Nanotechnology Course/ Ph-457 Lecture 1

Fundamentals Properties of Nanomaterials

By

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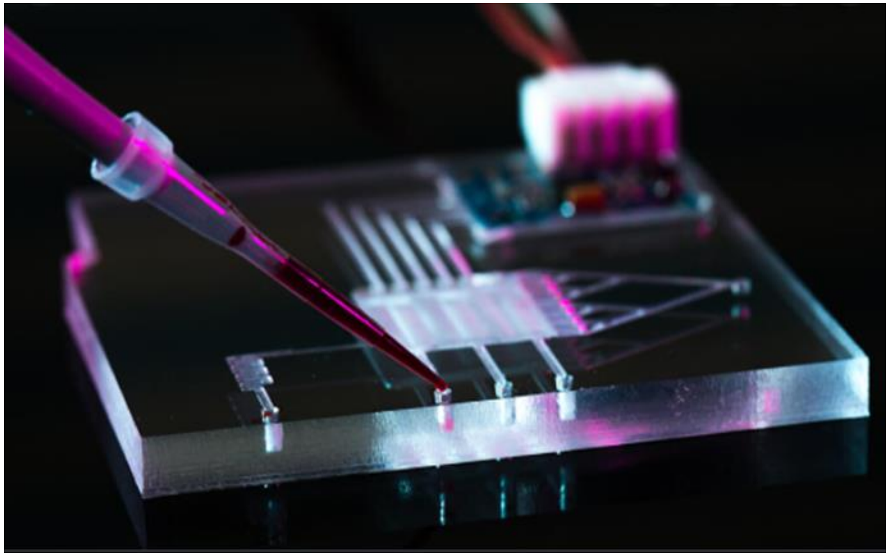
The topics of the course

- Chapter One: Fundamental Properties of Nanomaterials
- Chapter Two: Preparation Methods of Nanomaterials
- Chapter Three: Nanomaterials Characterization
- Chapter Four: Application of Nanomaterials

What is the Nanotechnology?

- The National Nanotechnology Initiative characterizes nanotechnology as manipulating matter with at least one dimension between 1 and 100 nanometers.



What is the Nanotechnology?

- NASA is defined nanotechnology as “The creation of functional materials, devices and systems through control of matter on the nanometer length scale (1–100 nm), and exploitation of novel phenomena and properties (physical, chemical, biological) at that length”.

How small is Nanoscale?

- Nano is Greek means dwarf but Nano is infinitely smaller than a dwarf.

- It is one billionth of a meter or 10^{-9} m.

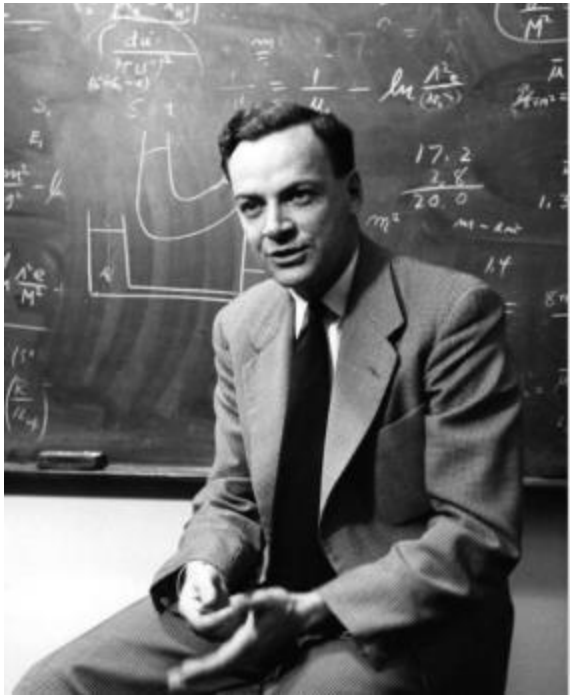
How small is Nanoscale

- The nanometer is the scale used to measure objects in the nanoworld.

10. Elephant	5 m
9. Human	1 m
8. Head of pin	2 mm
7. Grain of sand	1 mm
6. Dust mite	200 µm
5. Human hair	100 µm
4. Red blood cell	10 µm
3. Virus	100 nm
2. Diameter of DNA	2 nm
1. Atom	0.1 nm

History of Nanomaterials

- Richard Feynman, a Nobel Laureate in Physics, delivered the inaugural lecture on the applications of nanoscale materials. His lecture, titled "There's Plenty of Room at the Bottom," was presented on 29 December 1959 during the annual meeting of the American Physical Society at the California Institute of Technology.



History of Nanomaterials

- In 1974 **Norio Taniguchi** first used the defined term nanotechnology as: **mainly consisting of the processing of separation, consolidation, and deformation of materials by one atom or one molecule**

History of Nanomaterials

Table 1.2 Chronological table of nanotechnology.

Year	Remarks	Country/people
1200–1300 BC	Discovery of soluble gold	Egypt and China
290–325 AD	Lycurgus cup	Alexandria or Rome
1618	First book on colloidal gold	F. Antonii
1676	Book published on drinkable gold that contains metallic gold in neutral media	J. von Löwenstern-Kunckel (Germany)
1718	Publication of a complete treatise on colloidal gold	Hans Heinrich Helcher
1857	Synthesis of colloidal gold	M. Faraday (The Royal Institution of Great Britain)
1902	Surface plasmon resonance (SPR)	R. W. Wood (Johns Hopkins University, USA)
1908	Scattering and absorption of electromagnetic fields by a	G. Mie (University of Göttingen, Germany)

