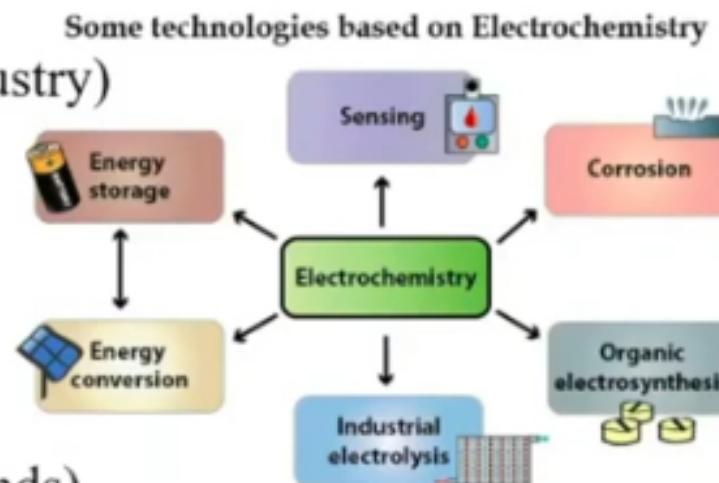


Electrochemistry and Chemical Sensors

- ❖ Electrochemistry studies the relationship between *electricity and chemical reactions*

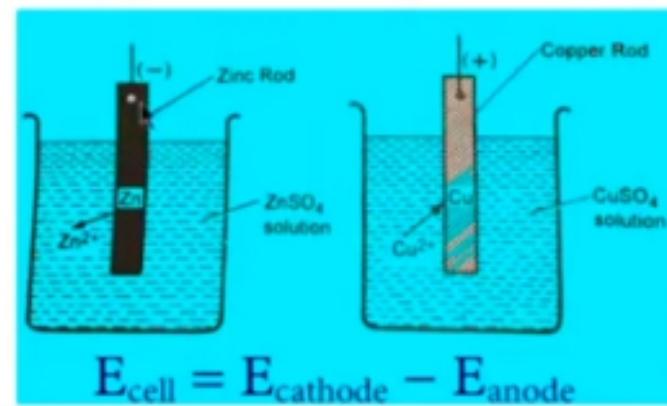
□ Electrochemistry has several practical applications

- ✓ Electrochemical industries (for example, Chloralkaline industry)
- ✓ Biomedical applications (electrodialysis, biosensors)
- ✓ Energy conversion and storage systems
(Batteries, photovoltaics, and supercapacitors)
- ✓ Fuel cells (Storing and utilization of energy in chemical bonds)
- ✓ Corrosion engineering
- ✓ Environmental remedies (oxidative treatment of harmful dyes)



Electrochemistry and Chemical Sensors

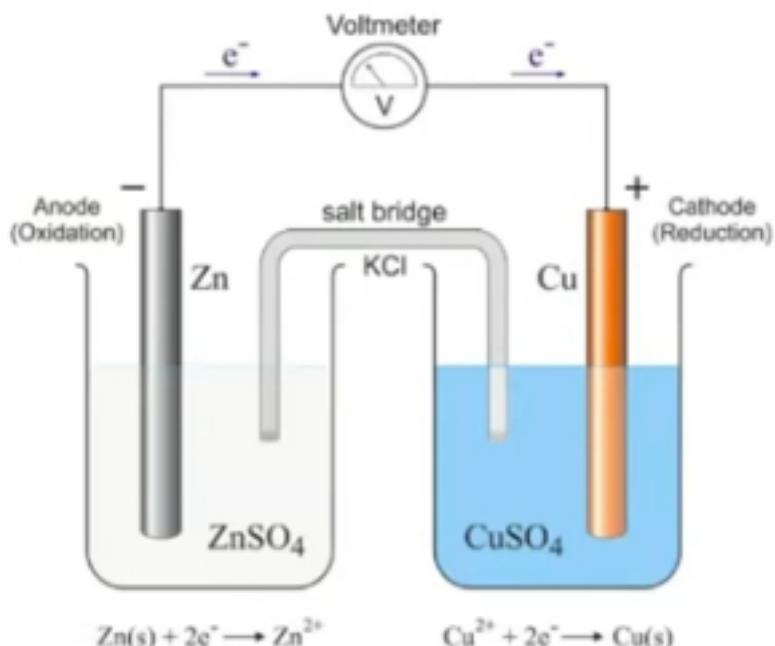
- **Electrode potential** is a measure of the tendency of an electrode to gain or lose electrons when it's in contact with a solution of its ions.
- **Electrode:** An electrical conductor that allows electrons to enter or leave a chemical system
- **Half-cell:** A single electrode immersed in a solution of its ions.
- **Oxidation or Reduction:** This potential difference arises because of the tendency of the metal to either lose electrons (oxidation) or gain electrons (reduction).
- **Standard Electrode Potential (E°):** The electrode potential is measured under standard conditions (usually 298 K, 1 atm pressure, and 1 M concentration of ions). The standard hydrogen electrode (SHE) is used as a reference and has a standard electrode potential of 0 V.
- **Electrochemical Cells:** By connecting two half-cells with different electrode potentials, a galvanic (or voltaic) cell is formed, and a spontaneous redox reaction can generate electrical energy



Electrochemistry and Chemical Sensors

➤ A **galvanic cell**, also known as a **voltaic cell**, is an electrochemical cell that converts chemical energy into electrical energy through spontaneous redox reactions. It's a device where a chemical reaction generates an electrical current.

