Non-Metallic Materials

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Chapter 1: General Information on Plastics

1.1 Introduction

Look around you and you'll see that plastics are everywhere. From the water bottle you take to school to the silicone rubber tips of your favorite headphones. The nylon and polyester in your sneakers. Not only inanimate objects, but many of the proteins in your body are polymers.

Plastic is a material made up of a wide range of synthetic or semi-synthetic organic compounds that are malleable and can therefore be molded into solid objects. Plasticity is the general property of all materials that allows for permanent deformation without breaking.

Plastics are made from natural materials such as cellulose, coal, natural gas, salt, and crude oil through a process of polymerization or polycondensation.

All plastics are polymers, but not all polymers are plastics; plastic is a subcategory of polymer. Polymers are uniform molecules made up of small monomers, while plastics are long-chain molecules made up of large monomers. Polymers can be natural or synthetic, but plastics are synthetic materials.

Polymers are a specific type of chemical substance characterized by their high molecular weight. Furthermore, they have a specific structure: they are made up of repeating units called seas. Their high molecular weight means that the detachment or attachment of a single sea does not significantly alter the chemical and physical properties of the compound. This is an important difference compared to oligomers (substances made up of a small number of seas) – in the case of oligomers, such a change can lead, for example, to a different melting point.

Polymers are primarily associated with plastics. However, this group of compounds is actually much broader. Besides synthetic polymers, which are the building blocks of plastics, there are also natural polymers, common in nature. They constitute one of the basic components of living organisms.

A good understanding of plastics in general begins with an understanding of their natural counterpart. The scientific term resin refers to specific types of mixtures of organic compounds that are not soluble in water. Resins are typically secreted by plants (especially woody plants) as a kind of natural "bandage" to aid recovery when the plant has suffered damage in some way. These substances are highly viscous, transparent to yellowish-brown, and flammable. They are remarkable—and have historically been valued economically—for their ability to convert into polymer arrangements (long chains of organic substances) and harden into solids.

At the risk of oversimplifying, plastics can simply be considered synthetic versions of resins. Like natural resins, the synthetic substances called "plastics" contain thick liquids that can harden under certain conditions. Although they share behavioral similarities with natural resins, it is important to note that plastics have significantly different chemical compositions.

