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Wollo University-Kombolcha Institute of Technology

Department of Chemical Engineering

Engineering Materials (ChEg4131)

by

Alamrew B.

2020/2021



General Information:



➤ Course Information

- ✓ Academic year: 2019/2020
- ✓ Study Points: 3 Cr
- ✓ Duration: 48 hrs.
- ✓ Periodicity: 2nd semester

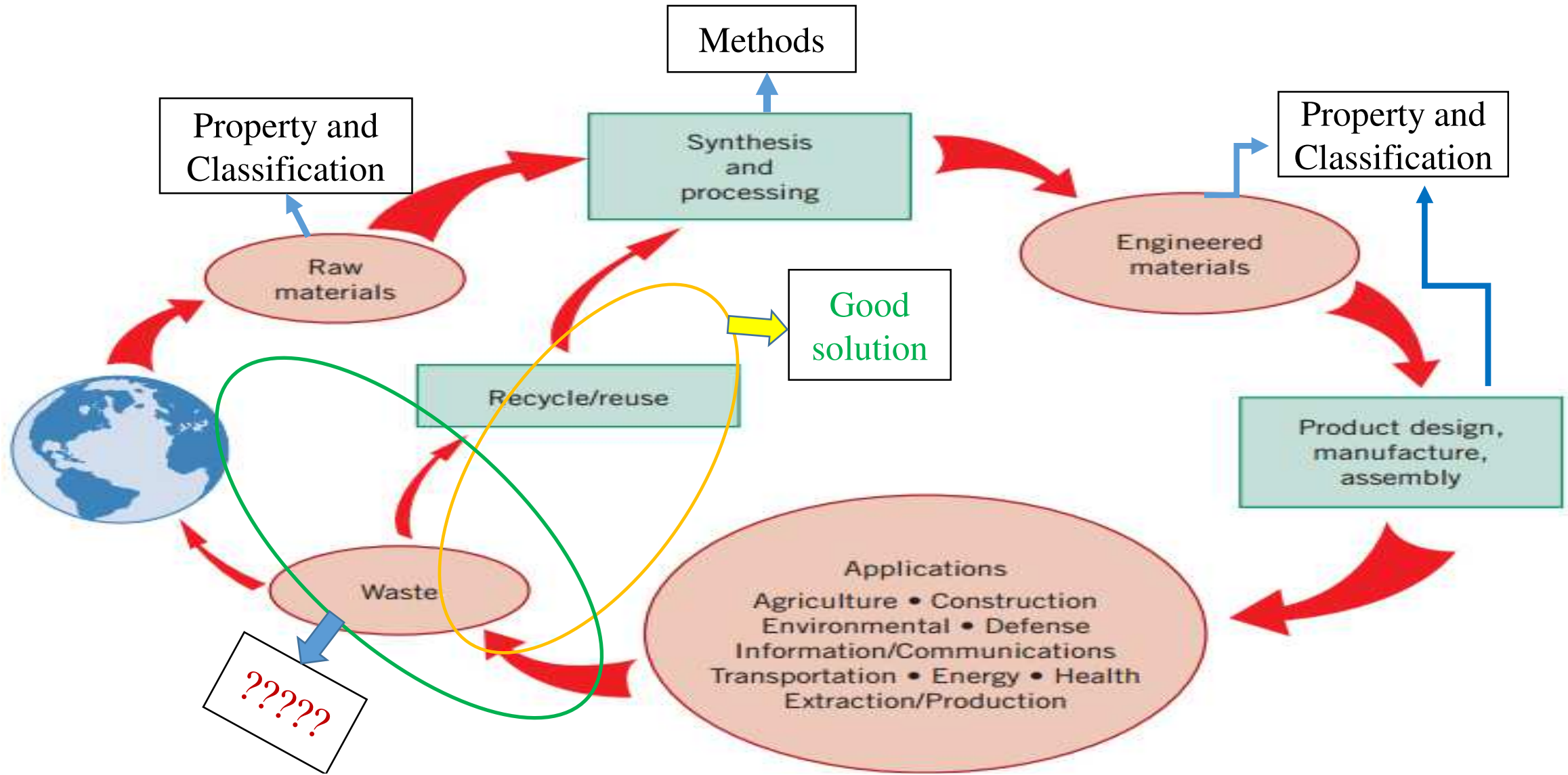
➤ Course objective

The course will covers

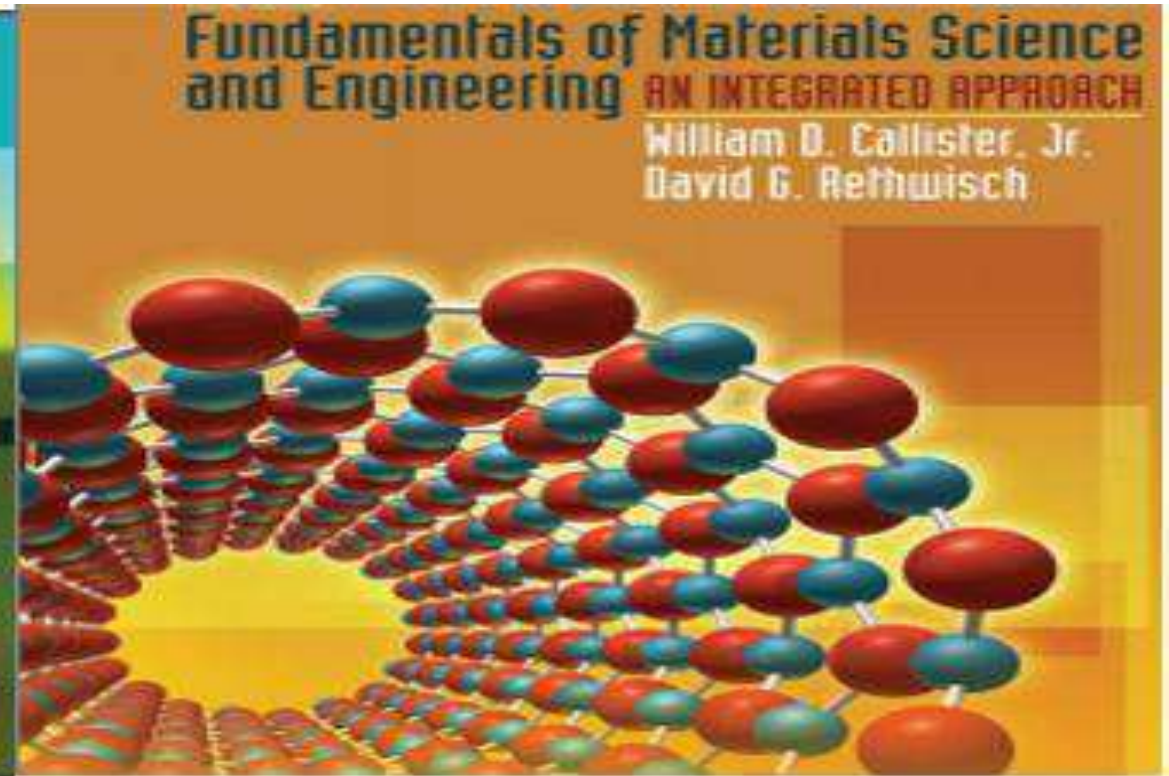
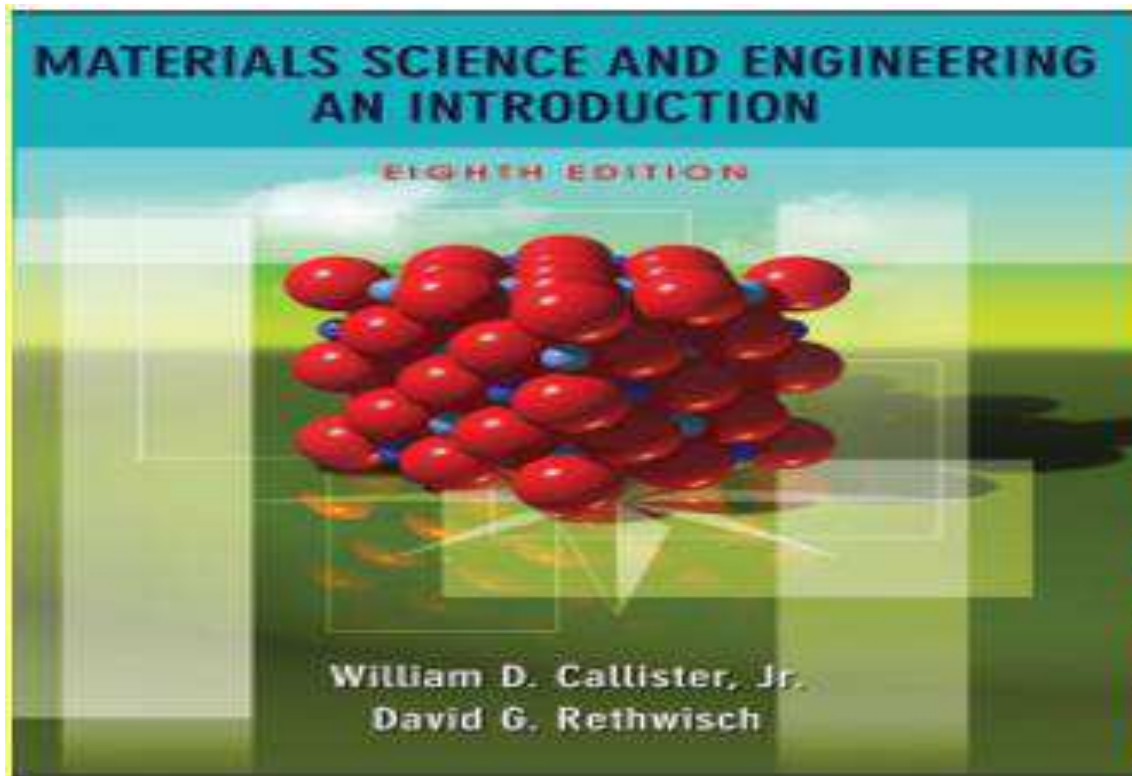
- ✓ properties of materials with an emphasis on understanding fundamental issues.
- ✓ Relationships between the processing, micro and macro structure of materials with their properties.



➤ Course Objectives



- ✓ William D. Callister, Jr. Fundamentals of Materials Science
- ✓ Er. R.K.Rajput . Text book of Materials Science and Engineering
- ✓ Fundamental of material science and Engineering; An Integrated Approach, 2nd. Ed.





Course Contents



- ✓ Introduction.
- ✓ Properties of Materials.
- ✓ Classification of materials.

Chapter one

- ✓ Atomic Structure and Inter-atomic Bonding.
- ✓ Structures of Metals, Ceramics and Polymers.

Chapter two

- ✓ Imperfections in Solids and Diffusion.
- ✓ mechanism of deformations and Strengthening in crystalline materials.

Chapter three

- ✓ Failure, Phase Diagram and Transformations.
- ✓ Corrosion and Degradation.
- ✓ Selection of engineering materials.

Chapter four

- Coca-Cola beverage fabricates three different material types are the containers. Beverages are marketed in aluminum (**metal**), glass (**ceramic**) and plastic (**polymer**) bottles.



Why, How, What ????????????

MATERIALS SCIENCE AND ENGINEERING

❖ **Materials Science:**

- ✓ Involves investigating the effect of the *structure* (in different scales: atomic, crystalline, micro, and macro) on *materials properties*.

Materials engineering:

- Focuses on determining the relationships among *structure*, *technological process*, and *functional properties*, and also the selection of materials and technological processes forming their structure and properties.
- The four components of the discipline of materials science and engineering and their interrelationships are

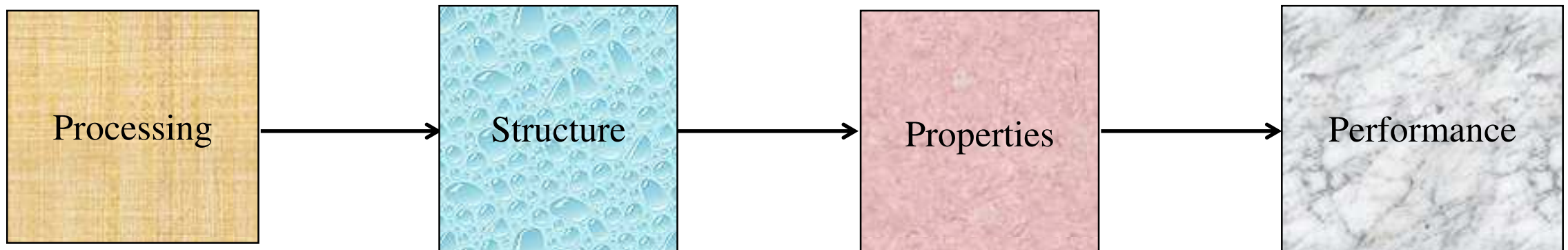
➤ **Materials scientist:**

✓ develop or synthesize *new materials*.

➤ **Materials engineer:**

✓ Create *new products or systems* using existing materials

✓ Develop *techniques for processing materials*.



