1. Nanomaterials

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NANOMATERIALS

- Nano ⟶ Greek word "dwarf"
- 1 nm = 10^{-9} m
- 1 nm = 10 "H" atoms (or) 5 "Si" atoms

SEM: Scanning Electron Microscope

TEM: Transmission Electron Microscope

AFM: Atomic Force Microscope

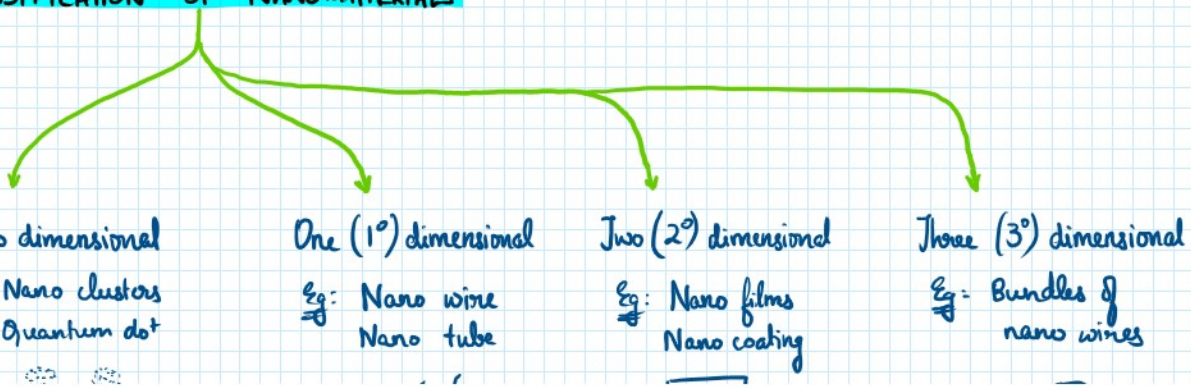
NANOSCIENCE, NANOTECHNOLOGY

- Design
- Structure
- Characterization
- Properties
- Applications

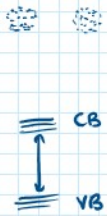
BULK MATERIALS & NANOMATERIALS : PROPERTIES

METAL / PROPERTY	BULK	NANO
Gold (Au)	Yellow	Red
Aluminium (Al)	Non-combustible	Combustible
Melting point	HIGH	LOW
Conductivity	HIGH	LOW

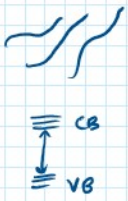
CLASSIFICATION OF NANOMATERIALS



Eg: Nano clusters
Quantum dot

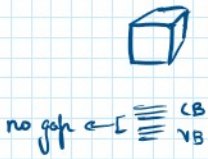


Eg: Nano wire
Nano tube



Eg: Nano films
Nano coating

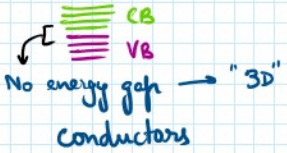
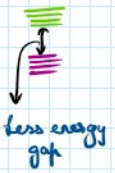
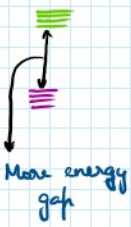
Eg: Bunches of nano wires



WHY DO NANOMATERIALS EXHIBIT DIFFERENT PROPERTIES?

- Large surface area
- Spatial confinement / Quantum confinement
- Energy gap
- Reduced imperfections

PROPERTIES OF NANOMATERIALS

PROPERTY	BULK	NANOMATERIALS	
① Surface area	Less surface area	More surface area [depends on material]	
② Spatial confinement / Quantum confinement		2D  1D  Semiconductors	0D  Insulator
③ Energy gap $\propto \frac{1}{\text{atom size}}$	No energy gap	Some energy gap	More energy gap
④ Imperfections	More crystal imperfections	Reduced crystal imperfections	