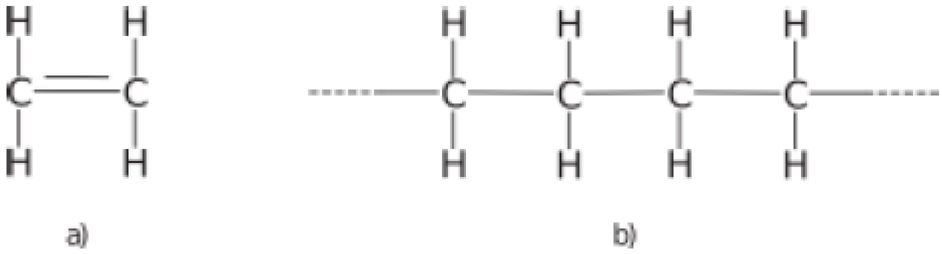


Fig. 1. C_2H_4 monomer and macromolecular chain $(C_2H_4)_n$

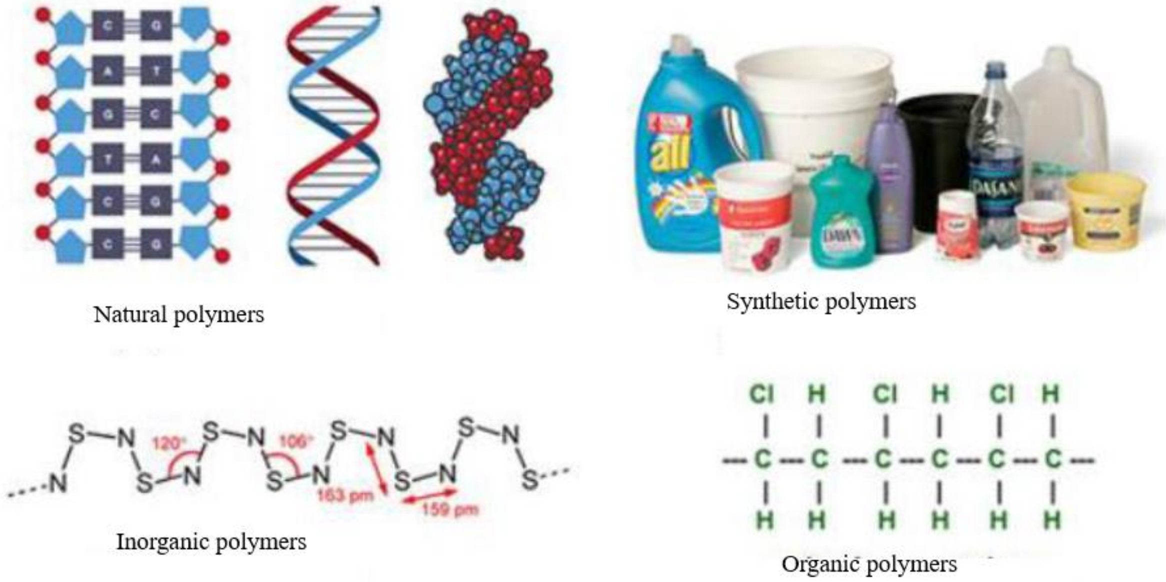


Fig. 2. Different types of polymers

1.2 Structure and Properties of Polymers

Engineering polymers include natural materials such as rubber and synthetic materials such as plastics and elastomers. Polymers are very useful materials because their structures can be modified and adapted to produce materials with a range of mechanical properties in a wide spectrum of colors and with varying degrees of transparency.

Polymers are made up of repeating steps of simpler compounds called monomers. Many chemicals have the potential to be polymerized into chains that form a material whose properties differ significantly from those of the monomer: these are polymers. Monomers can be organic chemical gases, oily liquids, amino acids, sugars, alcohols, and many other chemical types.

1.2.1 Structure

Polymers are large, linear-chain molecules composed of sequences of repeating monomer units linked by covalent bonds. Polymers can be classified as organic or inorganic. It is well known that organic polymers are primarily composed of carbon and hydrogen atoms and frequently of certain heteroatoms such as oxygen, nitrogen, and sulfur. Organic polymers are used as plastics and elastomers, films, and fibers in many fields due to their attractive properties, such as ease of processing, high strength, and low density. Despite their widespread importance, organic polymers have a number of drawbacks. For example, many organic polymers are unsuitable for high-temperature applications and become very brittle at very high temperatures.

In addition to polymers containing only carbon or other organic atoms in their chain, polymers containing "inorganic" atoms can also be formed.

These compounds are of interest because their reactivity, structure, and physical properties offer the potential for developing new technological applications. Many are now well-known. The most widely developed contain silicon in the form of polysiloxanes and polysilanes. Another common class is that of polyphosphazenes.

1.2.2 Properties

The difference in structure, the type of intermolecular forces involved, and the method used for synthesis are some of the factors that influence the properties of polymers. The properties to be considered are physical, chemical, and mechanical properties.

- **Physical Properties of Polymers**

The physical properties of polymers demonstrate their observable and quantifiable behavior, which is influenced by a number of factors, including their structure. The physical properties of polymers are described below:

• **Solubility:** When a polymer is dissolved in a suitable solvent, it absorbs water and swells. Slowly, the polymer dissolves into a viscous and heterogeneous solution. In contrast, a non-polymer like NaCl, when added to water, ionizes and forms a homogeneous solution. This polymer behaves differently with respect to solvents.