❖ Why do we study materials?

➤ *To solve design problems involving materials.*

Examples:-

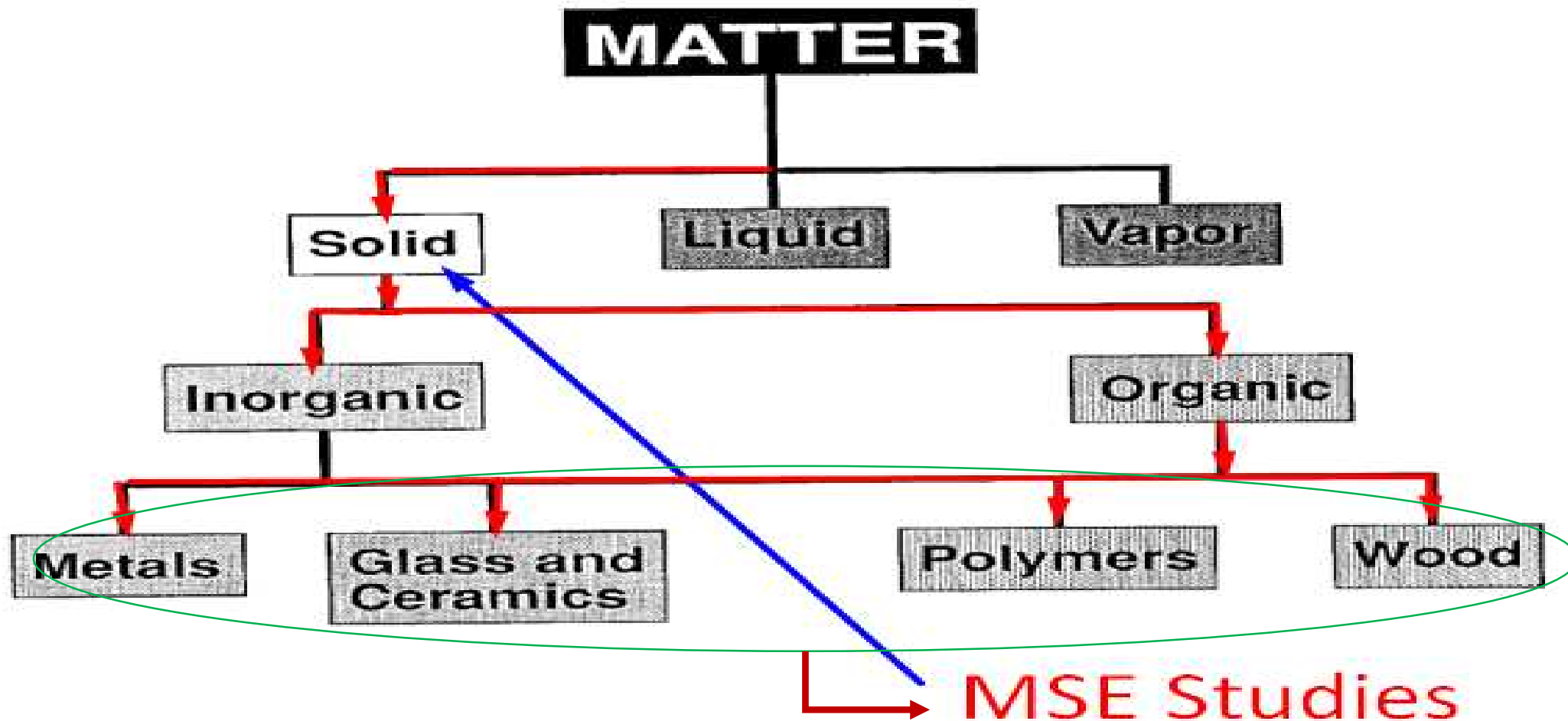
- ✓ To select appropriate materials
- ✓ Structure for a building and design products
- ✓ ***An oil refinery components***
- ✓ For an integrated products ex electronic chip
- ✓ Etc. **read more.....??????????**

THE CHALLENGE!!!

- ✓ *Selecting the right material from the thousands that are available.*

Classification of Matters

➤ Physical Classification by State





Classification of Matters



❖ Traditionally, Materials Science and Engineering is a multidisciplinary approach to science that involves designing, choosing, and using **the following major classes of materials:**

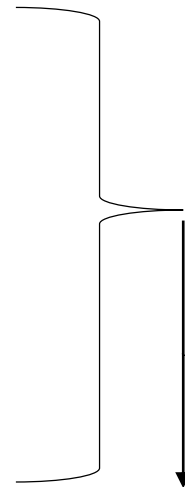
➤ Metals

➤ Ceramics

➤ Polymers

➤ Composites

➤ *Advanced Materials*



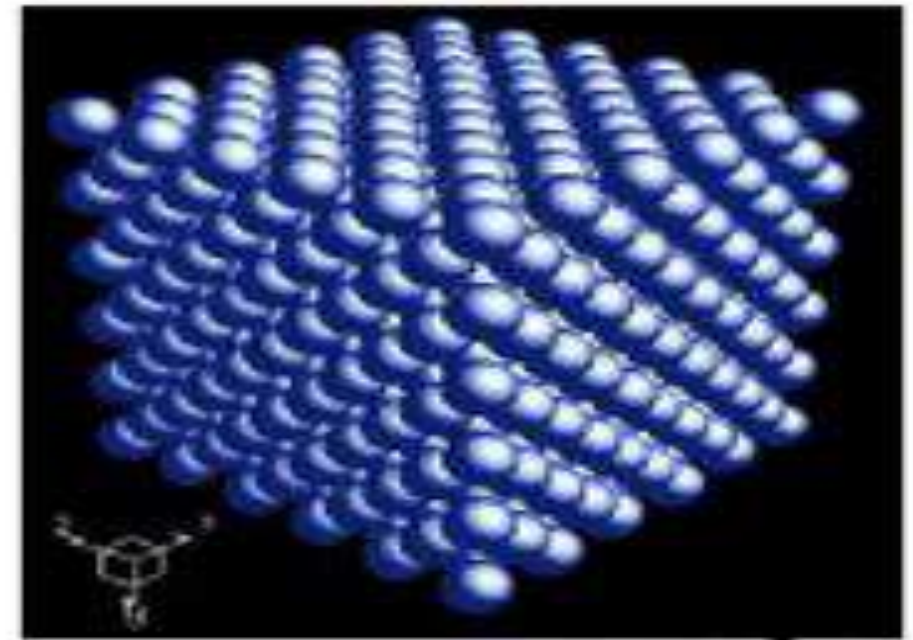
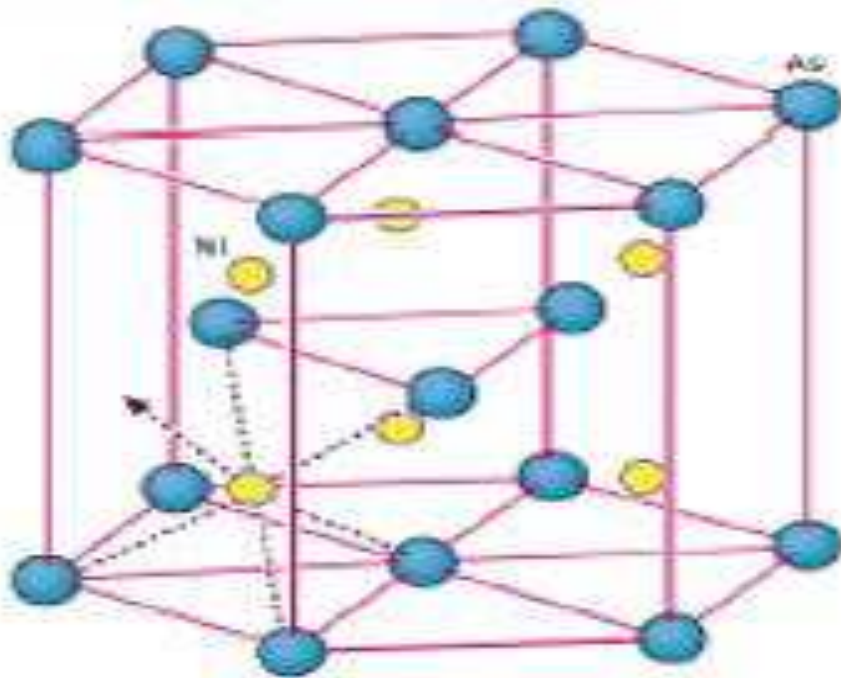
Nano materials

Conductors and insulators

Smart Materials

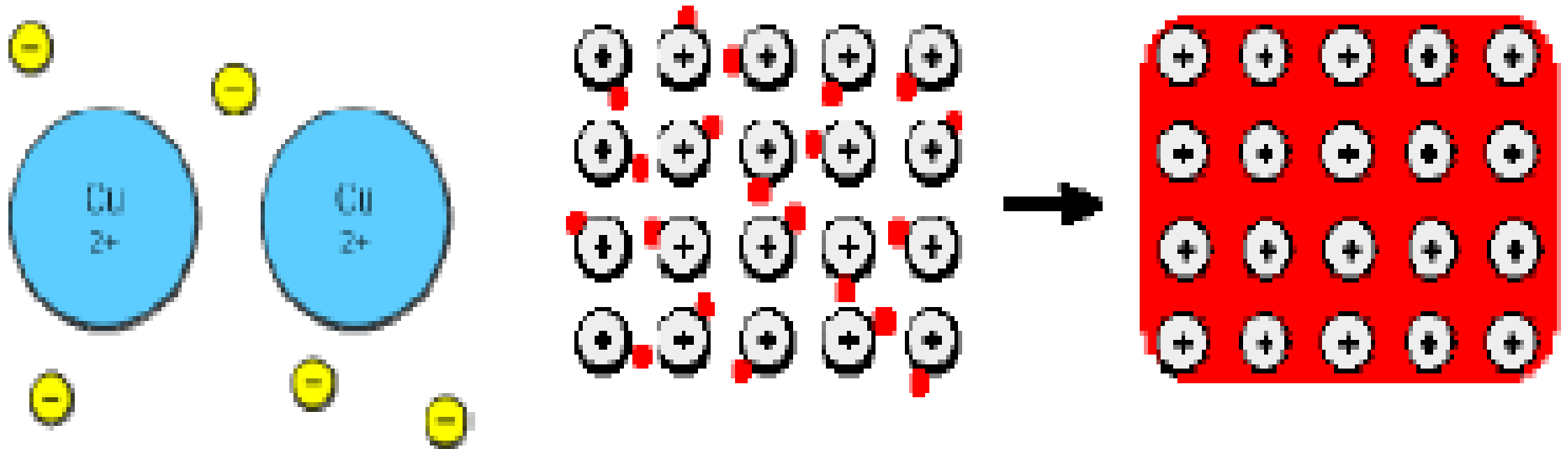
➤ Metals

- Composed of one or more **metallic elements** (e.g., Fe, Al, Cu, Ti, Au, and Ni), and often also incorporate non-metallic elements (e.g., C, N₂, and O₂) in relatively small amounts.
- Arranged in ***ordered manner (crystalline)*** and are ***dense***.



➤ Metals

- Are relatively *stiff* and *strong* yet are *ductile*, and are *resistant to fracture*.
- Have large numbers of *nonlocalized electrons* which are not bound to particular atoms.





❖ *Ceramics*

- Are compounds between **metallic** and **non-metallic elements**
- Are most frequently **oxides, nitrides, and carbides**.
Example: Al_2O_3 , SiO_2 , SiC , Si_3N_4
- Are relatively **stiff** and **strong** and typically **very hard**
- Exhibited **extreme brittleness** (lack of ductility) and are highly susceptible to **fracture**.

❖ *Ceramics*

- Are typically insulated to *heat* and *electricity*
- Are more resistant to *high temperatures* and *harsh environments* than metals and polymers.