- ❖ **Anode** – Oxidation occurs at this electrode.
- ❖ **Cathode** – Reduction occurs at this electrode.
- ❖ **Salt bridge** – Contains electrolytes which are required to complete the circuit in a galvanic cell.
- ❖ **Half-cells** – reduction and oxidation reactions are separated into compartments.
- ❖ **External circuit** – Conducts the flow of electrons between electrodes
- ❖ **Load** – A part of the circuit utilizes the electron to flow to perform its function.



Electrochemistry and Chemical Sensors

- The **Nernst Equation** enables the determination of cell potential under non-standard conditions. It relates the measured cell potential to the reaction quotient and allows the accurate determination of equilibrium constants (including solubility constants)

$$\Delta G = \Delta G^\circ + RT \ln Q$$

At equilibrium $Q = K$

$$\Delta G = -nFE_{cell} \quad \text{and} \quad \Delta G^\circ = -nFE^\circ_{cell}$$

Hence Electrical potential energy

$$E_{cell} = E_{cell}^\circ - \frac{RT}{nF} \ln Q$$

$$E_{cell} = E_{cell}^\circ - \frac{0.0257}{n} \ln Q$$

Nernst equation

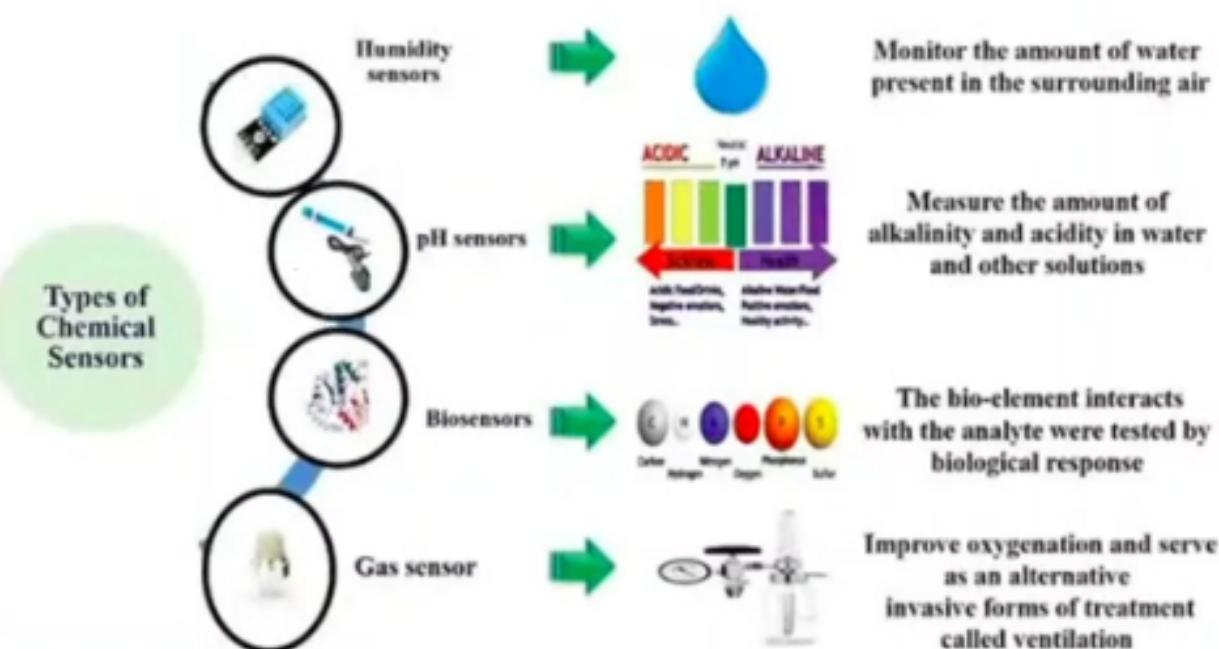
$$E_{cell} = E_{cell}^\circ - \frac{0.0592}{n} \log_{10} Q$$

Types of electrochemical cells, batteries, and fuel cells. Theories of corrosion, Anodic and cathodic protection, protective coatings, and corrosion inhibitors. Electroplating, electro-machining, electro-winning, electro-refining, green electro-organic synthesis.