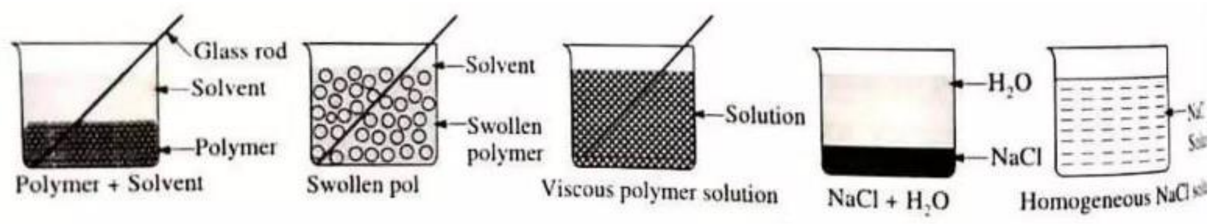
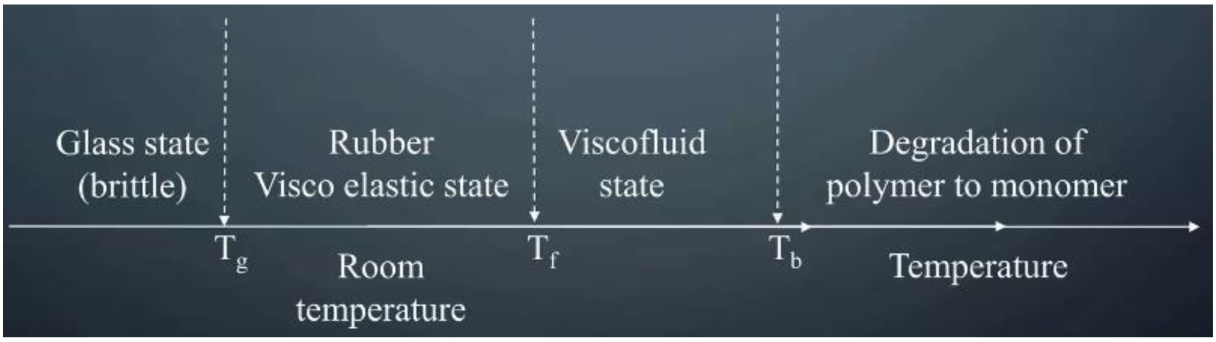


Fig.3: Figure: Solubility of a polymer

• **Effect of heat on polymers:** At room temperature, all polymers are solids existing in a rubbery or viscoelastic state. As the temperature increases, the polymer melts, and this is called the polymer's melting point (T_f), where the material exists in a viscoelastic state. As the temperature rises to boiling (T_b), the polymer decomposes into monomers that exist in the vapor phase and in the solid and liquid phases, depending on the temperature. When the temperature drops below zero degrees Celsius, a temperature is reached where the polymer becomes hard, brittle, and glassy, behaving like glass. This temperature is called the glass transition temperature (T_g).

The polymer remains supple, flexible and rubbery above Tg and below Tg, the polymer becomes hard, brittle and glassy.

For example: Tg of rubber = -73°C



- **Diffusion and permeability**: Crystalline polymers resist the diffusion of molecules through voids or other spaces and tend to resist diffusion due to a much higher degree of molecular packing. Diffusion rates are higher in rubber.

o Mechanical Properties

Polymers exhibit different behaviors with respect to the following mechanical properties:

• **Toughness:** Impact resistance is measured in toughness. Below the glass transition temperature (Tg), polymers break with a brittle fracture and become stronger as the temperature rises from room temperature to Tg. The size of the crystal structure also determines toughness. Small, spherical crystal masses increase toughness.

• **Strength:** Polymer strength depends on the polymer chain length, branching, and crosslinking, which are controlled by the elastomeric properties, crystallinity, and chain branching. A polymer's strength increases with increasing molecular weight. Intermolecular attractive forces, the presence of a polar group, and chain length all contribute to polymer strength.

