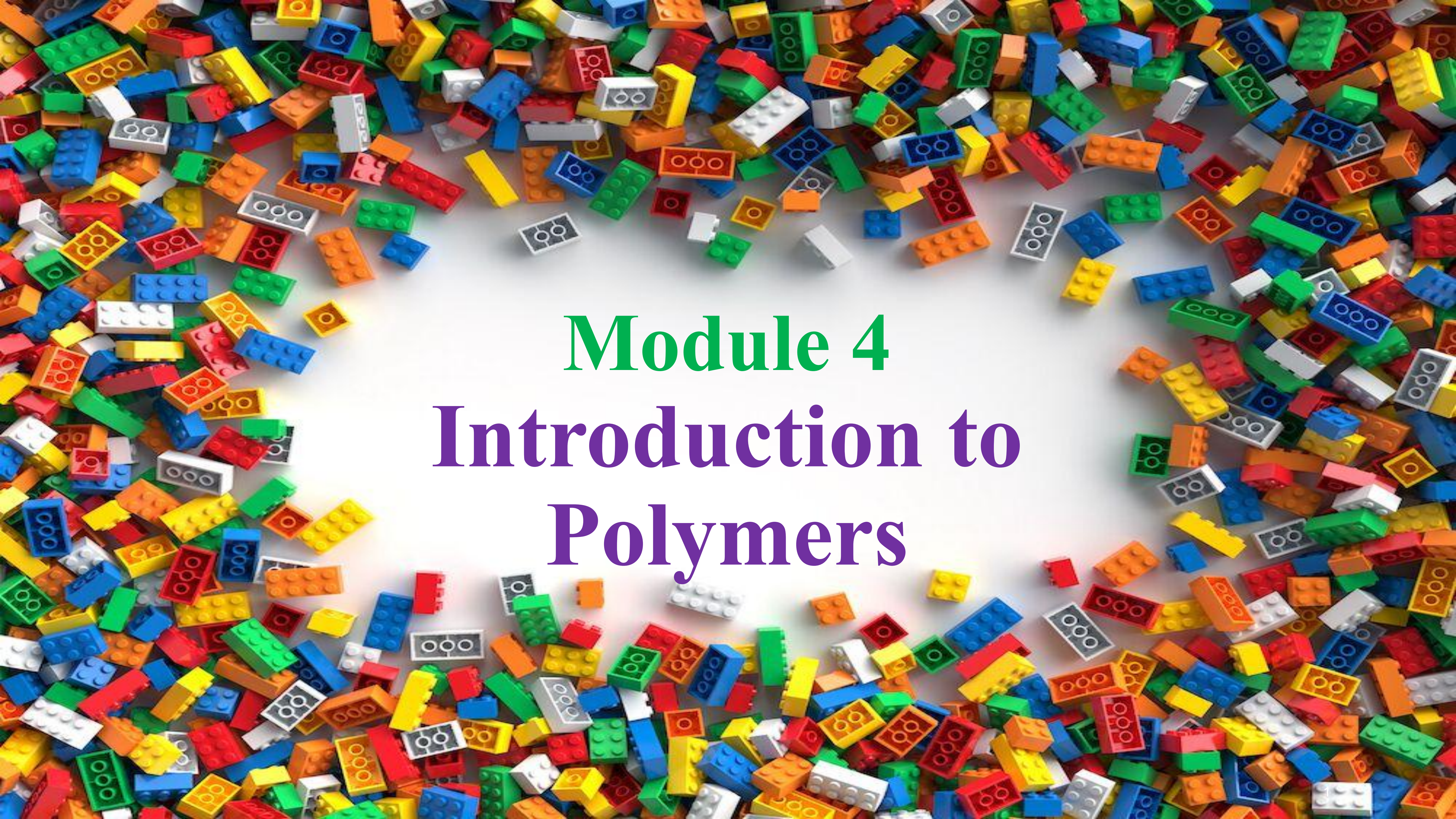


Module 4

Introduction to Polymers

Detailed Content

A) Macro-molecular science, the basic concept of polymers, Chemical bonding in polymers, Classification of Polymers.