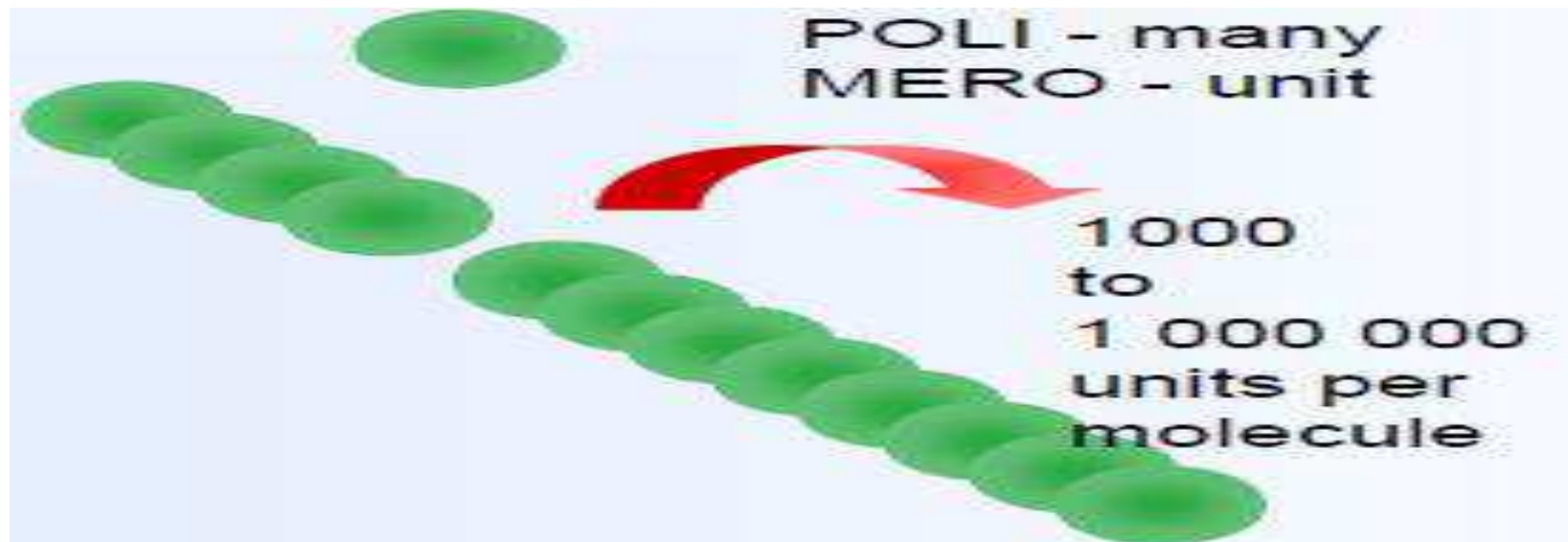


❖ *Polymers*

- Include the familiar **plastic** and **rubber materials**.
- Are **organic compounds** that are chemically based on **C, H**, and Other non-metallic elements (i.e., **O, N**, and **Si**).
- Have very large molecular structures, often chainlike in nature, that often have a backbone of carbon atoms.
 - **Examples:** PE, PVC, PC, PS, silicone rubber.

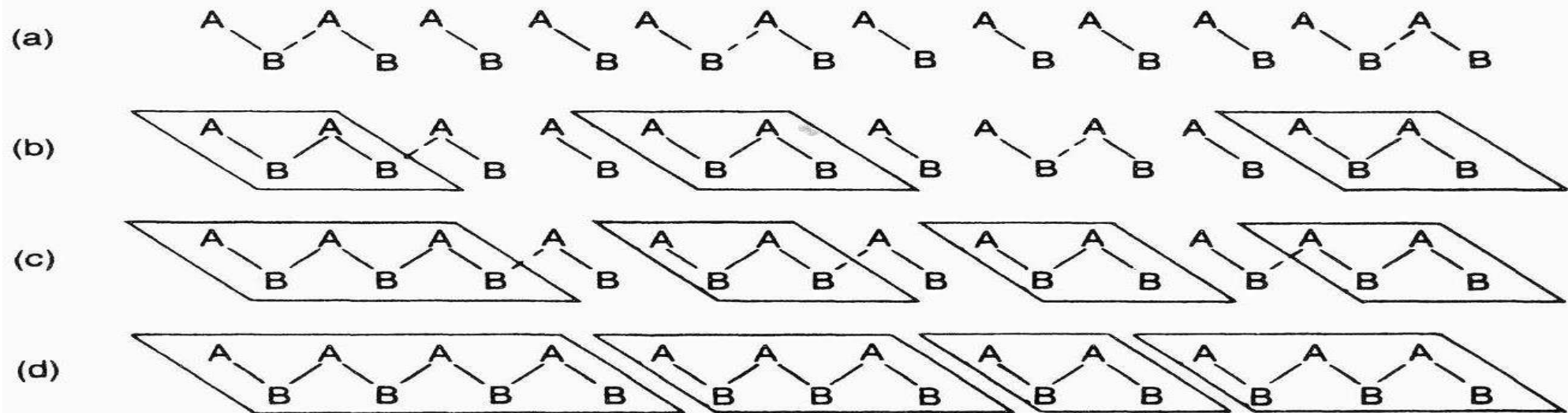
❖ *Polymers*

- Are materials formed by very large molecules – usually called **macromolecules**
- In a polymer a small group of atoms is repeated several times to form the macromolecule.
- This small group of atoms is the repeating unit of the polymer (**monomers**).



❖ Polymers

Step-Growth Polymerization



❖ *Polymers*



- The number of times the repeating unit is repeated in a polymer macromolecule is the *degree of polymerization (n)*.

- C_4H_{10} : gas
- C_5H_{12} : liquid
- $\text{C}_{16}\text{H}_{34}$: solid (wax)



❖ *Polymers*

- Have **low densities** and **not as stiff nor as strong** as metals and ceramics
- However, on a **per-mass basis** are comparable to the metals and ceramics.
- Many of them are **extremely ductile and pliable** (i.e., plastic) (i.e., easily formed into complex shapes).
- Are relatively **inert chemically** and **unreactive** in a large number of **low electrical conductivities** and are **nonmagnetic**. environments.
- **Drawback:** their tendency to **soften and/or decompose** at modest temperatures which limits their use.

❖ *Polymers*





❖ *Composites*

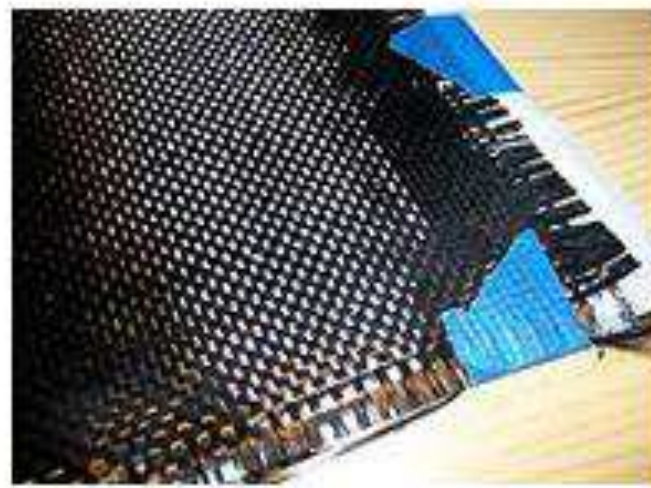
- Are composed of two (or more) individual materials (metals, ceramics, and polymers).
- *Design goal:*
 - ✓ to achieve a *combination of properties* that is not displayed by any single material
 - ✓ to *incorporate the best characteristics* of each of the component materials.

❖ Composites

- some naturally occurring materials are composites—for example, **wood** and **bone**.
- **Example: fiberglass**, in which small glass fibers are embedded within a **polymeric material** (normally an epoxy or polyester).



Plywood



A cloth of woven carbon fiber filaments



Fibre-reinforced composite materials



• *Advanced Materials*

- utilized in *high-technology applications*.
- Are used for devices or products that function using relatively *intricate and sophisticated principles*.

Examples :-

- ✓ electronic equipment (camcorders, CD/DVD players, etc.)
- ✓ computers
- ✓ fiber-optic systems
- ✓ Spacecraft, Aircraft, military rocketry.
- Include:-
 - ✓ **Semiconductors**
 - ✓ **Biomaterials**
 - ✓ smart materials and **Nano engineered materials**



❖ *Advanced Materials*

Semiconductors

- have electrical properties that are intermediate between the electrical *conductors* and *insulators*
- Their electrical properties are extremely sensitive to the presence of minute concentrations of *impurity atoms*.
- Have made possible the advent of *integrated circuitry* that has totally revolutionized *the electronics and computer industries*.



❖ *Advanced Materials*

❖ *Electrical conductors and insulators*

- Employed in *components implanted into the human body* to replace diseased or damaged body parts.
- Must not cause adverse biological reactions.
- *Metals, ceramics, polymers, composites, and semiconductors* may be used as *biomaterials*.



❖ *Advanced Materials*

✓ **Smart Materials**

- are materials which are able to *sense changes in their environment* and then respond to these changes in predetermined manners.
- have components of a *sensor* (that detects an input signal), and an *actuator* (that performs a responsive and adaptive function).

- ✓ **Sensors:** -optical fibers piezoelectric materials
 - ❖ microelectromechanical systems

- ✓ **Actuators:** -
 - ❖ shape-memory alloy
 - ❖ piezoelectric ceramics
 - ❖ magnetostrictive materials
 - ❖ Electrorheological/magnetorheological fluids.

❖ *Advanced Materials*

Biomaterials





❖ *Advanced Materials*

Nanomaterials

- May be any one of the four basic types (i.e., metals, ceramics, polymers, and composites) distinguished by their size.
- The study of the properties of these materials is termed *nanotechnology*.
- The dimensions of the structural entities of these materials are on the order of a nanometer (10^{-9} m).

❖ There are *six* different property classifications of materials.

- Mechanical
- Electrical
- Thermal
- Magnetic
- Optical
- Deteriorative



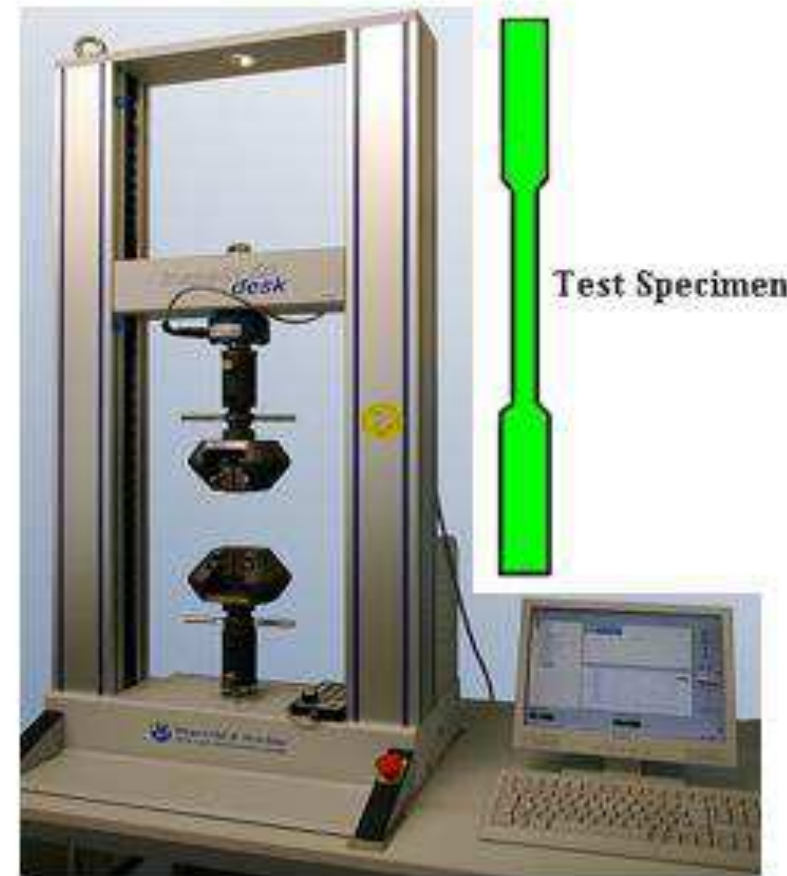
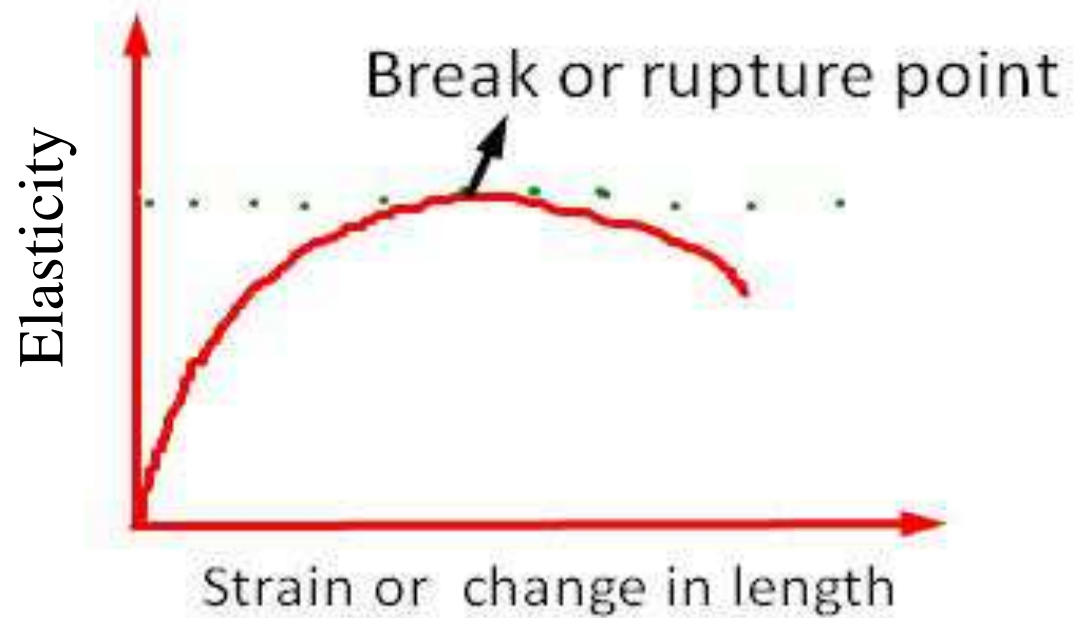
Mechanical Properties