SURFACE AREA DEPENDENT PROPERTIES

PROPERTY	BULK	NANOMATERIALS
Surface atoms	More	Less

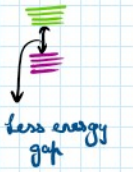
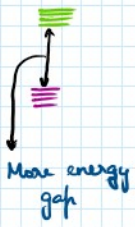
Surface atoms	More	Less
Surface area	Less	More
Weight	More	Less
Catalytic activity	Less reactive	More reactive
Combustion	Non-combustible	Combustible
Chemical reactivity	Less reactivity	More reactivity

PROPERTIES

- Electrical
- Optical
- Mechanical
- Thermal
- Magnetic

ELECTRICAL PROPERTIES

Depends on spatial/quantum confinement, surface scattering

PROPERTY	BULK	NANOMATERIALS	
		2D / 1D	0D
Spatial confinement / Quantum confinement	 No energy gap → "3D" exhibits conductivity	 less energy gap;  Slightly more energy gap; Semiconductors → less conductivity	 More energy gap; Insulator
Surface scattering	Conductivity increases	ELASTIC SCATTERING: Conductivity increases	INELASTIC SCATTERING: Conductivity decreases. • free e^- path • scattered e^- loses

		• free e^- path • scattered e^- loses its velocity
Surface area	Less surface area	More surface area
Crystal	More crystal defects	Less crystal defects

OPTICAL PROPERTIES

Depends on Surface Plasmon Resonance (SPR) and energy gap

NOTE: Surface Plasmon Resonance (SPR)

Positive crystal lattice surrounded by e^-

→ Surface e^- are polarised → These e^- oscillate with certain frequency → These oscillations are collectively known as plasmon

→ Plasmon frequency matches incident radiation frequency → Resonance occurs → SPR exhibits colours

NOTE: Energy gap

Energy gap $\propto \frac{1}{\text{nanoparticle size}}$ (Bulk → no energy gap)

Au size	Wavelength
100 nm	λ = 575 nm
10 - 20 nm	λ = 524 nm
6 - 10 nm	λ = 517 nm

↓ Blueshift

MECHANICAL PROPERTIES

PROPERTY	BULK	NANOMATERIALS
Surface area	Less surface area	More surface area

Surface area	Less surface area	More surface area
Strength	Less strength	More strength >50 nm Cu ⟶ super hard material
Physical characteristics	Shows malleability, ductility	Does not show malleability, ductility
Energy gap	Energy gap = 0	2D, 1D ⟶ less energy gap ↓ semiconductors 0D ⟶ more energy gap ⟶ insulators

THERMAL PROPERTIES

PROPERTY	BULK	NANOMATERIALS
Thermal conductivity	Increases	Thermal conductivity ⟶ less ↓ due to crystal lattice vibration ← [phonon scattering ↳ discrete quantized quantity of vibrational mechanical energy
Number of bands	More no. of bands	Less no. of bands
Surface area	Less	More

MAGNETIC PROPERTIES

PROPERTY	BULK	NANOMATERIALS
Magnetic characteristics	Fe, Co, Ni ferromagnetism Pt, Au non-magnetic	Fe, Co, Ni superparamagnetism Pt, Au exhibits magnetism
Surface area	low surface area	High surface area
Catalyst (Au, Ag)	Less catalytic activity	More catalytic activity
Energy gap	No energy gap	SEMICONDUCTORS: Less energy gap

Energy gap	No energy gap	SEMICONDUCTORS: Less energy gap INSULATORS: More energy gap

APPLICATIONS

M: Medical applications ⟶ Nanomedicine, nanobots

E: Energy Storage Device ⟶ Batteries, fuel cells

E: Environment ⟶ CO_2, NO_2, NO_3, CO

E: Electronics ⟶ CdS, ZnS

C: Cosmetics ⟶ ZnO, TiO_2

C: Catalyst ⟶ Au, Ag (more catalytic activity)