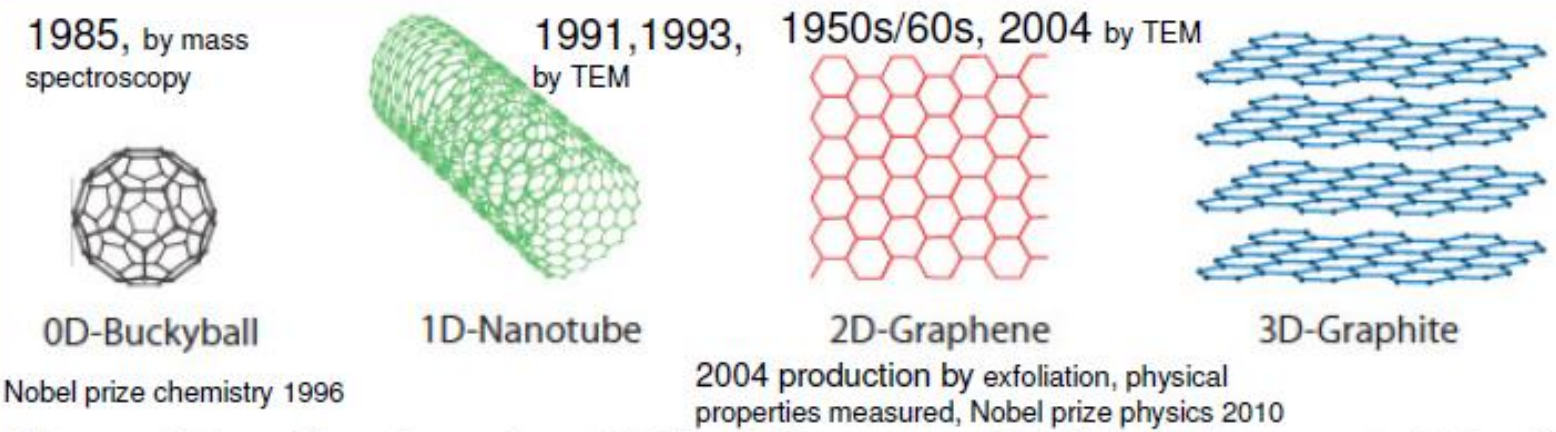


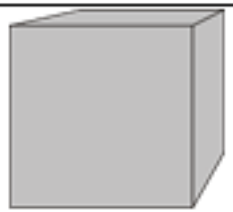
Figure 9.4. Graphene is a 2D building material for carbon materials of all other dimensionalities. It can be wrapped up into 0D buckyballs, rolled into 1D nanotubes or stacked into 3D graphite.

Classification of Nanomaterials

Nanomaterials can be classified dimension wise into following categories.

1. Zero-dimensional (0-D) nanomaterials: nanoclusters and nanodispersions etc.
2. One-dimensional (1-D) nanomaterials: nanofibers, nanorods, nanotubes etc.
3. Two-dimensional (2-D) nanomaterials: nanofilms, nanocoatings etc.
4. Three-dimensional (3-D) nanomaterials: quantum dots, nanoparticles, fullerene, fibrous, multilayer and polycrystalline materials

Classification of Nanomaterials

Number of nanosized dimensions nano-D = nD	Number of bulk dimensions (D)	Examples	
3 *(Nanoparticles, nanocrystals)*	0	nanoparticles, nanocrystals	
2 *(Nanowires, nanorods, nanotubes)*	1	nanowires, nanorods, nanotubes	
1 *(Nanolayers, nanofilms)*	2	nanofilms, nanocoatings, nanolayers	
0	3	quantum dots, nanoparticles,	