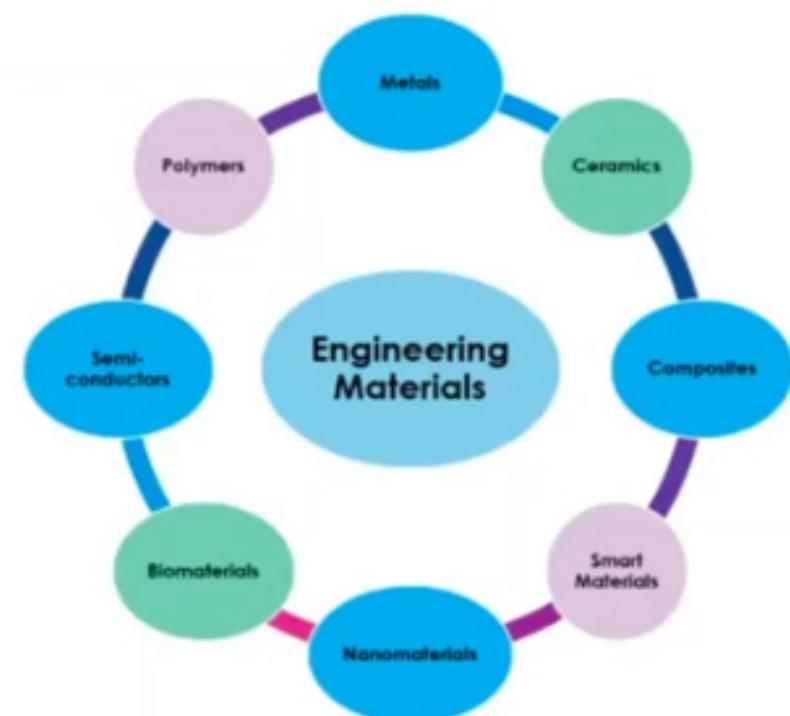
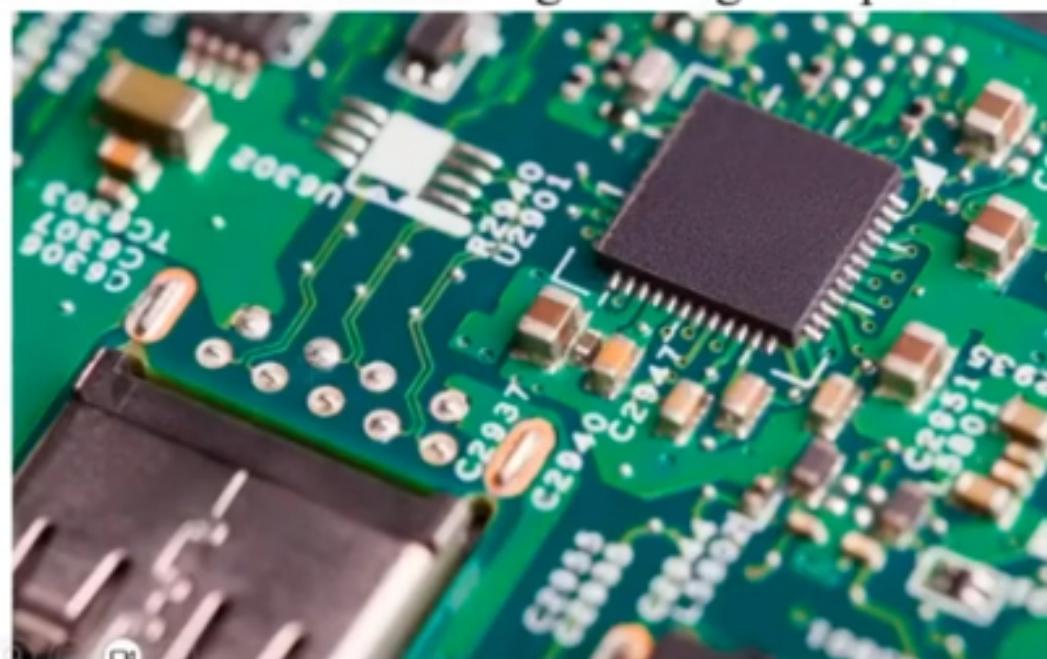
Electrochemistry and Chemical Sensors

- **Chemical sensors** are devices that detect and measure the presence and concentration of chemical substances (analytes) in a given sample.