B) Properties of Polymers:-

i) Molecular weight -Number average molecular weight, Weight average molecular weight, Numerical

ii) Crystallinity - Crystalline and amorphous polymers – Glass transition temperature,

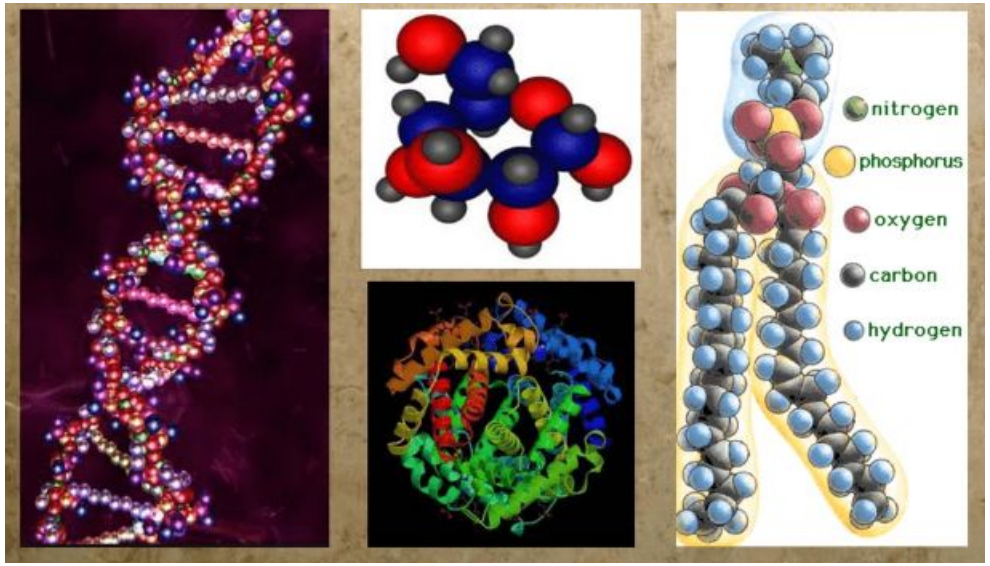
iii) Mechanical Properties: Hardness, tensile strength, creep, fatigue, impact resistance (introduction),

iv) Electrical properties: dielectric strength, insulation resistance, surface resistivity (Introduction),

v) Optical properties: refractive index, transmittance, photoelectric property, colour

Macro-molecular Science

- Macro-molecular science is the study of large molecules, including polymers.
- It explores the structure, properties, and synthesis of these molecules.
- Understanding these aspects helps us create new materials and solve problems in various fields, such as medicine and engineering.



The Basic Concept of Polymers

- Polymers are large molecules composed of repeating structural units called monomers.
- They are formed by a process called polymerization.
- Polymers are abundant in nature, from DNA to proteins, and are also synthesized in laboratories for diverse applications
- Natural polymers are found in nature and include cellulose in plants and proteins in animals.
- Synthetic polymers are human-made and include materials like polyethylene and nylon, which are used for packaging and clothing respectively.
- Biopolymers are large polymers essential for life, such as DNA and RNA, which carry genetic information.

Chemical Bonding in Polymers

Polymers are held together by strong covalent bonds between monomers. These bonds determine the physical and chemical properties of polymers. The type of bonding influences a polymer's flexibility, strength, and melting point.

Covalent Bonds : These bonds form when atoms share electrons to achieve a stable electronic configuration.

Intermolecular Forces: Weak forces between polymer chains can include van der Waals forces, hydrogen bonding, and dipole-dipole interactions.

Classification of Polymers

Classification of polymer		
Nature of monomer	**Tacticity**	**Chemical nature**
Homopolymer	Isotactic	Organic
Heteropolymer	Atatic	Inorganic
	Syndiotactic	

Thermoplastics

Thermoplastics are polymers that soften when heated and become solid again when cooled. They are often used for packaging, toys, and other applications.

1

Heating

Thermoplastics become soft and moldable.