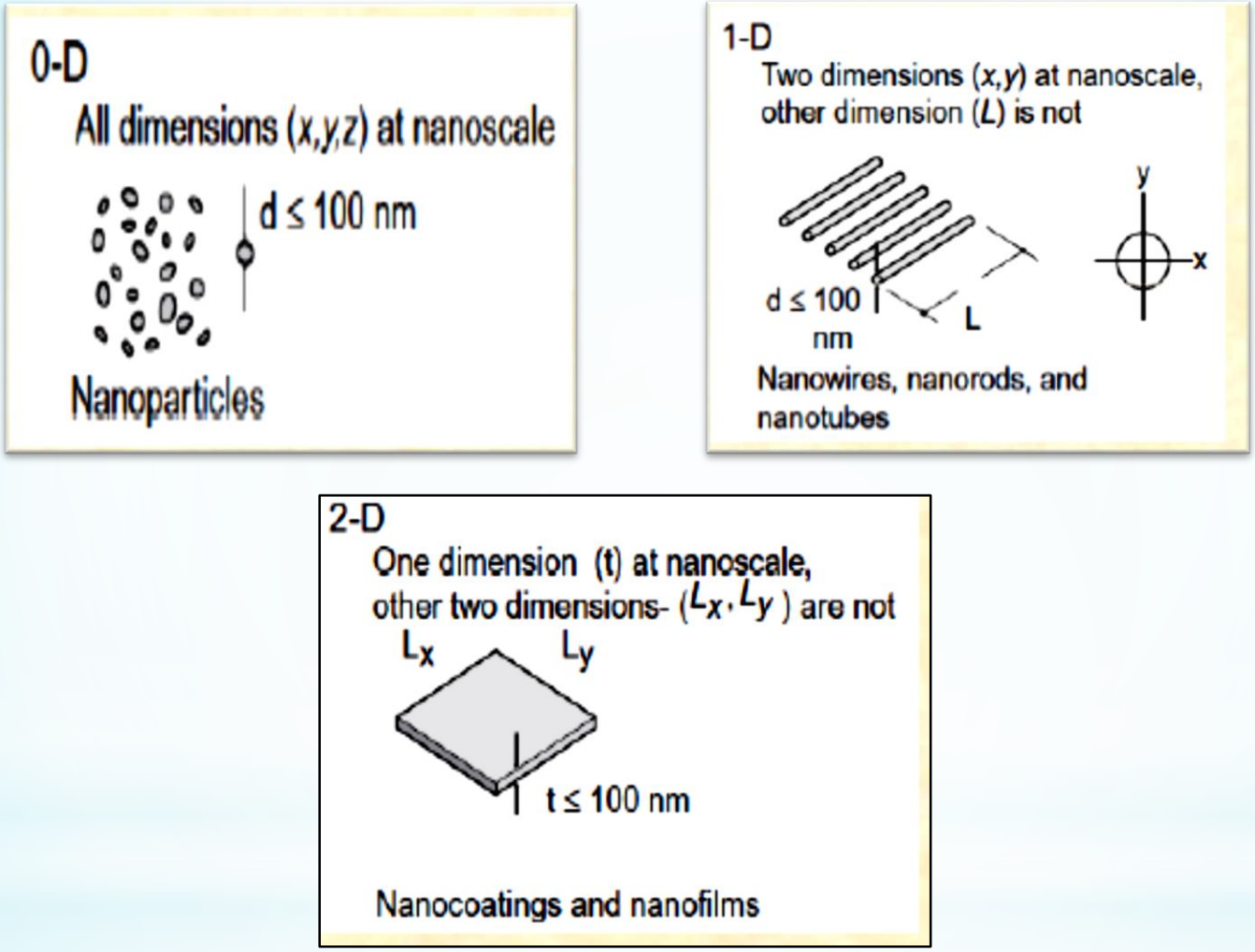
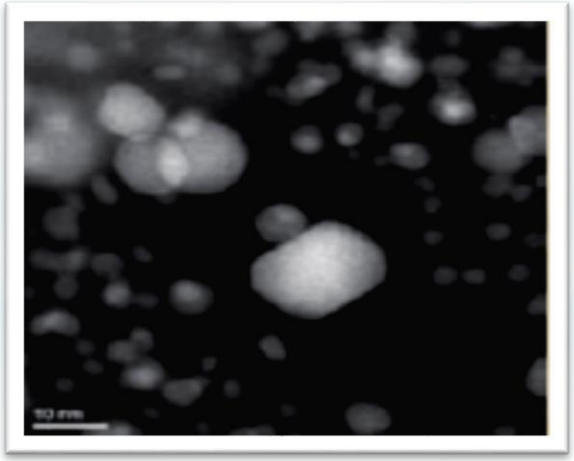


Figure 1. (0D), 1D and 2D nanomaterials.