Engineering Materials

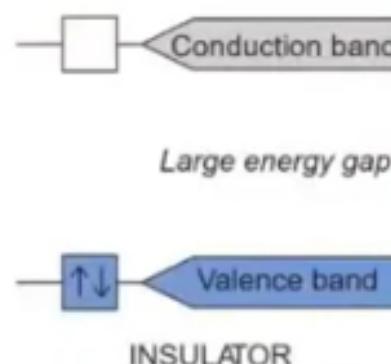
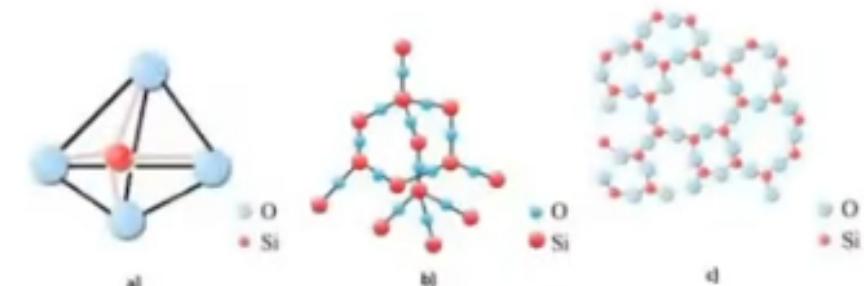
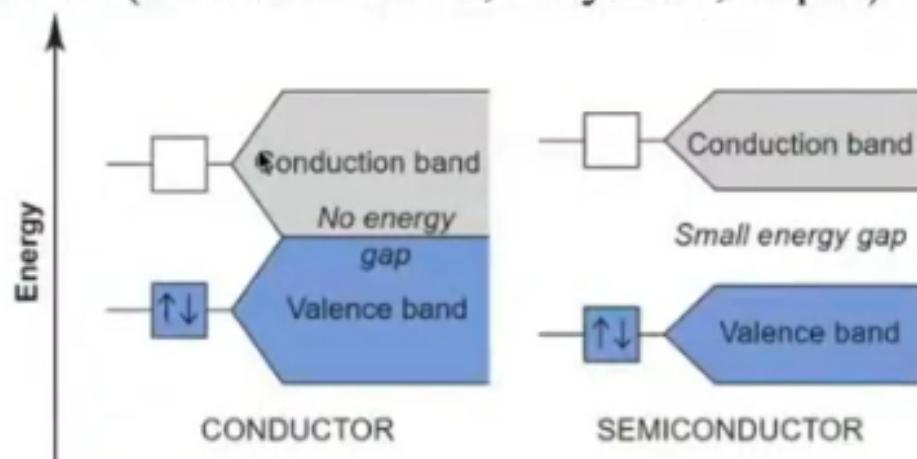
➤ **Engineering materials** are substances used in the creation of structures and components, and their selection is crucial for successful engineering projects. Key material properties include **density, elasticity, strength, and thermal conductivity**. Materials are broadly classified into **metals, ceramics, polymers, and composites**, each with unique characteristics and applications across various engineering disciplines



Engineering Materials

➤ Classifications of materials-Based on Electrical Conductivity

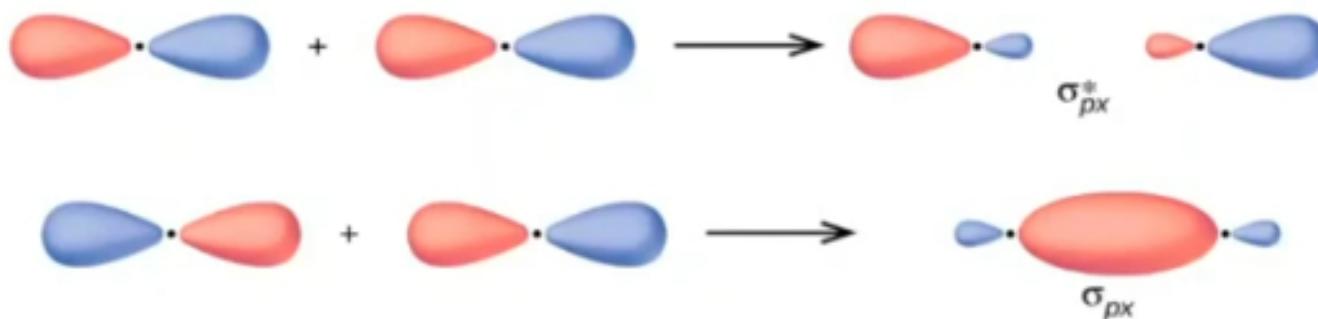
- 1) Conductors (Metals and graphite)
- 2) Semiconductors (Silicon, GaAs, InP, etc.)
- 3) Insulators (Ceramic oxides, Polymers, Paper)