2

Cooling

Thermoplastics solidify and retain their shape.

3

Reheating

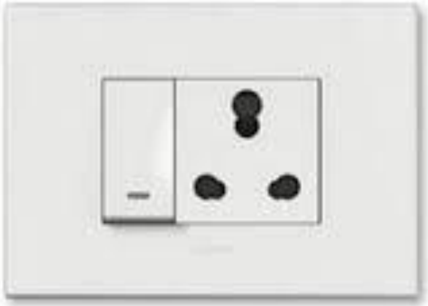
The process can be repeated multiple times.

Thermosets

Thermosets are polymers that undergo irreversible chemical changes upon heating, becoming permanently hard and rigid.

These are often used for construction, adhesives, and other applications requiring high strength and durability.

Thermoplastics	**Thermosets**
Reversible changes upon heating	Irreversible changes upon heating
Can be remolded	Cannot be remolded
Lower strength	Higher strength



Elastomers

Elastomers are polymers that can be stretched to several times their original length and then return to their original shape. They are often used for tires, rubber bands, and other applications requiring elasticity.

High Elasticity

Can stretch to several times their original length.

Flexibility

Able to bend and deform without breaking.

Resilience

Can recover their original shape after deformation.

Properties of Polymers

i)Molecular weight

a)Number Average Molecular Weight

$$M_n = \frac{\sum N_i M_i}{\sum N_i}$$

b)Weight Average Molecular Weight

$$M_w = \frac{\sum N_i M_i^2}{\sum N_i M_i}$$

where, Ni-Number of molecules

Mi- Molecular weight of i^{th} polymer

Polydispersity Index

The polydispersity index (PDI) is a measure of the breadth of the molecular weight distribution in a polymer sample. It is calculated as the ratio of the weight average molecular weight to the number average molecular weight.

$$PDI = \frac{Mw}{Mn}$$

ii) Crystallinity

Crystalline and Amorphous Polymers

Crystalline Polymers

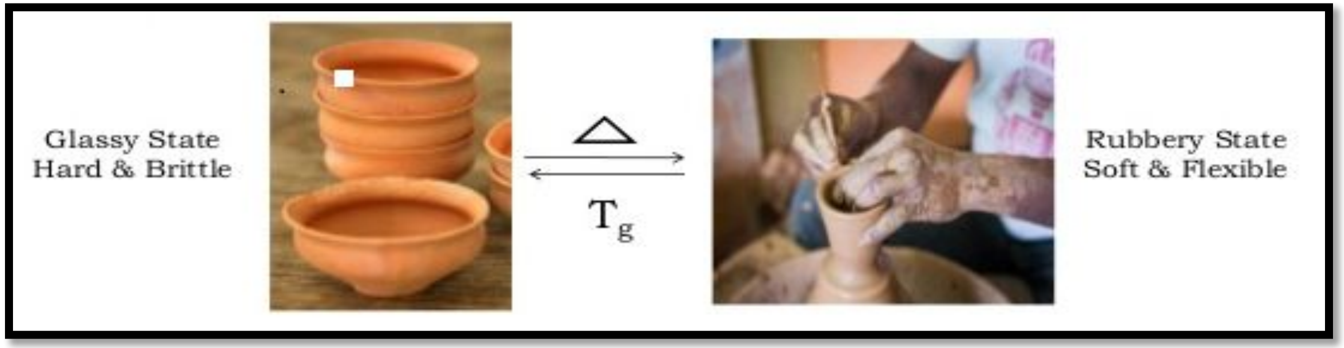
Crystalline polymers have a highly ordered, three-dimensional structure. Chains are arranged in a regular lattice, similar to crystals. They exhibit high strength, stiffness, and melting point.

Amorphous Polymers

Amorphous polymers have a less ordered structure, with chains randomly oriented. They lack long-range order, often exhibiting greater flexibility and lower melting points.

Glass Transition Temperature

The glass transition temperature (Tg) is the temperature below which an amorphous polymer transitions from a rubbery, flexible state to a rigid, glassy state.