- Tensile Strength
- Compressive Strength
- Shear Strength
- Toughness
- Elasticity
- Plasticity
- Ductility
- Malleability
- Hardness

Tensile Strength

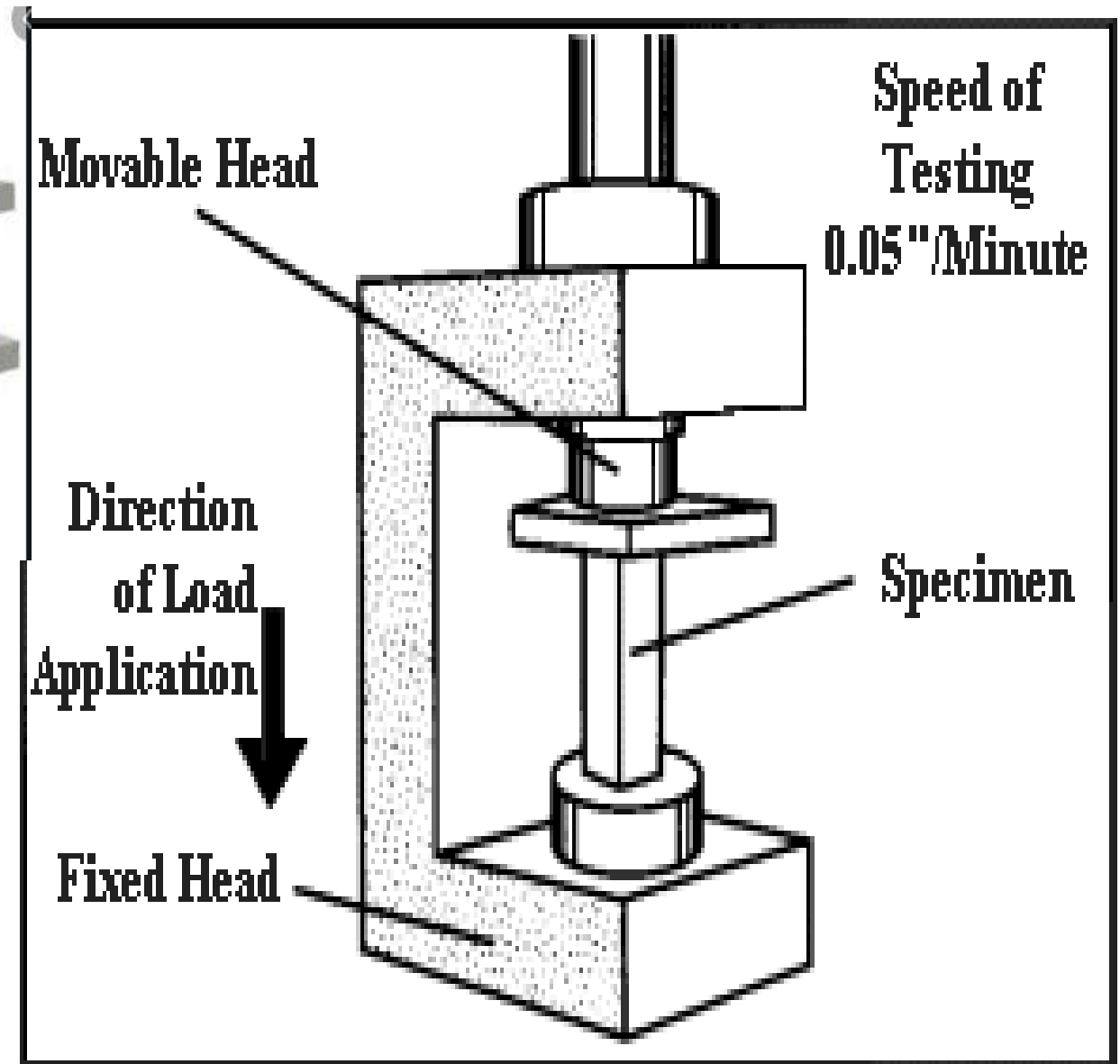
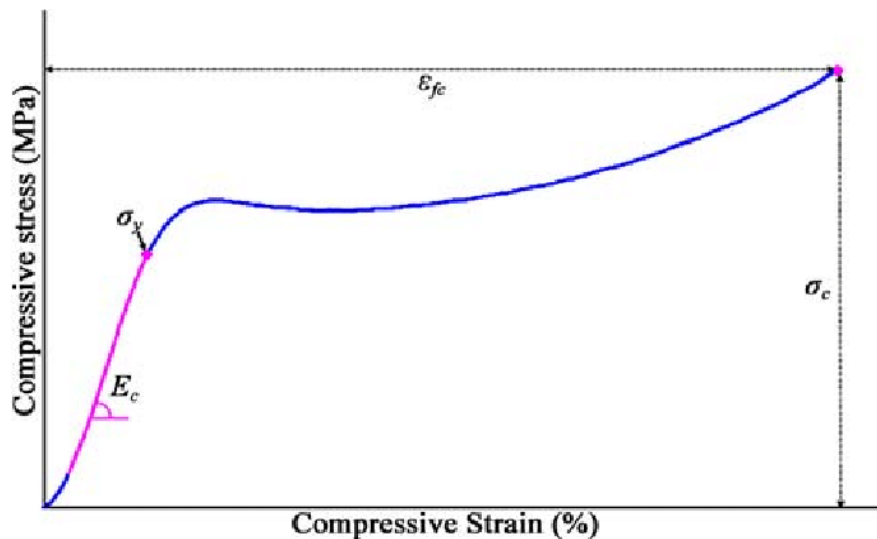
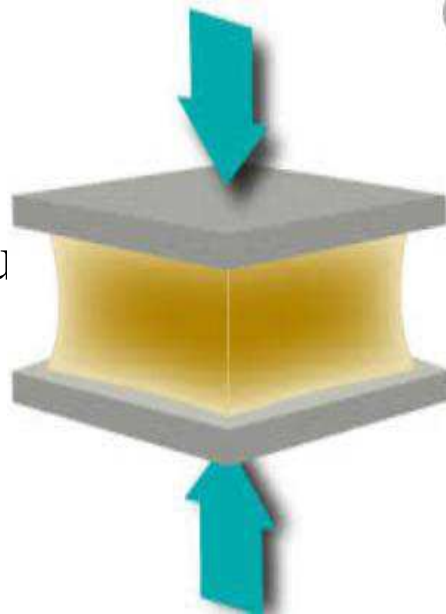
➤ Withstand **stretching loads**

without breaking

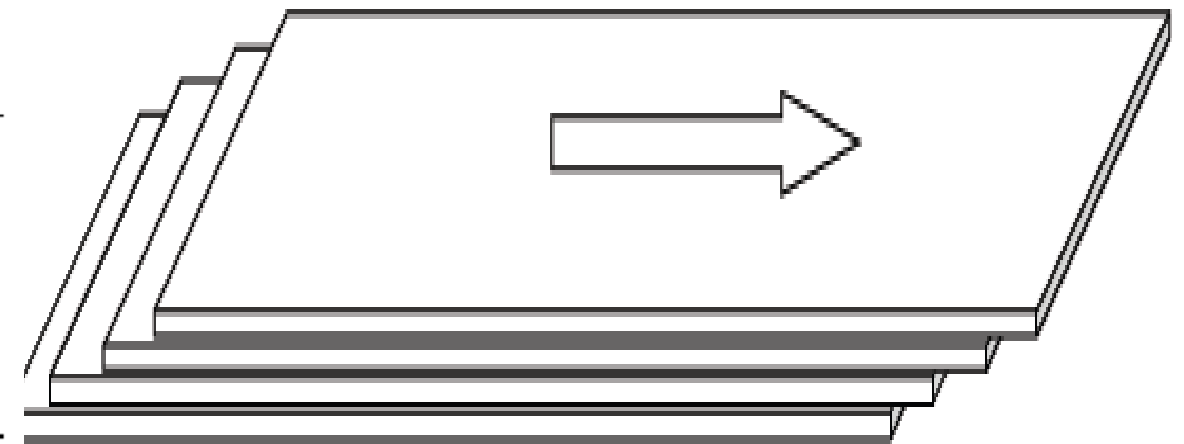
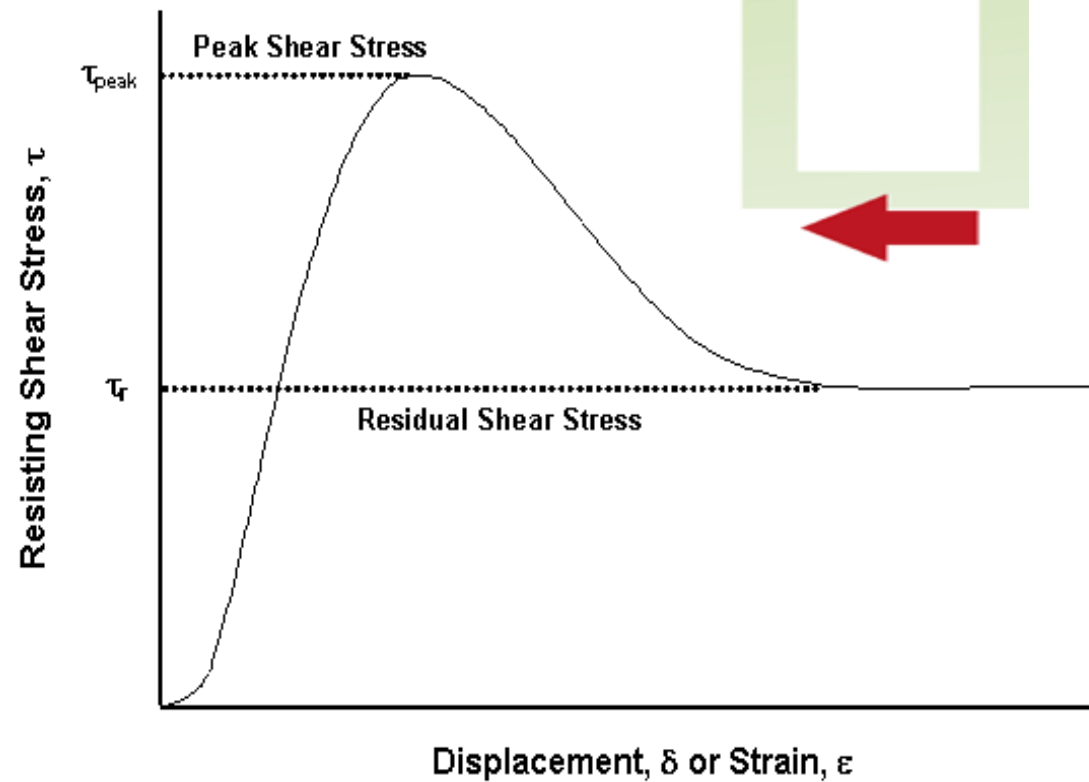


➤ Compressive Strength

- ✓ Withstand **compressive (squeezing) loads** without breaking.