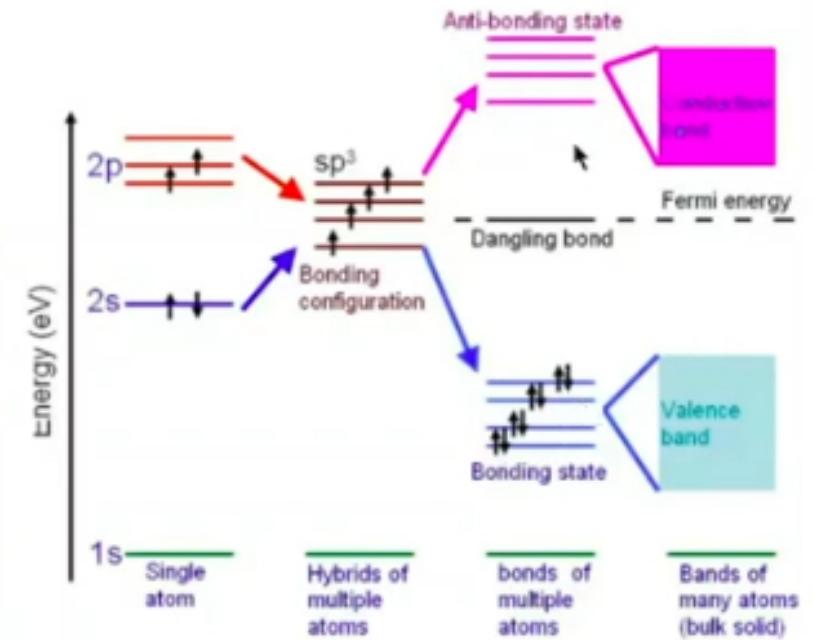
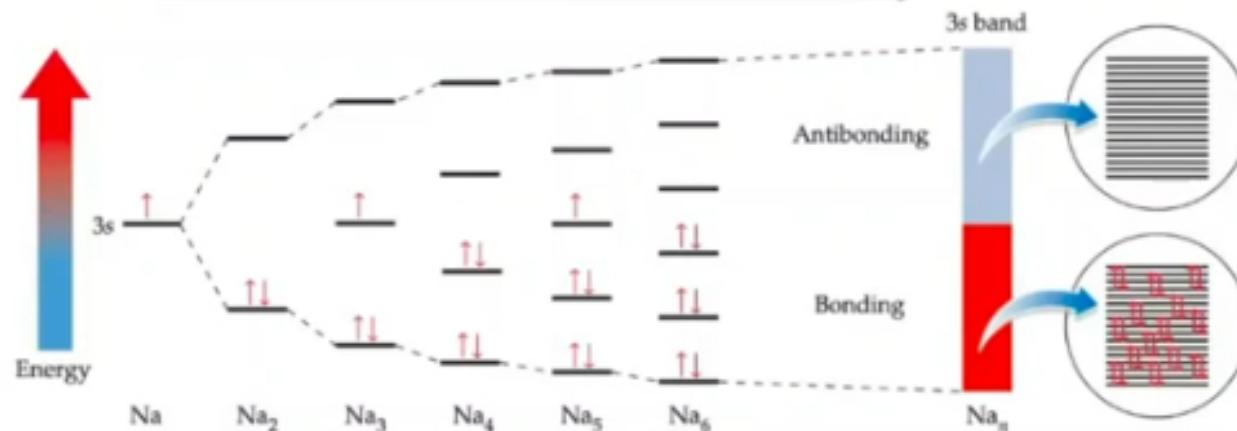
Engineering Materials

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Band Theory



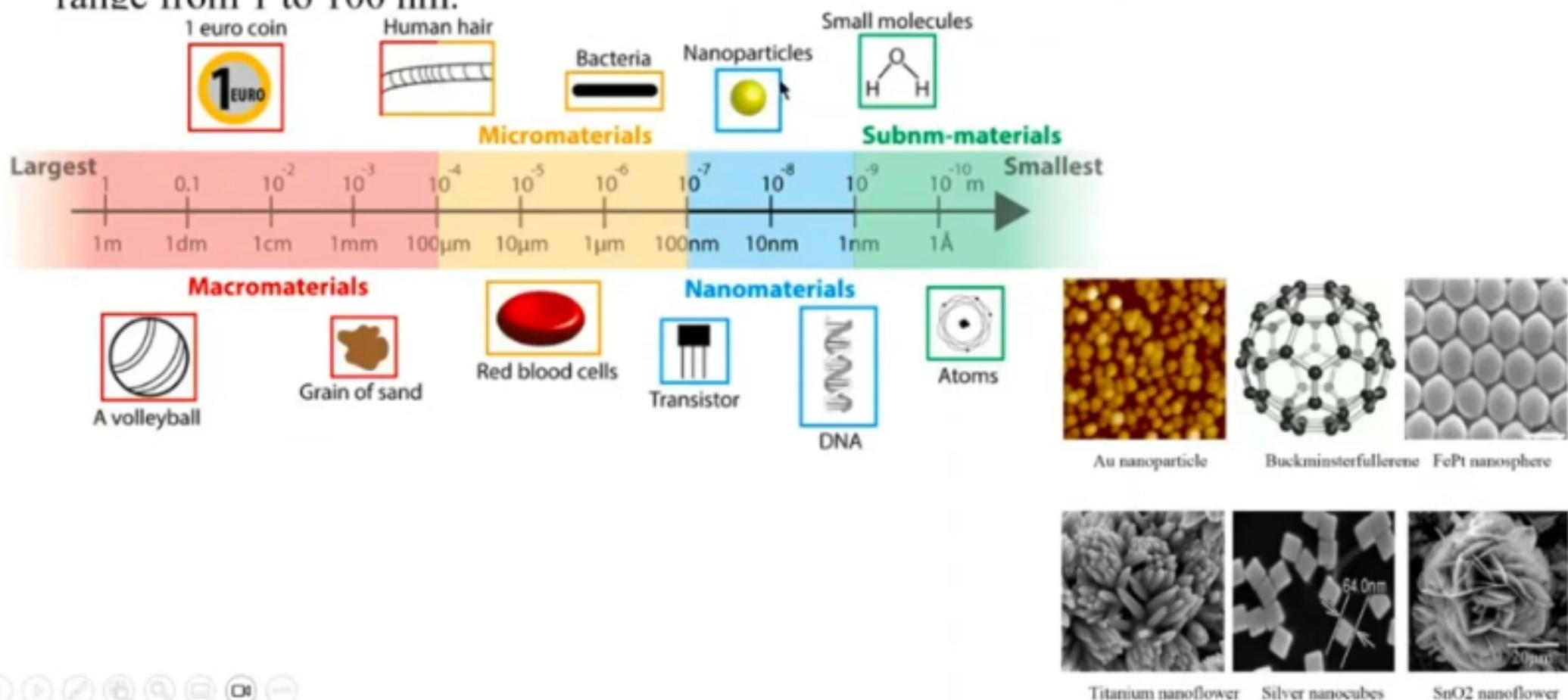
As the value of n increases, the energy levels merge into an almost continuous band.