Below Tg

Polymer is in a glassy state, hard and brittle.

Above Tg

Polymer is in a rubbery state, flexible and deformable.

The temperature at which it becomes soft and rubbery is glass transition temperature (T_g)

Facts about (T_g)

i. Its values depends upon Chain length & extent of cross linking.

ii. T_g of a polymer varies with the rate of heating or cooling.

iii. T_g of a linear polymer is lower than that of partially cross linked polymer.

iv. Below T_g , the polymer is hard and brittle.

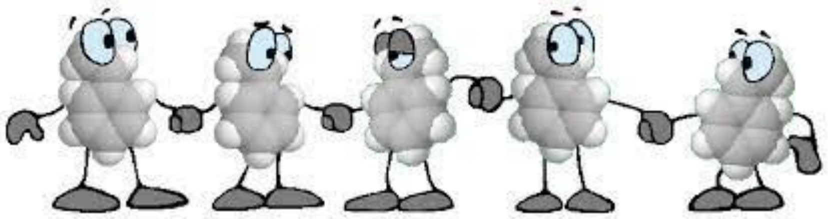
Viscoelasticity

Viscoelasticity refers to the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation.

- **Viscous Behavior:** Resistance to flow (like a liquid).
- **Elastic Behavior:** Ability to return to its original shape after deformation (like a solid).




Mechanical Properties



The mechanical properties of polymers are one of the features that distinguishes them from small molecules.. The mechanical properties of a polymer involve its behavior under stress. These properties tell a polymer scientist or engineer many of the things he or she needs to know when considering how a polymer can be used.

- How strong is the polymer? How much can you stretch it before it breaks?
- How stiff is it? How much does it bend when you push on it?
- Is it brittle? Does it break easily if you hit it hard?
- Is it hard or soft?
- Does it hold up well under repeated stress?

1. Hardness

Hardness is the measure of a material's resistance to localized deformation, such as indentation or scratching.

Significance

- Wear Resistance
- Surface Durability:
- Processing and Application Suitability

2.Tensile strength

Tensile strength is the maximum amount of tensile (stretching) stress a polymer can withstand while being stretched before breaking.

Significance

Structural Integrity
Design and Performance
Processing and Manufacturing
Durability and Longevity

eg:polyamide imide(PAI),Ultem,Nylon

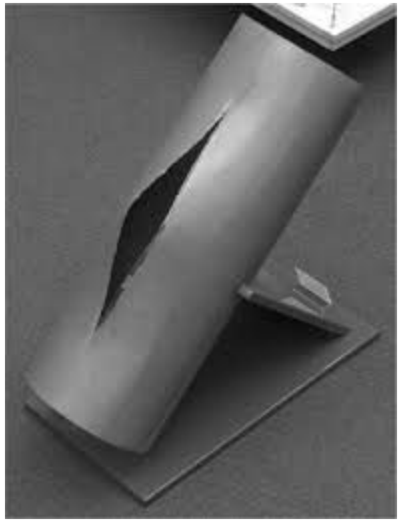
3.Creep

Creep may be defined as a time-dependent deformation at elevated temperature and constant stress.

Significance

A creep test is important because it allows :

- engineers to design parts
- To understand the relationship between stress and temperatures
- Impact on Performance and Safety
- Material Selection and Design



4.Fatigue

Fatigue is the weakening of a polymer caused by repeated or cyclic loading. It occurs over time as the material is subjected to fluctuating stresses that eventually lead to failure, even if the stress levels are below the material's ultimate tensile strength.

Significance

- Impact on Safety and Reliability
- Economic Considerations
- Design and Engineering

5. Impact resistance

Impact resistance is the ability of a polymer to absorb and withstand high-energy impacts without breaking or undergoing significant deformation. It measures how well a material can resist sudden and forceful impacts.