Some Physical Properties of Nanomaterials

- **Magic Numbers**

As previously mentioned, a reduction in particle radius results in an increased surface-to-volume ratio. Consequently, the proportion of surface atoms rises as the particle size diminishes. Generally, for a sphere, the relationship between the number of surface and bulk atoms can be expressed by specific formulas. **The fraction of atoms F_A** on the surface of a spherical nanoparticle can be expressed as

$$F_A = \frac{3}{r_A n^{1/3}}$$

- **Surface area A** and **volume V of the nanoparticles** were calculated in the following format equations:

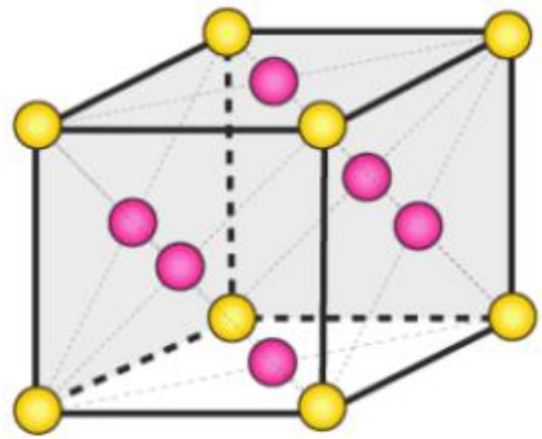
$$A = 4\pi r_A^2 n^{2/3} \qquad V = \frac{4\pi}{3} r_A^3 n$$

- r_A is the atomic radius, n is the number of atoms

Some Physical Properties of Nanomaterials

- Consider a crystalline nanoparticle as an example: in addition to the particle's morphology (shape), we must also consider its crystalline structure.
- For demonstration purposes, we consider a nanoparticle exhibiting a face-centred cubic (FCC) structure. This crystal structure holds practical significance, as nanoparticles of gold (Au), silver (Ag), nickel (Ni), aluminium (Al), copper (Cu), and platinum (Pt) display structure.

❖ FCC has 14 atoms on the surface



Face-centred Cubic Unit Cell (FCC)

- The total number of surface atoms: $N^S_{total} = 12\,n^2 + 2$
- The total number of Bulk atoms:

$$N^B_{total} = 4n^3 - 6n^2 + 3n - 1$$

Some Physical Properties of Nanomaterials

- **Why is the magic number important??**

1) Enhanced Stability

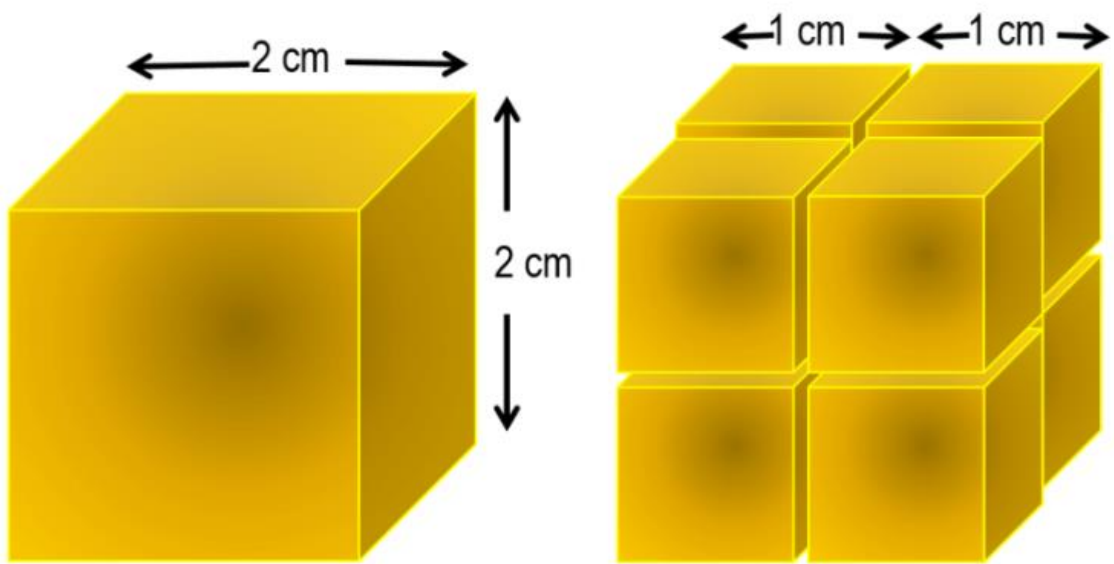
Nanostructures with magic numbers often exhibit greater stability due to their optimized atomic arrangements, leading to lower surface energies and increased resistance to aggregation or degradation.

2) Unique Properties

The particular atomic arrangements linked to magic numbers can yield unique electrical, optical, magnetic, or catalytic characteristics.

Some Physical Properties of Nanomaterials

- **Surface area-to-volume ratio**



# of Cube (s)	Dimensions (cm)	Surface Area ($l \times l \times 6$ cm^2)	Volume ($l \times l \times l$ cm^3)	Surface Area/Volume ratio
1	2 x 2	(2 x 2 x 6) = 24	(2 x 2 x 2) = 8	3
8	1 x 1	8 (1 x 1 x 6) = 48	8 (1 x 1 x 1) = 8	6

Reference of image: https://www.thepsci.eu/nano/

Some Physical Properties of Nanomaterials

How would the total surface area increase if a cube of 1 m^3 were progressively cut into smaller and smaller cubes, until it is formed of 1nm^3 cubes? **Table 1** summarises the results.

Size of cube side	Number of cubes	Collective Surface Area
1 m	1	6 m^2
0.1 m	1000	60 m^2
0.01 m = 1cm	10^6 = 1 million	600 m^2
0.001 m = 1mm	10^9 = 1 billion	6000 m^2
10^{-9} m = 1 nm	10^{27}	$6x10^9$= 6000 Km^2

THANK YOU