- Withstand **offset** (shearing)
loads without breaking



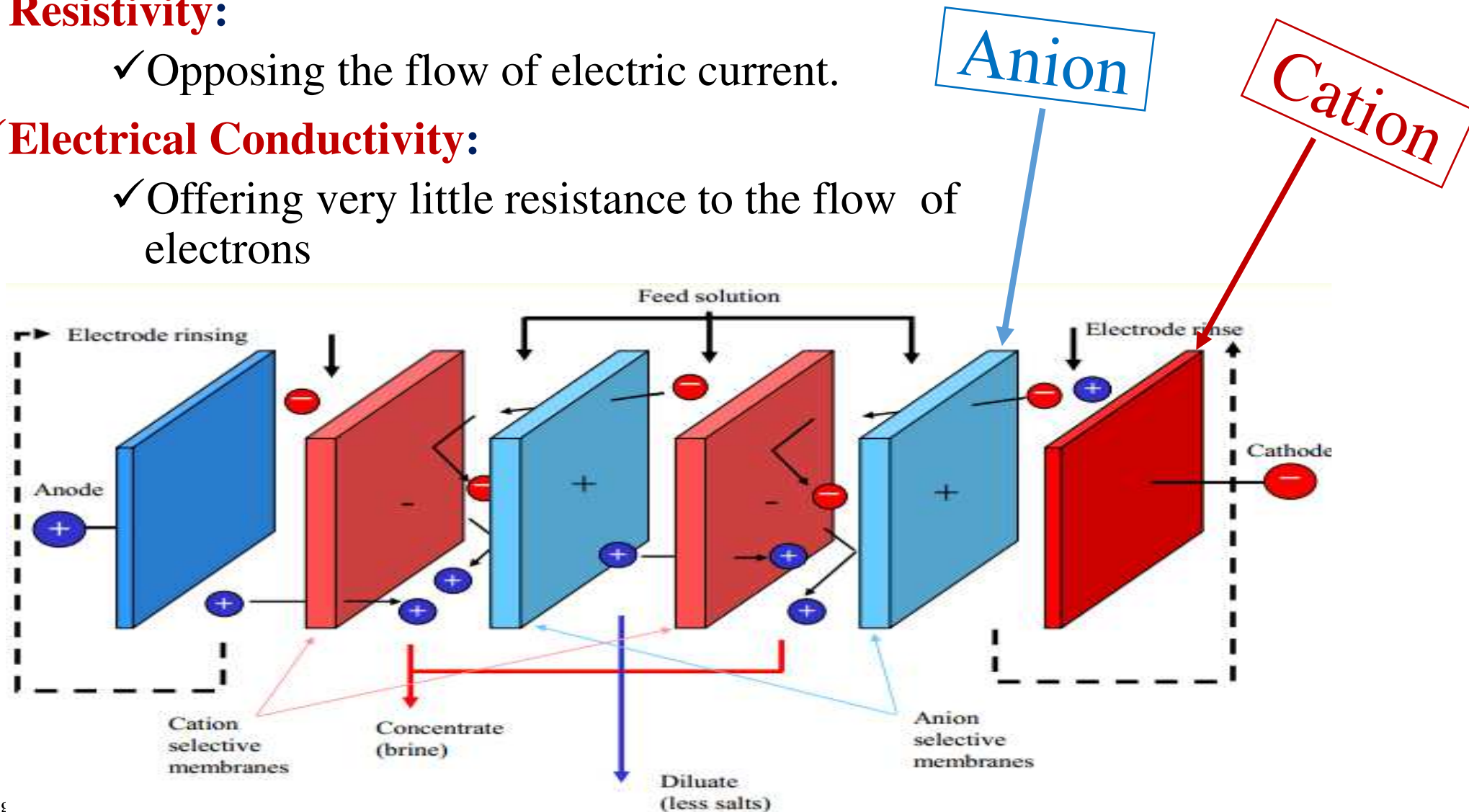
➤ Electrical Properties

✓ Resistivity:

- ✓ Opposing the flow of electric current.

✓ Electrical Conductivity:

- ✓ Offering very little resistance to the flow of electrons

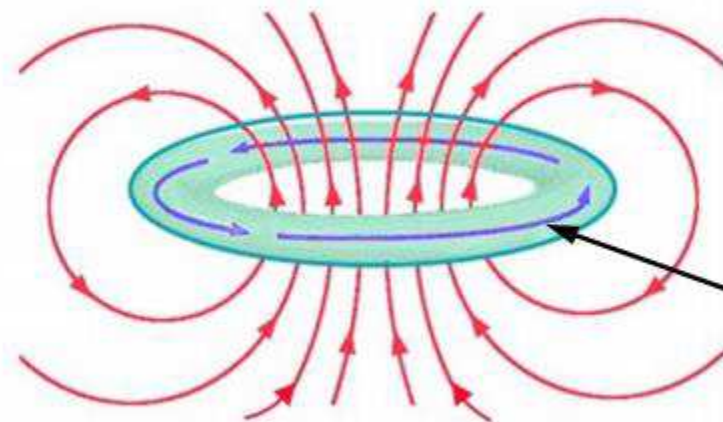
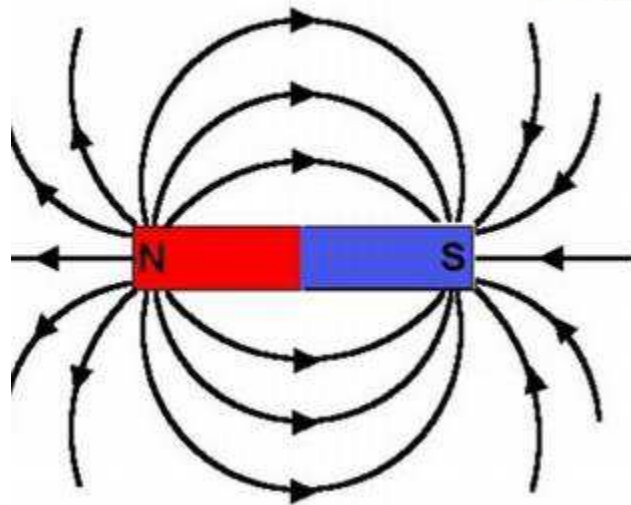


➤ Magnetic Properties

❖ *Magnetic Permeability:*

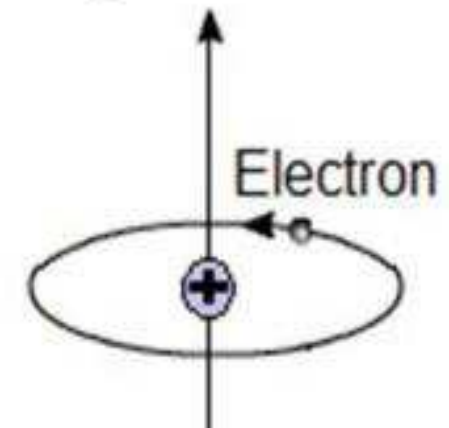
- ✓ Is the ability of a material to be **easily magnetized** and **demagnetized**
- ✓ Retains virtually **no magnetism** when the magnetising force is removed.

Magnetic lines of force



Current

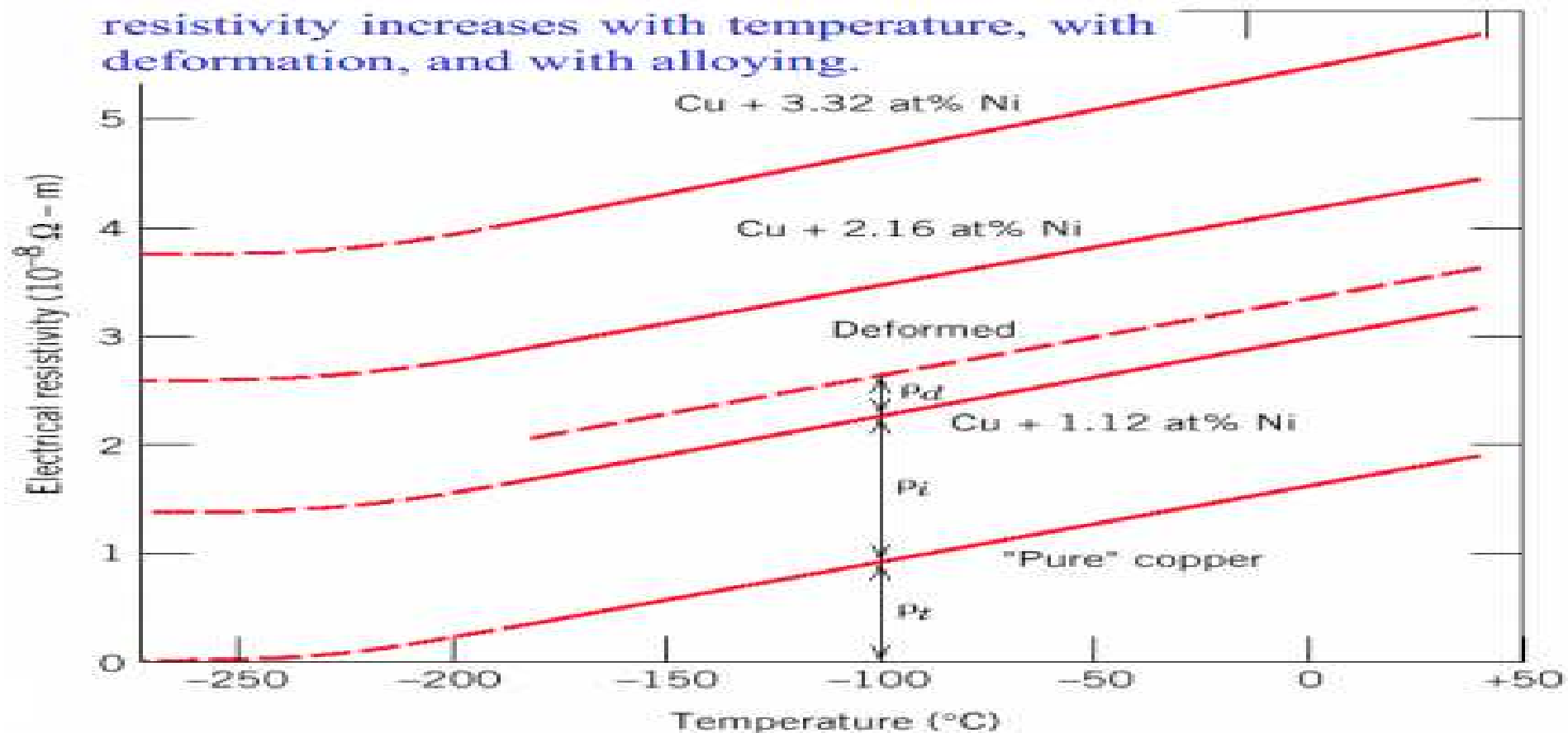
Magnetic moment



➤ Electrical Properties

✓ Resistivity:

✓ Opposing the flow of electric current.





❖ Thermal Properties

Thermal Conductivity:

- ✓ measure of the rate at which *heat* is transferred through a material.
- ✓ *microstructure* sensitivity property.

Specific Heat:

- ✓ *amount of heat* per unit mass required to raise *temperature by 1°C*.
- ✓ can be expressed either at *constant pressure (C_p)* or at *a constant volume (C_v)*.

Thermal expansion Coefficient: degree of expansion divided by the change in temperature .

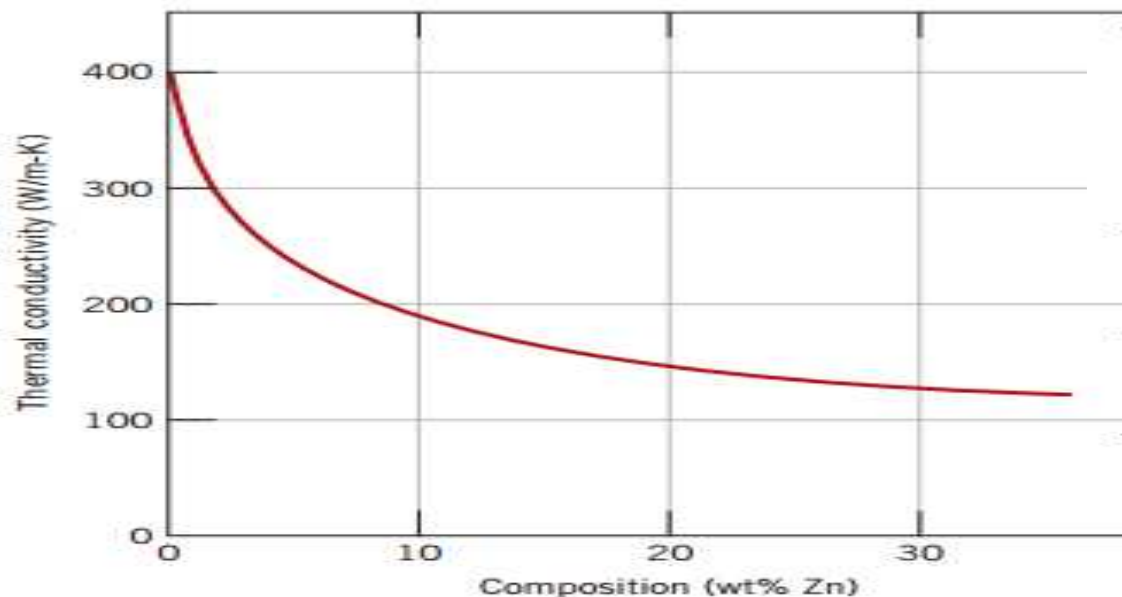
❖ Thermal Properties

i. Thermal Conductivity:

- ✓ measure of the rate at which *heat* is transferred through a material.
- ✓ In mathematical terms, the **thermal conductivity** q is expressed.