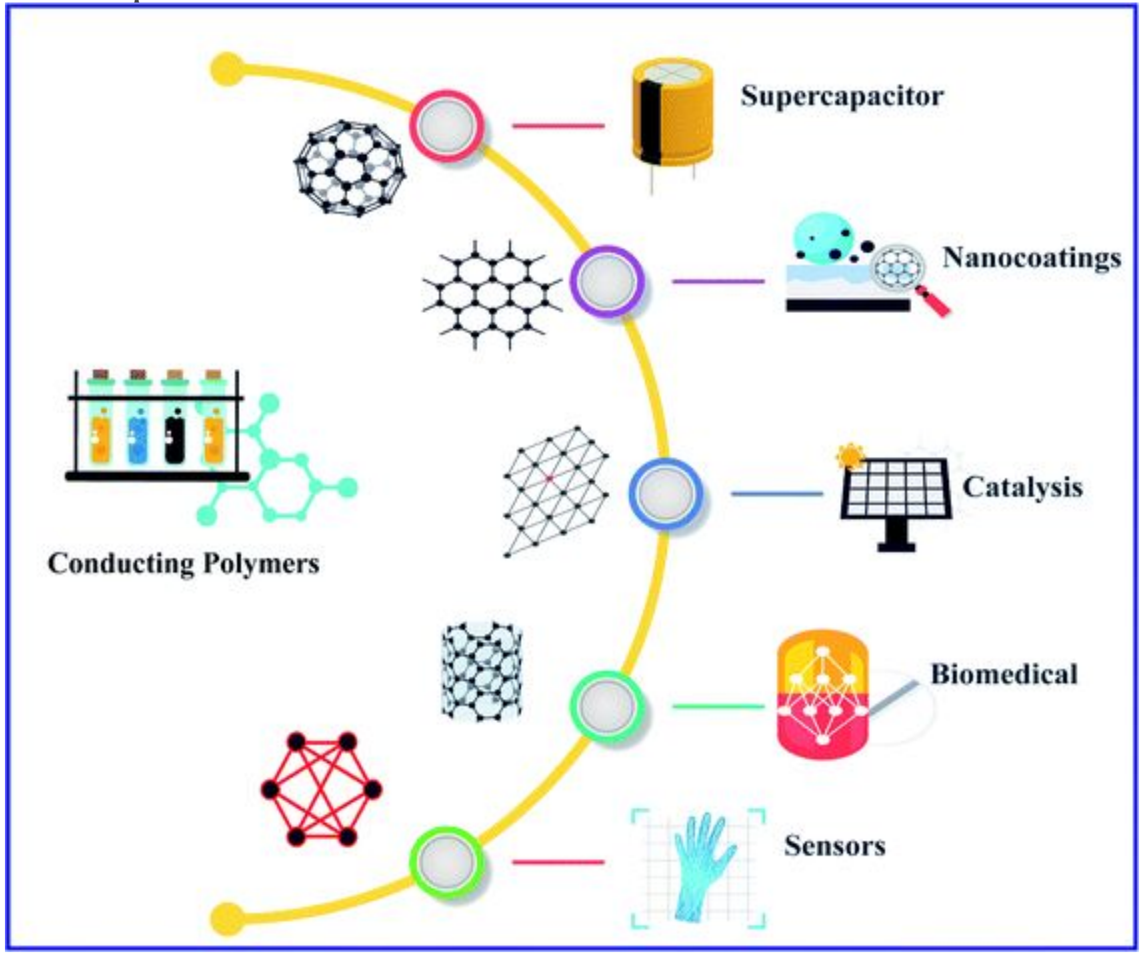
Significance

- Impact on Safety and Reliability
- Durability and Protection
- Performance in Extreme Conditions
- Economic Considerations
- Design and Engineering

Electrical Properties

They are used to insulate wires,cables and other electrical components.

In 1970's, it was discovered that some polymers and organic substances show electrical properties resembling those of semiconductors, metals, or even superconductors. – organic semiconductors, OLED (organic light emitting diode)



1. Dielectric strength

Dielectric strength is the maximum electric field a polymer can withstand without breaking down or allowing electrical current to pass through. It measures the polymer's ability to act as an insulator.