Zero-dimensional nanomaterials

Nanoparticles can:

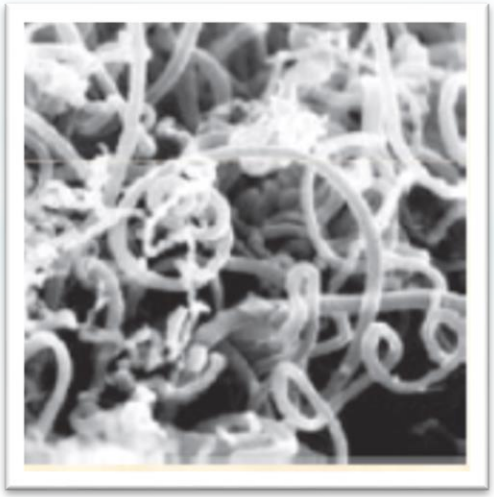
* Be amorphous or crystalline
* Be single crystalline or polycrystalline
* Be composed of single or multi-chemical elements
* Exhibit various shapes and forms
* Exist individually or incorporated in a matrix
* Be metallic, ceramic, or polymeric



One-dimensional nanomaterials

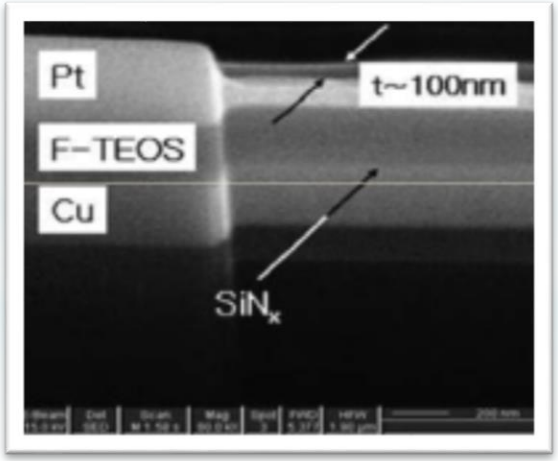
1-D nanomaterials can be

* Amorphous or crystalline
* Single crystalline or polycrystalline
* Chemically pure or impure
* Standalone materials or embedded in within another medium
* Metallic, ceramic, or polymeric



2-D nanomaterials 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



Three-dimensional nanomaterials

* Bulk nanomaterials are materials that are not confined to the nanoscale in any dimension. These materials are thus characterized by having three arbitrarily dimensions above 100 nm.

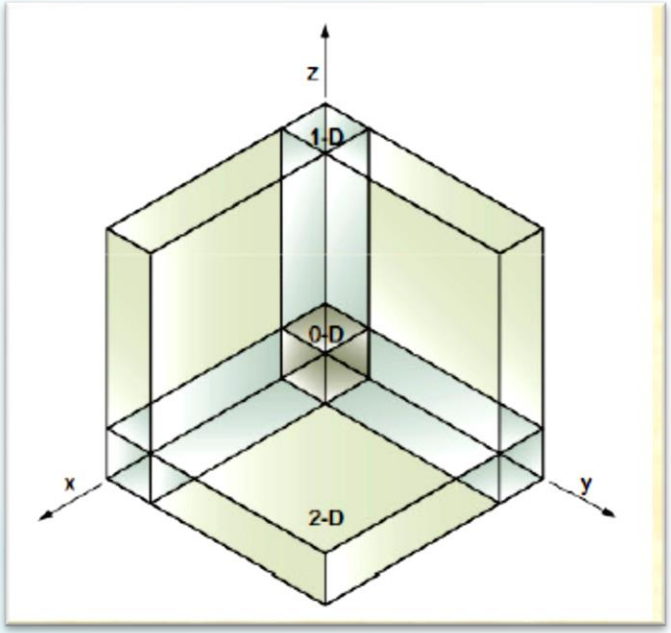
*Materials possess a nanocrystalline structure or involve the presence of features at the nanoscale.

*In terms of nanocrystalline structure, bulk nanomaterials can be composed of a multiple arrangement of nanosize crystals, most typically in different orientations.

*With respect to the presence of features at the nanoscale, 3-D nanomaterials can contain dispersions of nanoparticles, bundles of nanowires, and nanotubes as well as multinanolayers.

Three-dimensional space showing the relationships among 0-D, 1-D, 2-D, and 3-D nanomaterials.

Three-dimensional space showing the relationships among 0-D, 1-D, 2-D, and 3-D nanomaterials.



0-D:	All dimensions at the nanoscale
1-D:	Two dimensions at the nanoscale, one dimension at the macroscale
2-D:	One dimension at the nanoscale, two dimensions at the macroscale
3-D:	No dimensions at the nanoscale, all dimensions at the macroscale