

Introduction to Polymers

Introduction to Polymers – Study Notes

1. What Is a Polymer?

- **Definition:** A polymer is a large molecule (macromolecule) composed of repeating structural units called *monomers* linked together by covalent bonds.
 - **Key Characteristics**
 - High molecular weight (often $> 10^5 \text{ g}\cdot\text{mol}^{-1}$)
 - Chain-like architecture (linear, branched, cross-linked)
 - Physical properties depend on chain length, arrangement, and intermolecular forces
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2. Types of Polymers

Category	Source	Typical Examples	Notable Features
Natural Polymers	Biological origin	Cellulose, DNA, proteins, silk, rubber	Biodegradable, often functional in living systems
Synthetic Polymers	Man-made (petrochemical feedstock)	Polyethylene (PE), Polystyrene (PS), Polyvinyl chloride (PVC), Nylon, Teflon (PTFE)	Tailorable properties, mass-produced
Biopolymers (bio-based & biodegradable)	Renewable resources (e.g., corn, sugarcane)	Polylactic acid (PLA), Polyhydroxyalkanoates (PHA)	Reduced environmental impact
Thermoplastics vs. Thermosets	Based on thermal behavior	Thermoplastics: PE, PP, PVC (melt & reshape) Thermosets: Epoxy, Phenolic resin (cure into a rigid network)	Recyclability vs. dimensional stability

3. Polymerization Mechanisms

Mechanism	Process Overview	Typical Monomers	Example Products
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Addition (Chain? Growth) Polymerization	Initiator creates a reactive site; monomers add one by one without by-products.	Vinyl monomers (CH ₂ =CHX)	Polyethylene, Polystyrene, Poly(methyl methacrylate)
Condensation (Step? Growth) Polymerization	Monomers with two functional groups react, releasing a small molecule (e.g., water, HCl).	Diols & diacids, diamines & diacids	Polyesters (PET), Polyamides (Nylon), Polyurethanes
Ring-Opening Polymerization	Cyclic monomers open and link, often giving polymers with fewer side groups.	Lactides, epoxides	Poly(lactic acid) (PLA), Polycaprolactone
Copolymerization	Two or more different monomers are polymerized together, creating tailored sequences.	Any compatible monomers	Styrene-butadiene rubber (SBR), ABS (acrylonitrile-butadiene-styrene)

4. Structural Levels of Polymers

- Primary Structure** – Sequence of monomer units (chemical composition).
- Secondary Structure** – Local ordering (e.g., helical, folded chains) caused by hydrogen bonding or dipole interactions.
- Tertiary Structure** – Overall 3D arrangement of chains; includes crystalline regions and amorphous zones.
- Morphology** – Macroscopic organization:
 - **Crystalline domains** – ordered, high melting point, stiff.
 - **Amorphous domains** – disordered, glass transition (T_g), flexible.

5. Important Physical Properties

Property What It Describes Influencing Factors