Conductivity of solids,
optoelectronic materials,
OLED.

Engineering Materials

- **Nanotechnology** is the science and engineering of nanoscale systems, whose critical sizes range from 1 to 100 nm.



Engineering Materials

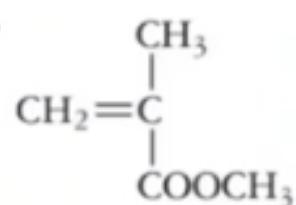
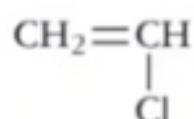
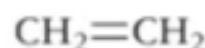
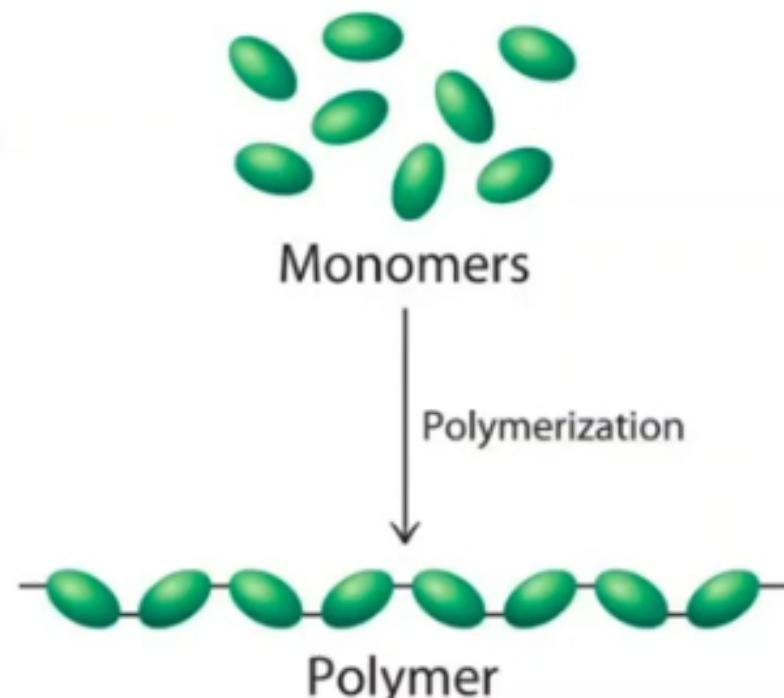
➤ Applications of Nanoparticles

1. Silver nanoparticles have good antibacterial properties, and are used in surgical instruments, refrigerators, air-conditioners, water purifiers etc.
2. Gold nanoparticles are used in catalytic synthesis of silicon nano wires, sensors for the detection of tumors, drug delivery cargos.
3. ZnO nanoparticles are used in electronics, ultraviolet (UV) light emitters, piezoelectric devices and chemical sensors.
4. TiO₂ nanoparticles are used as photocatalyst and sunscreen cosmetics (UV blocking pigment).
5. Antimony-Tin-Oxide (ATO), Indium-Tin-Oxide (ITO) nanoparticles are used in car windows, liquid crystal displays and in solar cell preparations.

Engineering Materials

➤ Polymer

- ✓ The word polymer is derived from the classical Greek words poly, meaning “many,” and meres, meaning “parts.”
- ✓ Simply stated, a polymer is a long-chain molecule that is composed of a large number of repeating units of identical structure.
- ❖ **Monomers:** These are simple molecules, which combine with each other to form polymers. Monomers are also called “building blocks” of polymers.
- ❖ For example, ethylene, methylmethacrylate, vinyl chloride, etc.