$$q = -k \frac{dT}{dx}$$

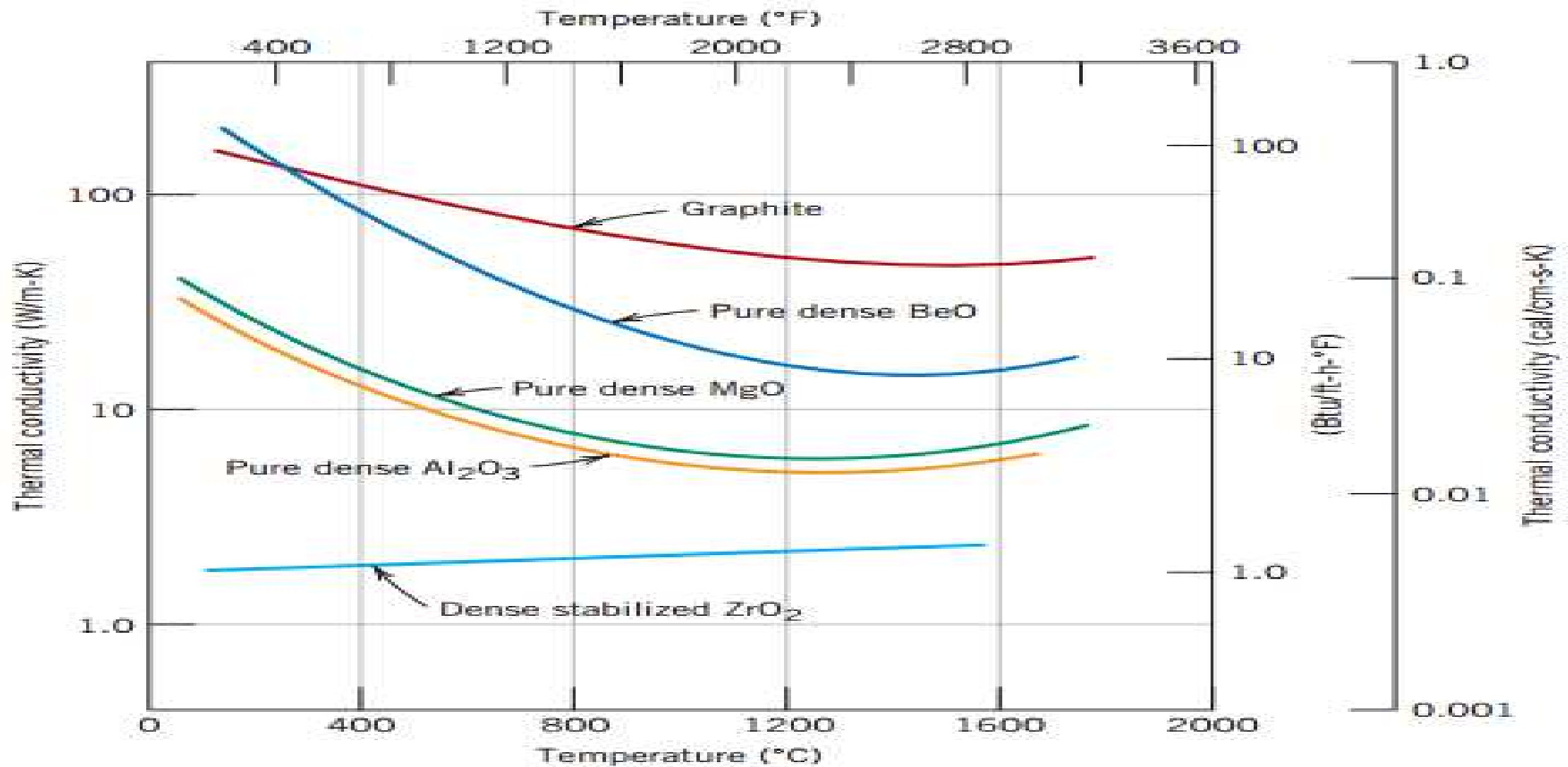
where q is *heat flux*, k is the thermal conductivity and dT/dx is the *temperature gradient* through the conducting medium



$q = f(\text{composition and temperature})$

Thermal conductivity versus composition for **copper–zinc alloys**.

❖ Thermal Properties



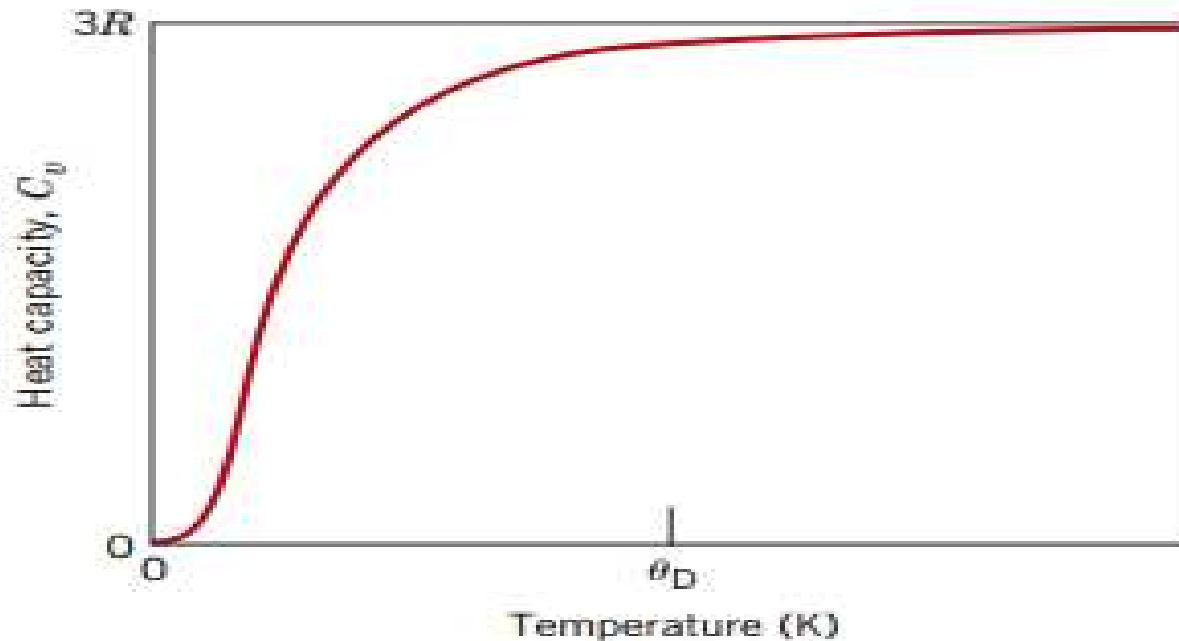
❖ Thermal Properties

ii. *Specific Heat:*

- ✓ *amount of heat* per unit mass required to raise *temperature by 1°C*.
- ✓ can be expressed either at *constant pressure (C_p)* or at *a constant volume (C_v)*.

$$C = \frac{dQ}{dT}$$

- where dQ is the energy required to produce a dT temperature change.
- In most case, $C_p > C_v$



- The temperature dependence of the heat capacity at constant volume.

❖ Thermal Properties

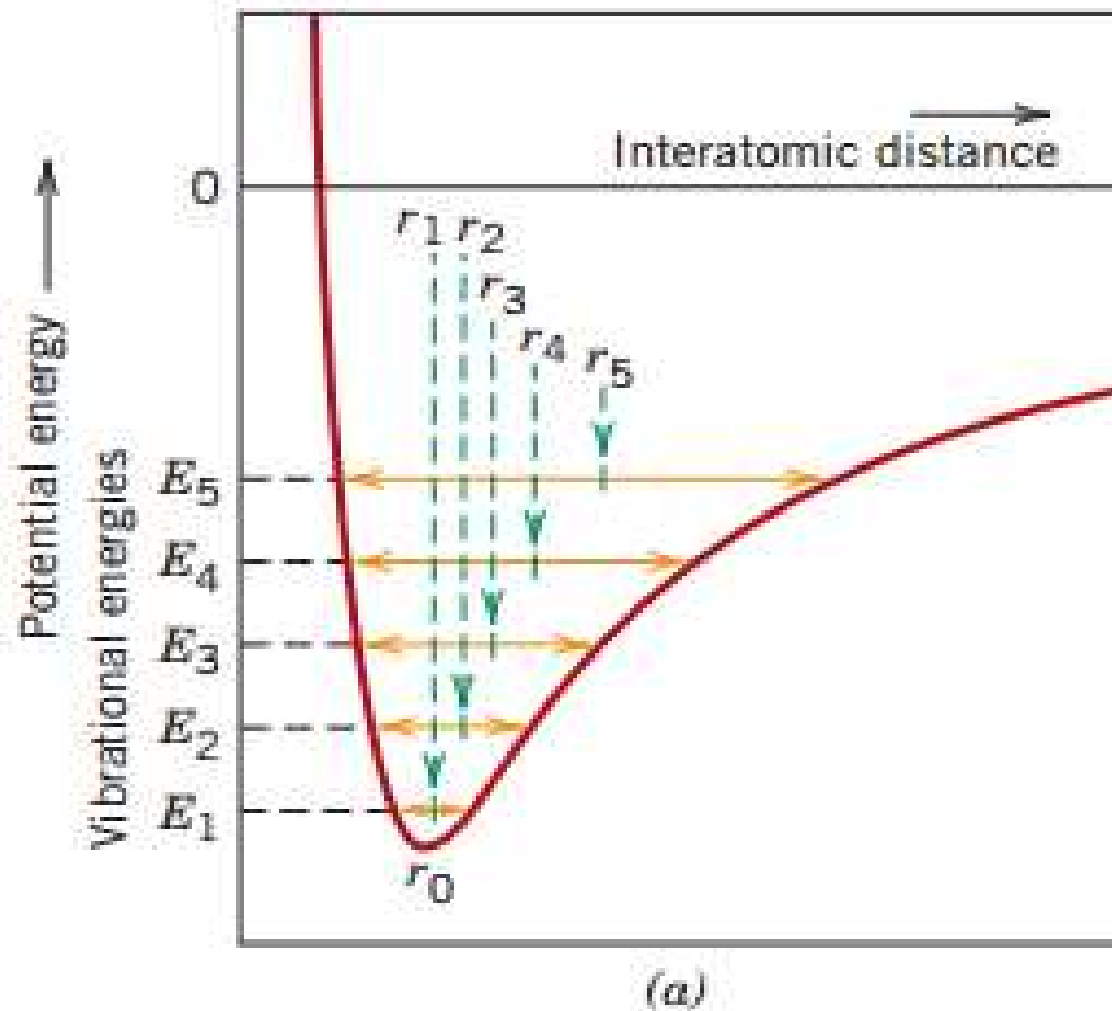
iii. Thermal expansion Coefficient:

- Most solid materials expand upon heating and contract when cooled.
- Degree of expansion divided by the change in temperature .

$$\frac{l_f - l_0}{l_0} = \alpha_l (T_f - T_0) \quad \text{Then.} \quad \frac{\Delta l}{l_0} = \alpha_l \Delta T$$

- Where l_0 and l_f represent, initial and final lengths with the temperature change from T_0 to T_f and α_l is linear coefficient of thermal expansion.

❖ Thermal Properties

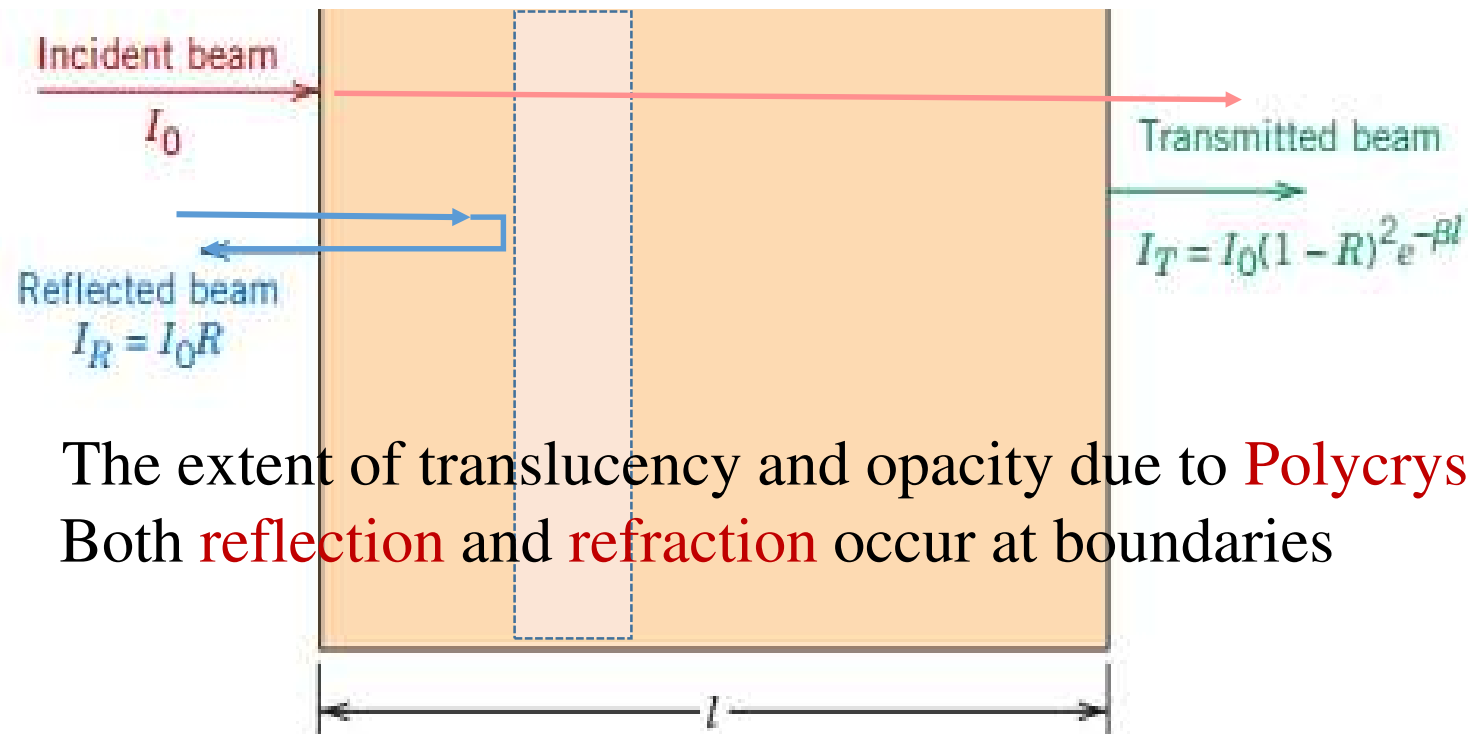


- Plot of potential energy versus interatomic distance, demonstrating the increase in interatomic separation with rising temperature.
- With heating, the interatomic separation increases from r_0 to r_1 to r_2 , and so on.