Significance

- The higher the dielectric strength of a material,the better its quality as an insulator
- High dielectric strength enhance the safety and reliability of electrical systems by preventing electrical breakdowns
- Preventing short circuits and protecting sensitive electronic devices from electrical interference.

2. Insulation resistance

Insulation resistance is the measure of how well a polymer resists the flow of electric current through it. It indicates the effectiveness of the polymer as an electrical insulator.

Significance

- It protects users from electric shocks and prevents electrical fires.
- It is crucial for preventing electrical leakage
- It contribute to the reliable performance of electrical and electronic devices.
- Durability in Harsh Environments

3. Surface resistivity

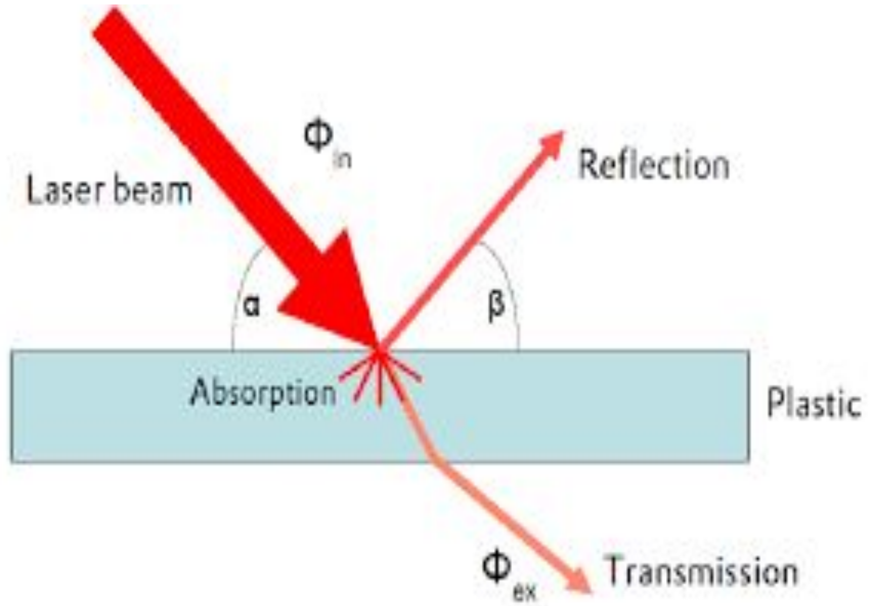
Surface resistivity measures how well a polymer resists the flow of electric current along its surface. It indicates the polymer's ability to act as an insulator when current is applied across its surface.