Engineering Materials

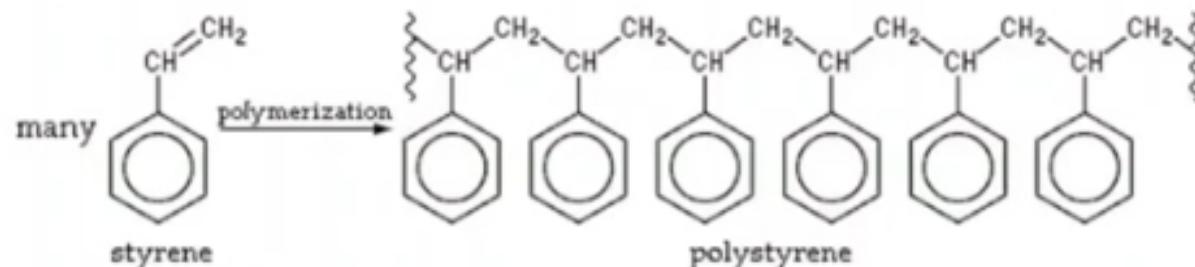
➤ Polymers Classification – On Thermal Processing

- Based on **thermal processing** behaviour polymers can be classified into two categories, **thermoplastic or thermosets**.

➤ Thermoplastics

- ✓ Polymers that can be heat-softened in order to process into a desired form (or shape) are called **thermoplastics**.

Examples: Polystyrene, polyolefins (e.g., polyethylene and polypropylene) and poly(vinyl chloride).



Engineering Materials

➤ Polymers Classification – On Thermal Processing

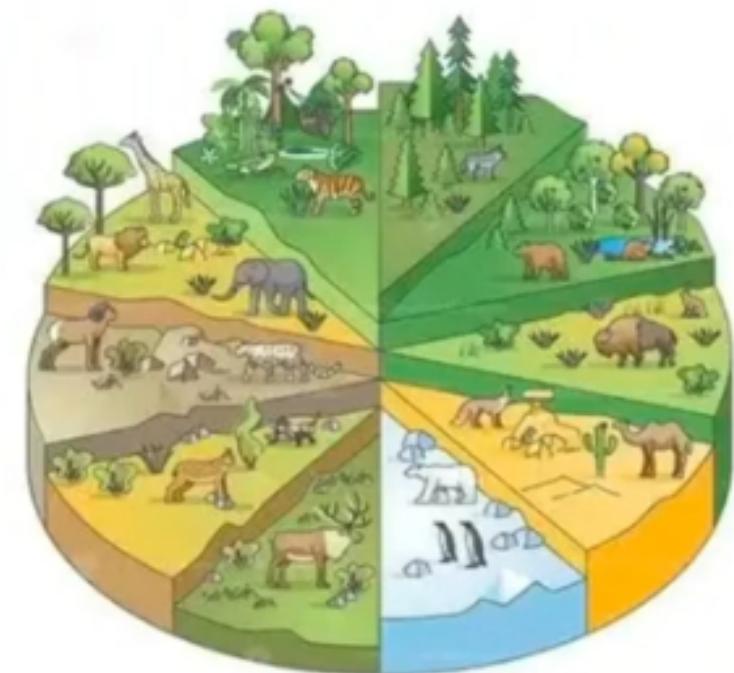
□ Thermoset (Thermosetting)

- Some polymers undergo chemical changes and cross-linking on heating and become permanently hard, rigid, and infusible on cooling. These are called thermosetting polymers.
- ✓ Such properties make thermosets suitable materials for composites, coatings, and adhesive applications.
- ✓ Principal examples of thermosets include epoxy, phenol-formaldehyde resins, and unsaturated polyesters that are used in the manufacture of glass-reinforced composites such as Fiberglass

Ecosystems, Biodiversity, Natural Resources, and Their Human Impacts

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- An **ecosystem** is a community of living organisms interacting with each other and their physical environment. These interactions involve the exchange of energy and nutrients, creating a dynamic and interconnected system.
- Key components of an ecosystem:
 - **Biotic components:** These are the living organisms within the ecosystem, including plants, animals, fungi, and microorganisms.
 - **Abiotic components:** These are the non-living elements, such as air, water, sunlight, soil, temperature, and nutrients



Ecosystems, Biodiversity, Natural Resources, and Their Human Impacts

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➤ **Biodiversity** is the variation among living organisms from different sources, including terrestrial, marine, and desert ecosystems, and the ecological complexes of which they are a part.