Optical Properties

- Are related to the *interaction of a material with electromagnetic*
- *Radiation* in the form of *waves* or *particles of energy* called *photons*.

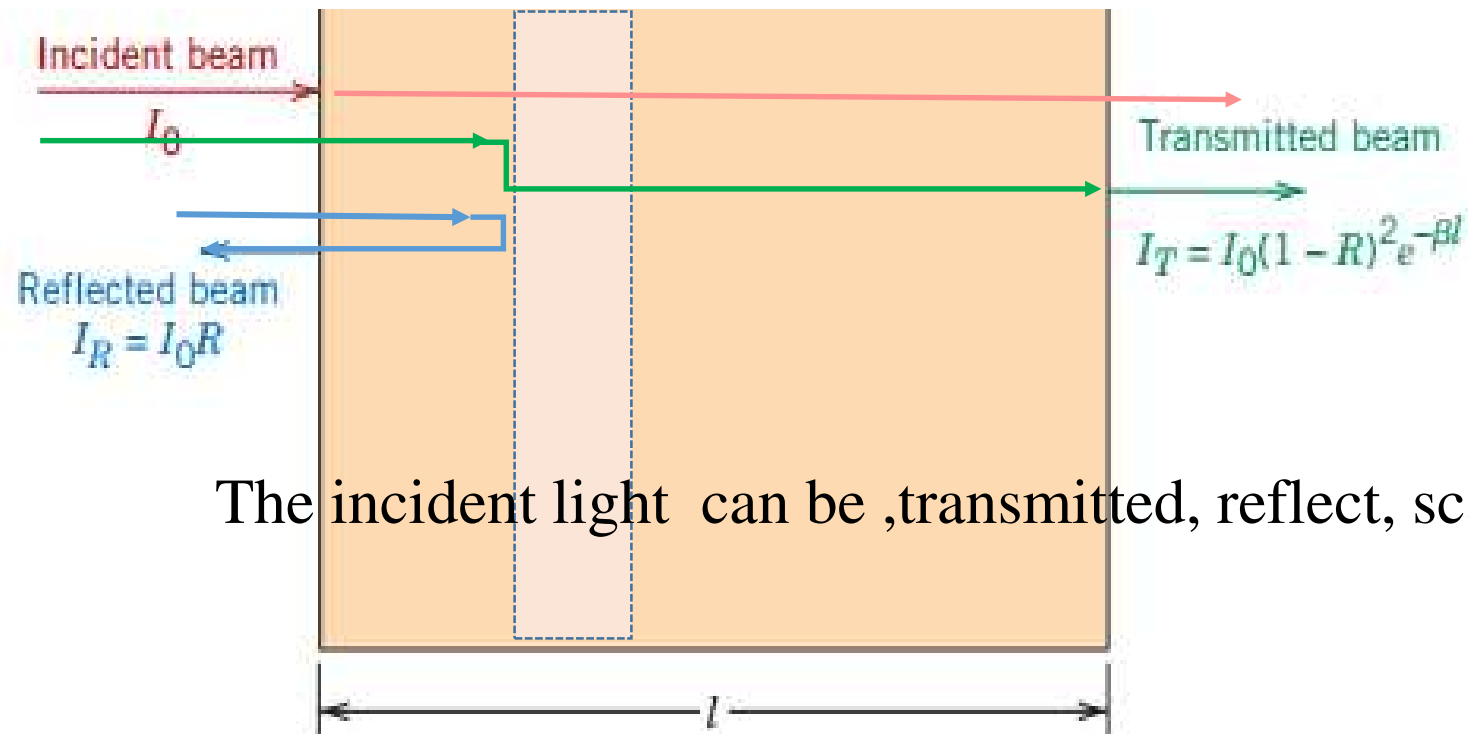
- ✓ Reflections
- ✓ Refractions
- ✓ Interference
- ✓ Diffraction
- ✓ Dispersion
- ✓ Scattering
- ✓ Polarization



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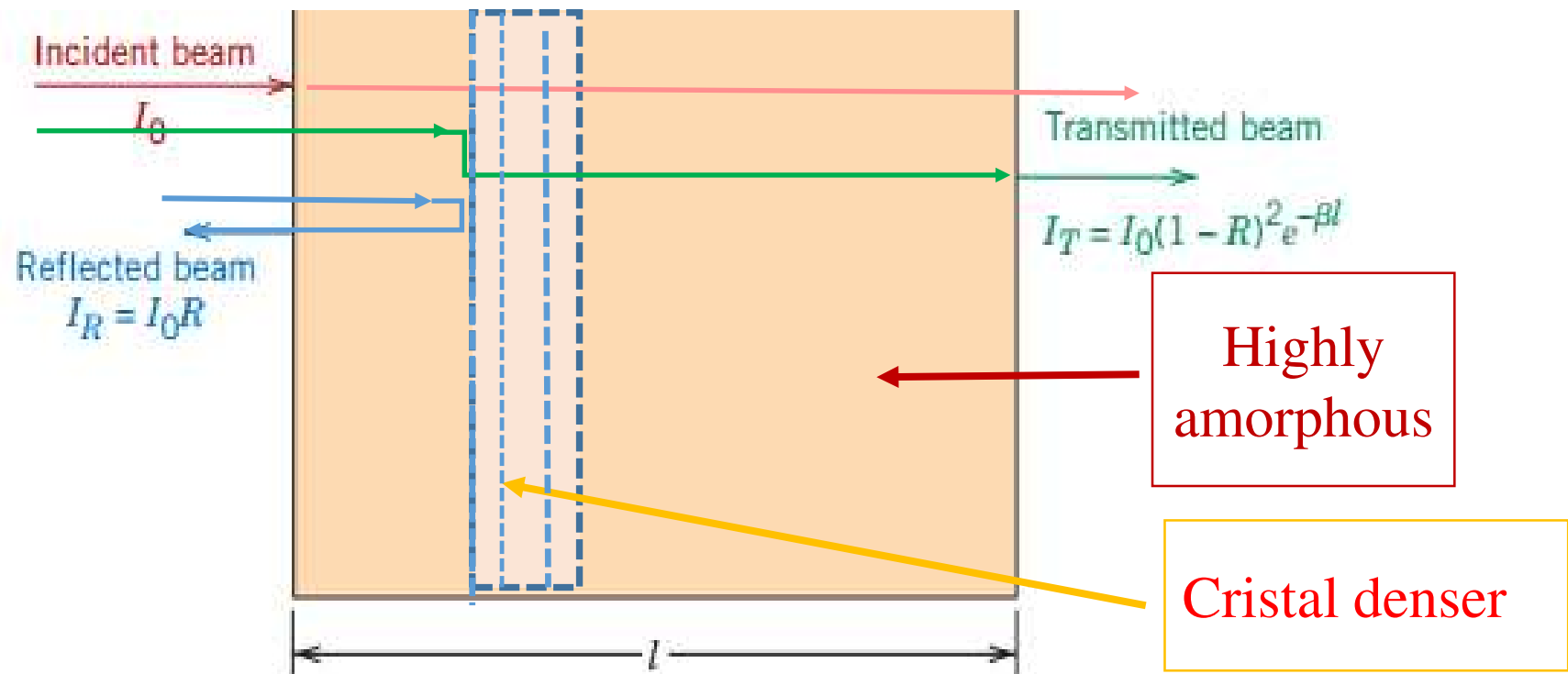
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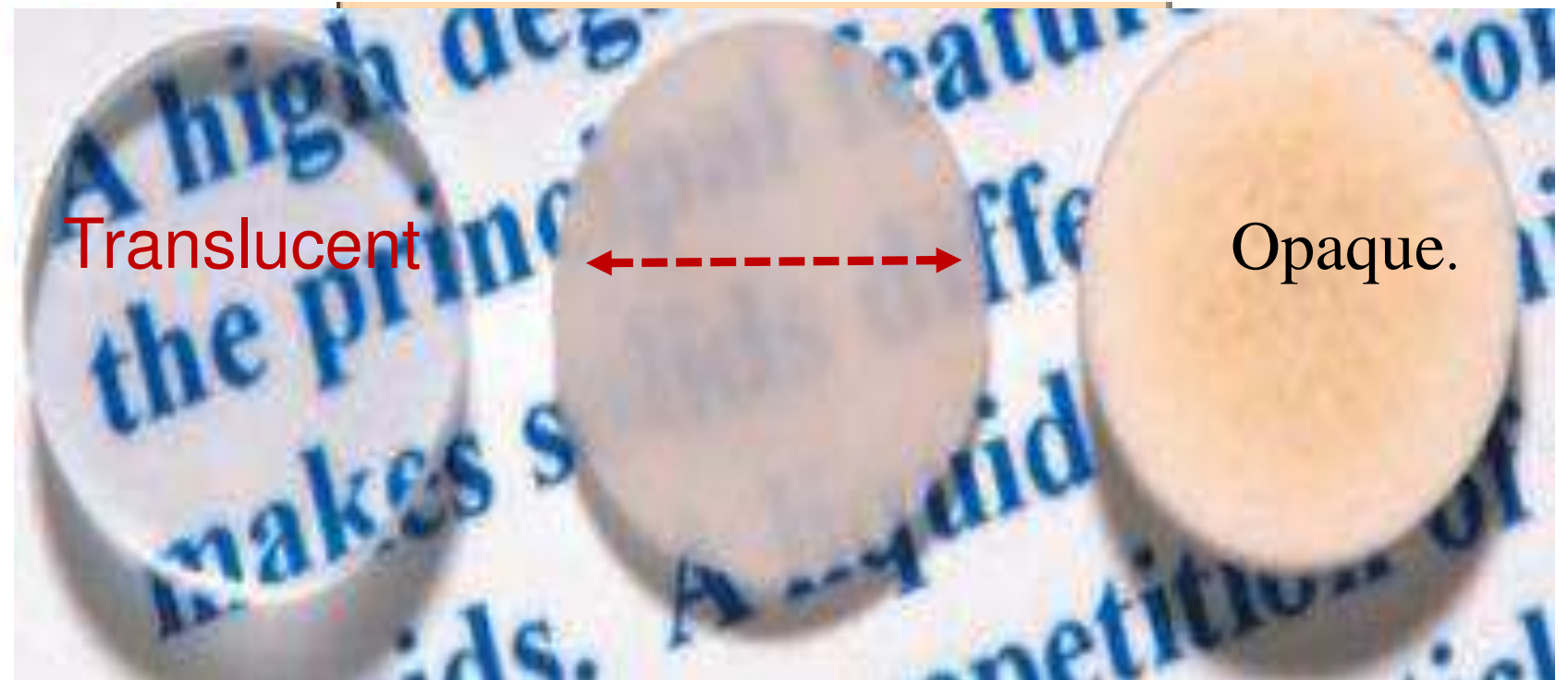
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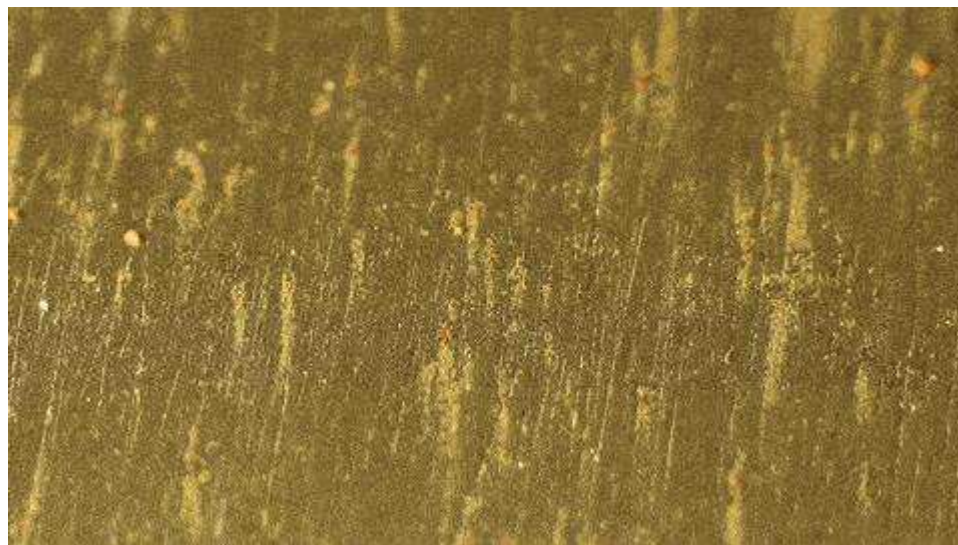
- ✓ Reflections
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❖ Deteriorative Properties