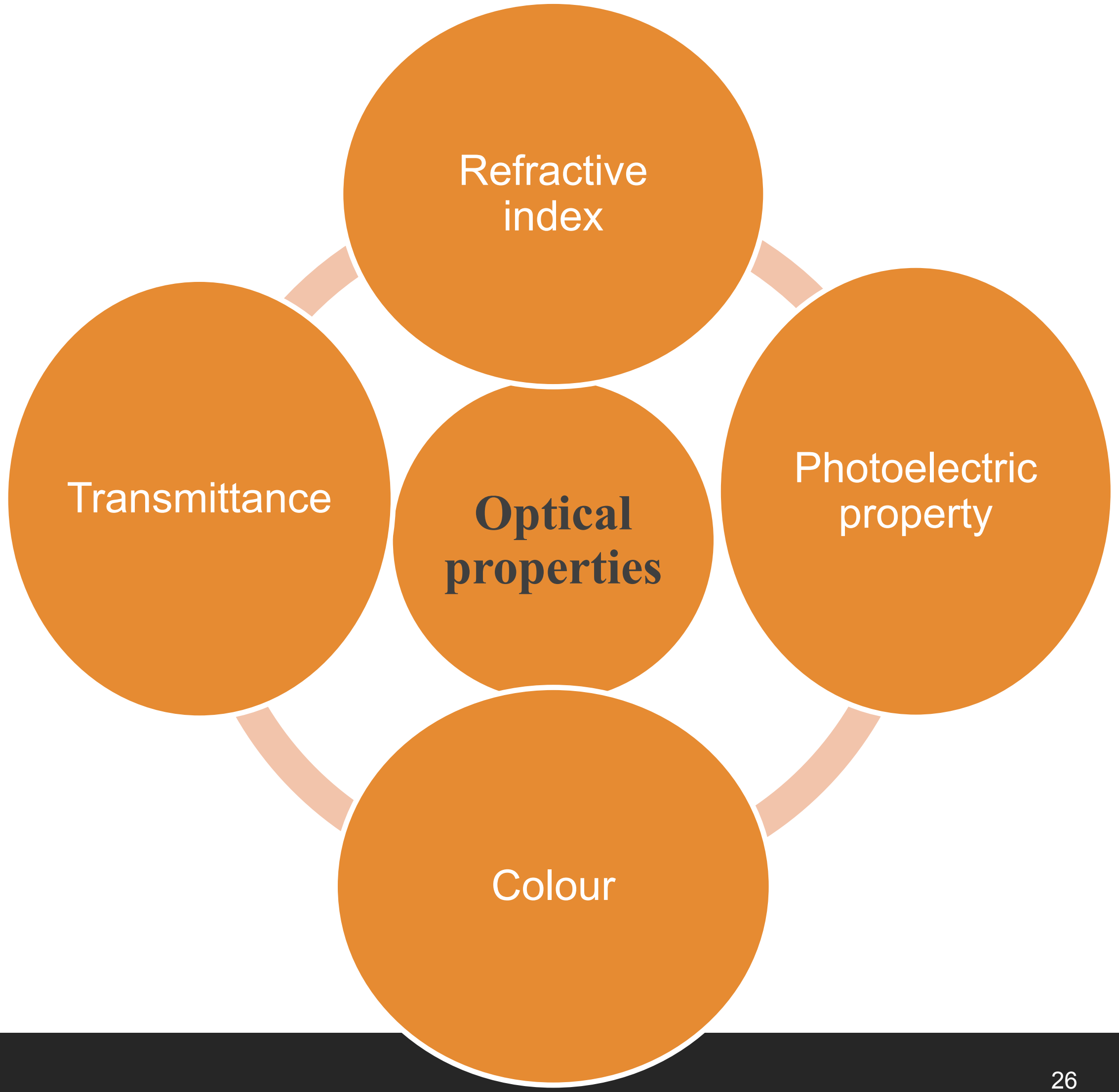
Significance

- High surface resistivity ensures that a polymer does not easily accumulate or discharge static electricity.
- To prevent or control static charge.
- Ensuring proper surface resistivity is critical for compliance with safety standards and regulations

Optical properties

Optical properties refer to how a polymer interacts with light, including how it transmits, absorbs, and reflects light.





1.Refractive Index

The refractive index (n) of a polymer measures how much light is bent or refracted when it passes through the material. It is defined as the ratio of the speed of light in a vacuum to the speed of light in the polymer

Significance

- Optical Clarity and Transparency
- By adjusting the refractive index, polymers can direct and control light effectively.
- Polymers with specific refractive indices are used in anti-reflective coatings
- Colour and Aesthetic Effects

2.Transmittance

It describes how much light s transmitted from a surface or optical element. It is a measure of how much light is transmitted compared to the amount of light incident on the polymer.