- ✓ Genetic diversity
- ✓ Species diversity
- ✓ Ecological diversity



Ecosystems, Biodiversity, Natural Resources, and Their Human Impacts

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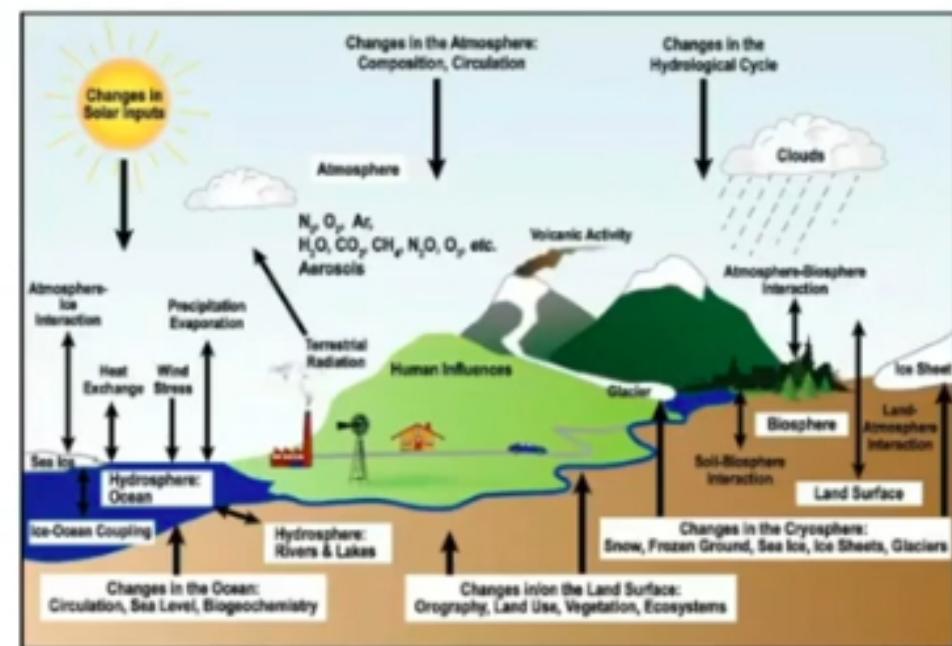
- **Natural resources** are materials and components that occur naturally on Earth and are valuable to humans. They include both renewable resources like sunlight, water, and forests, and non-renewable resources like fossil fuels and minerals. Genetic diversity
- ✓ Human activities have significant and often detrimental impacts on natural resources. These impacts include **deforestation, pollution, overexploitation of resources, and climate change.**
- ✓ All of which can lead to habitat destruction, biodiversity loss, and resource depletion



Pollutants and Waste Disposal Methods

► **Pollutants affect each of Earth's spheres** – the atmosphere, hydrosphere, lithosphere, and biosphere – in distinct ways due to their unique properties and interactions. Human activities, such as burning fossil fuels and industrial processes, are major contributors to pollution in these spheres

- **Atmosphere:** Pollutants like greenhouse gases (e.g., carbon dioxide, methane) and aerosols (e.g., particulate matter) are released into the atmosphere through various human activities. These pollutants can lead to climate change, alter weather patterns, and affect air quality. Specifically, air pollution can cause acid rain, which damages ecosystems and infrastructure



Pollutants and Waste Disposal Methods

- ❖ **Geosphere:** Landfills, mining activities, and industrial processes release pollutants that contaminate the soil and rocks of the geosphere. This contamination can reduce soil fertility, harm plant life, and potentially contaminate groundwater.
- ❖ **Hydrosphere:** Industrial discharge, agricultural runoff, and plastic pollution contaminate water bodies (rivers, lakes, oceans), impacting aquatic life and potentially affecting drinking water sources. **Eutrophication**, caused by excessive nutrient pollution, can lead to oxygen depletion in water bodies, harming aquatic ecosystems.
- ❖ **Biosphere:** Pollutants directly or indirectly affect all living organisms within the biosphere. Air and water pollution can cause respiratory illnesses, birth defects, and other health problems in humans and animals. Deforestation and habitat destruction, often linked to pollution, reduce biodiversity and disrupt ecosystems.

Pollutants and Waste Disposal Methods

- ❑ **Waste disposal methods** encompass a variety of techniques for managing waste, including landfilling, incineration, recycling, composting, and waste-to-energy processes. These methods aim to minimize environmental impact and maximize resource recovery from discarded materials
- Waste-to-energy (WtE) technologies convert non-recyclable waste into usable energy, primarily electricity and heat, through various processes like incineration, pyrolysis, and landfill gas recovery.



Environmental Hazards, Sustainability, Ethics and Laws

- ❖ **Environmental Hazards:** These are conditions or situations that can cause harm to the environment and human health. Examples include pollution (air, water, soil), deforestation, climate change, and loss of biodiversity
- ❖ **Sustainability:** This concept emphasizes the need to balance ecological, social, and economic needs. Sustainable practices aim to minimize environmental damage, conserve resources, and promote long-term ecological health
- ❖ **Environmental Ethics:** This branch of ethics explores the moral relationship between humans and the natural world. It considers the intrinsic value of nature, the rights of future generations, and the responsibilities of humans to protect the environment. Different ethical perspectives exist, such as anthropocentrism (human-centered) and ecocentrism (nature-centered)

Environmental Hazards, Sustainability, Ethics and Laws

❖ **Environmental Laws:** These are rules and regulations established by governments to protect the environment, manage natural resources, and mitigate pollution. They provide a legal framework for addressing environmental issues and ensuring sustainable practices. Examples include laws related to air and water quality, waste management, and conservation.

❖ **Interconnections:** Environmental hazards, sustainability, ethics, and laws are closely linked. Ethical considerations often inform the development of environmental laws, and these laws aim to promote sustainable practices to mitigate environmental hazards. For instance, laws regulating emissions can be seen as a response to the ethical imperative to protect future generations from climate change.



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THANK YOU