➤ Corrosion:

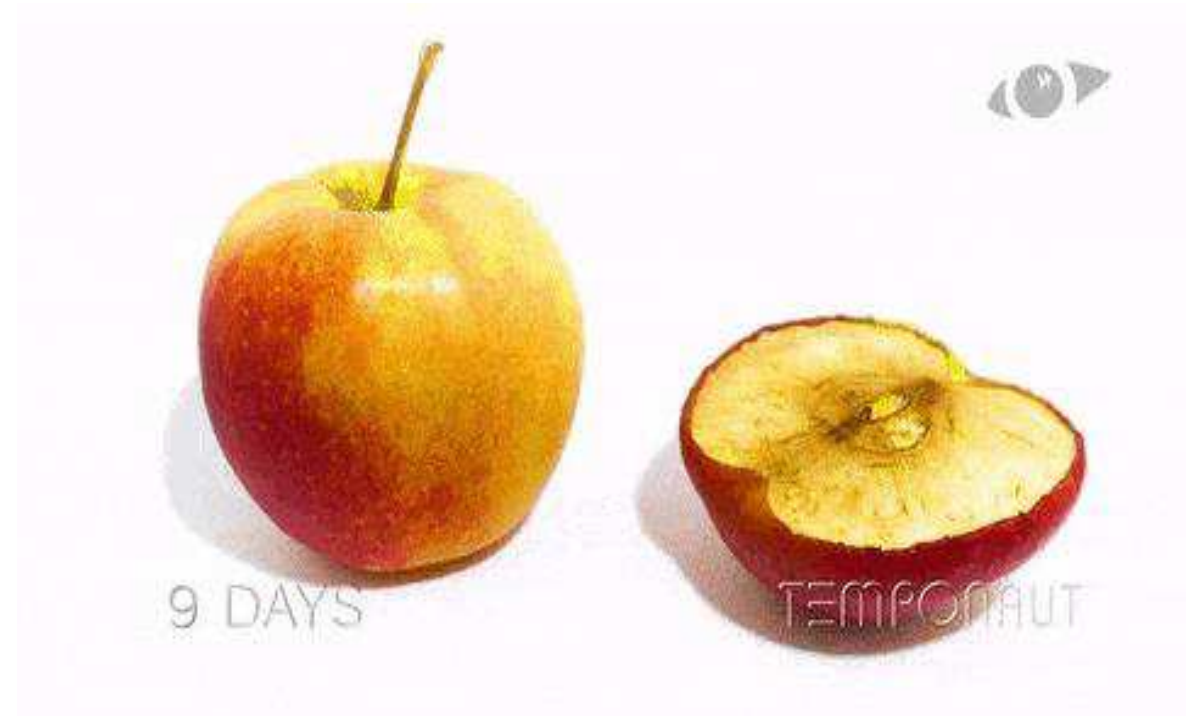
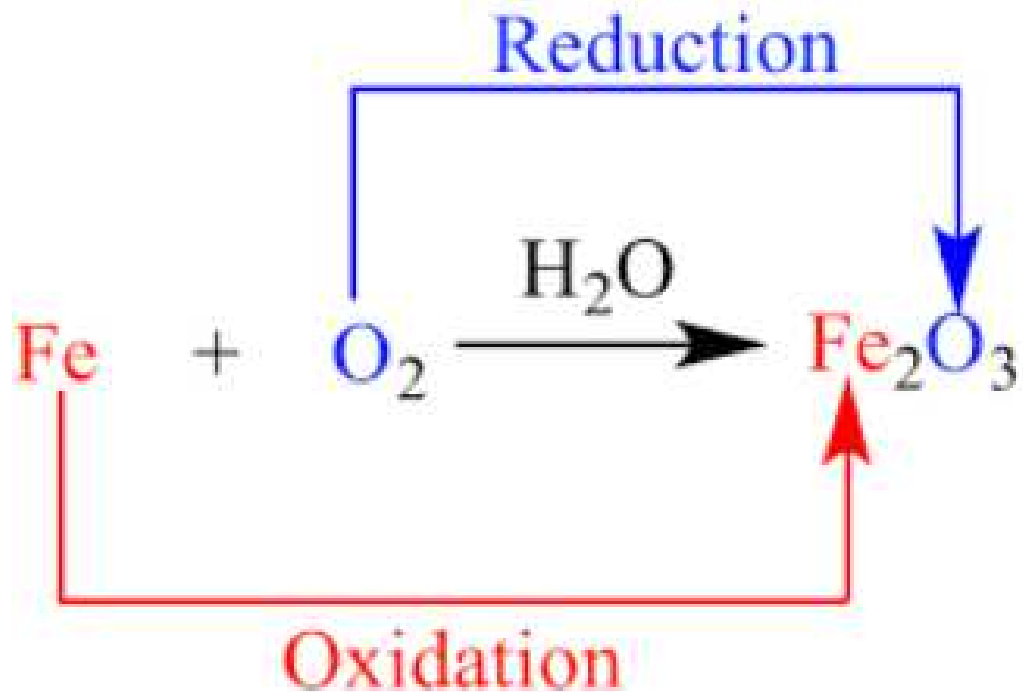
- ✓ Deterioration of a *metallic material* by a reaction with environmental chemicals.
- ✓ Occurs in order to *lower the free energy of the system*.
- ✓ Occur either *at high or low temperatures*.



❖ Deteriorative Properties

➤ Oxidation:

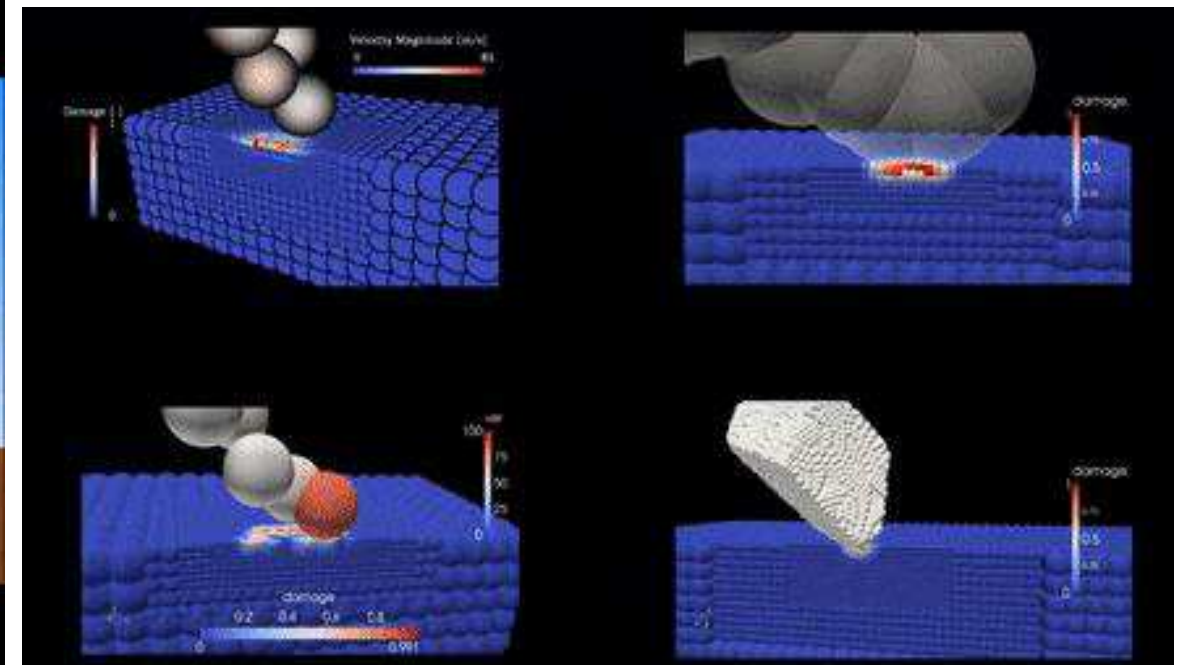
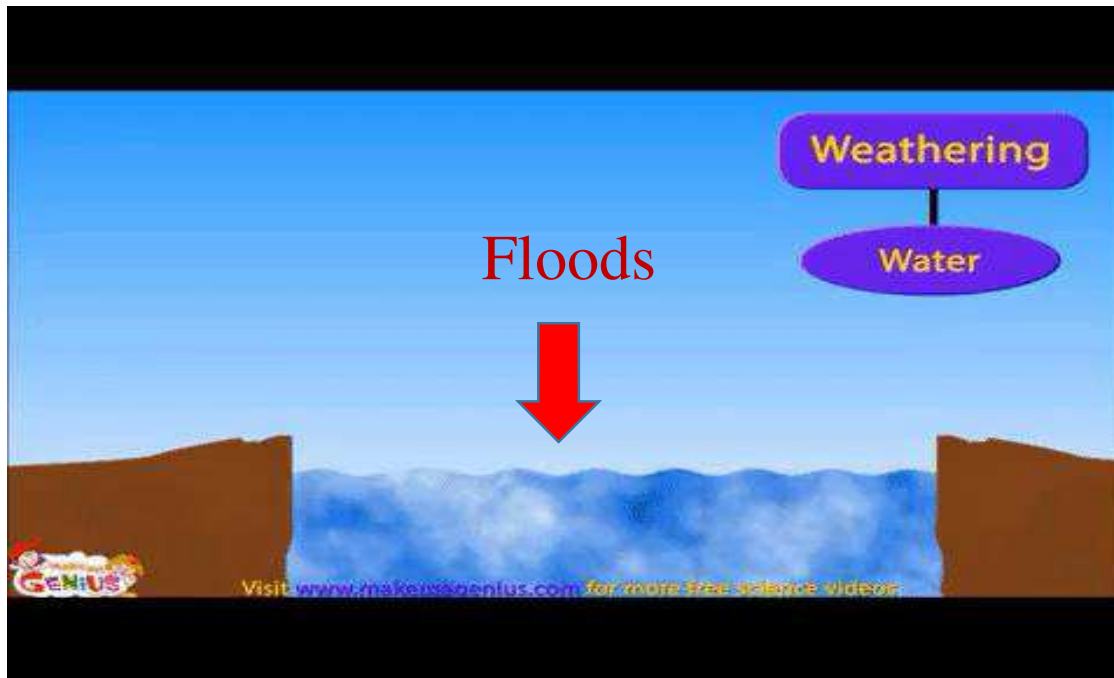
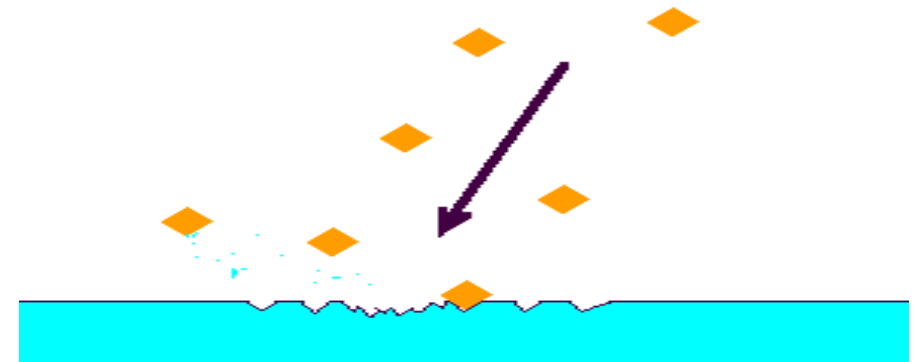
- ✓ Reaction of a chemical compound with *oxygen*.



❖ Deteriorative Properties

➤ Wear and Erosion:

- ✓ Is the removal of material from a component by *mechanical attack* of *solids* or *liquids*.





➤ Group work

1. Synthesis and Water Absorbency of Cross-linked Superabsorbent Polymers.
2. Use of Acetylated Softwood Kraft Lignin as Filler in Synthetic Polymers.
3. Composite biomaterials for bone repair.
4. Synthesis of Nonwoven Nanofibers by Electrospinning – A Promising Biomaterial for Tissue Engineering and Drug Delivery. Novel synthesis strategies for natural polymer and composite biomaterials as potential scaffolds for tissue engineering.
5. A Review of Waste Products Utilized as Supplements 2 to Portland Cement in Concrete.
6. Discovery of Cellulose as a Smart Material.
7. Carbohydrate contain synthetic polymer.
8. Nano engineered biomaterials for bone/dental regeneration