Significance

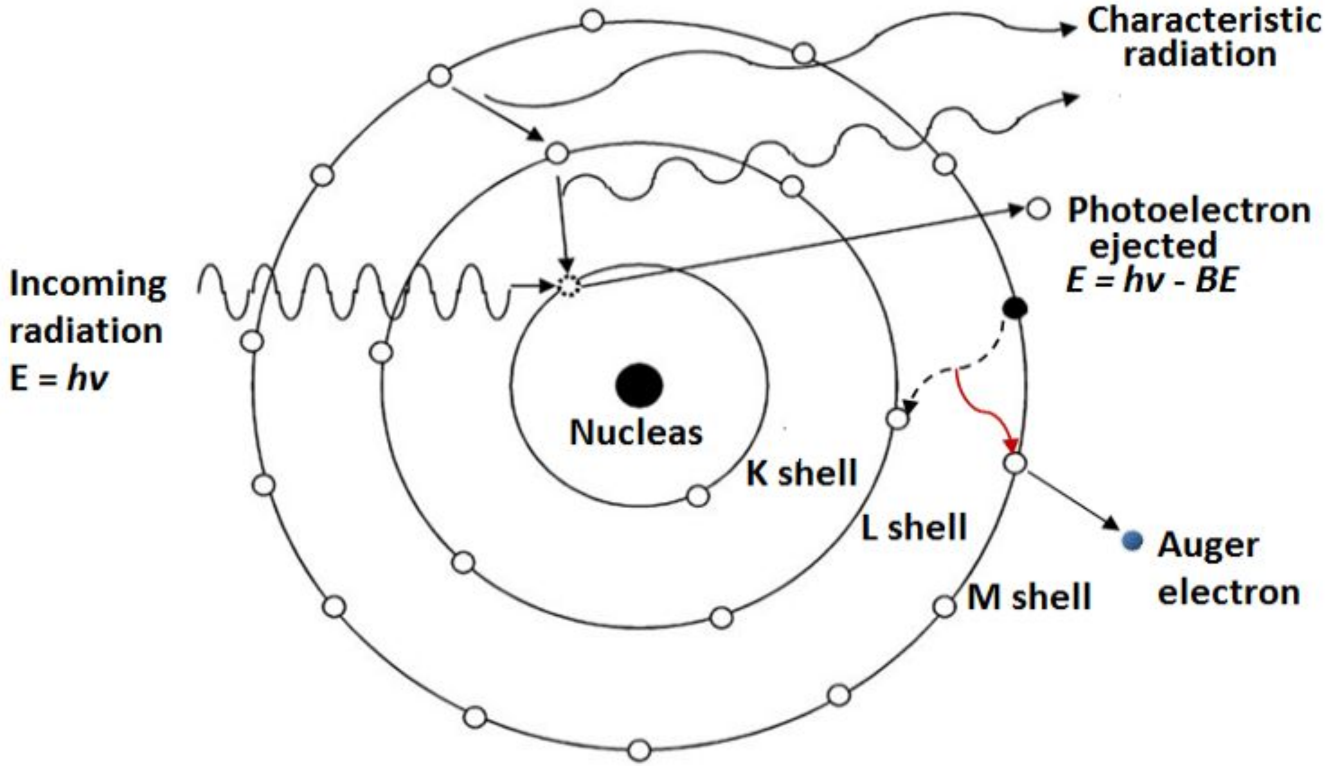
- In lighting applications, high transmittance polymers are used to maximize light efficiency and enhance illumination.
- Polymers with high transmittance allow maximum light to pass through, making them suitable for transparent materials.

3. Photoelectric property

Photoelectric properties refer to the behavior of a polymer when it interacts with light, particularly its ability to generate an electric charge or current when exposed to light.

Significance

- Photovoltaic Devices like solar cells
- OLED Displays: Polymers are used in organic light-emitting diode (OLED)
- Polymers with photoelectric properties are used in photo sensors and detectors that respond to light.



4. Colour

The color of a polymer is determined by its ability to absorb and reflect different wavelengths of light. The specific colors observed are a result of the wavelengths that are reflected back to the eye, while others are absorbed.

Significance

- Aesthetic and Design Appeal
- Branding and Marketing
- Color coding helps in distinguishing products and ensuring proper usage.
- UV-stable colors and coatings are used to enhance longevity and prevent fading

Reference Books

1. Engineering Chemistry, Jain and Jain, Dhanpat Rai Publication
2. A textbook of Engineering Chemistry, S. S. Dara, S. Chand and Company
3. Polymer science: Vasant Gowarikar, Wiley Estern Ltd, new Delhi
4. NPTEL Lecture series link: https://archive.nptel.ac.in/courses/103/106/105106205/

“Polymers are a testament to the power of the small to make a big difference.”
– Dr. Paul Flory

Thank you