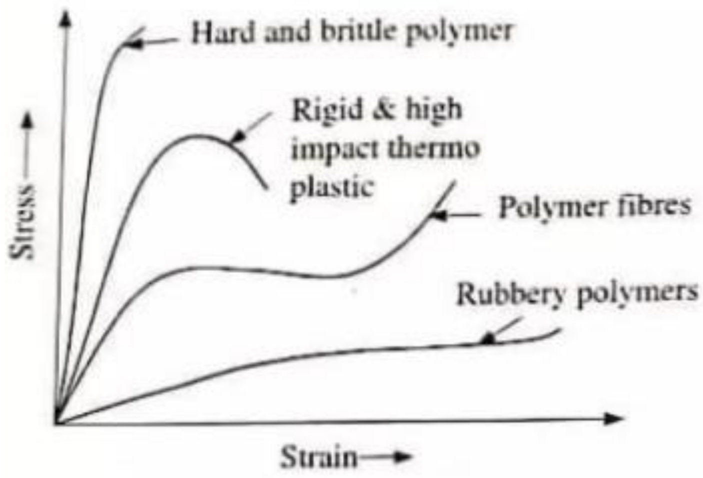


Fig.4: Type of polymer deformation

Four types of stress-strain curves (the line ends where the sample breaks)

✓ The strength of a polymer is determined by a stress-strain test.

✓ Typical stress-strain curves for different types of polymers are explained.

✓ The crystalline region cannot contribute to increasing tensile strength, while the amorphous region does.

• **Elasticity:** Elasticity is the property of returning to the original shape after the removal of deformation stresses. Natural rubber has high elasticity due to the coiled helix structure of polyisoprene.

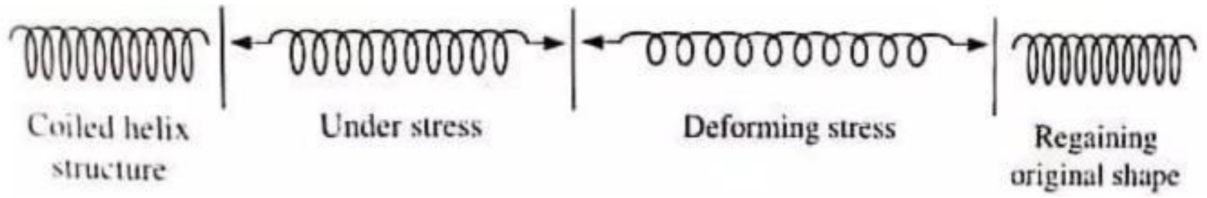


Fig.5: Flexible polymers handle low Tg

1.3 Implementation

Polymers and their many uses are an essential part of everyday life. From household appliances to containers, synthetic clothing, and more, many items are made of polymers. They are also widely used in industrial applications, as sub-components of machines and heavy machinery require some form of polymer.

Examples of Polymers

Here are some important examples of polymers used in everyday life:

Polyethylene: A widely used and common material; plastic bags and containers are actually a polyethylene-based polymer. However, they are not biodegradable and pose a risk to the environment.

LDPE: Low-density polyethylene is used to manufacture various machine parts, pipes, tubes, plastic bottles, and boxes.

PVC: The most common use of polyvinyl chloride is in electrical wires and other PVC-coated insulated equipment. It is also used in water pipes, providing corrosion-free applications.

Nylon: Nylon fibers are used to make water-resistant clothing such as raincoats and umbrellas. They are also used in the manufacture of carpets, parachutes, ropes, and textiles.

Rubber: Rubber is commonly used to make tires, but it is also important for making machine parts, lubricants, gloves, and more.

Teflon: Teflon is most often used in cookware, where a layer of Teflon is applied to the surface of pots and pans to make them non-stick.

Some areas of application:

Medicine

Many biomaterials, particularly heart valve replacements and blood vessels, are made from polymers such as dacron, teflon, and polyurethane.

Consumer Science

Plastic containers of all shapes and sizes are lightweight and less expensive than more traditional containers. Clothing, flooring, garbage bags, and packaging are other applications of polymers.

Industry

Automotive parts, fighter jet windshields, pipes, tanks, packaging materials, insulation, wood substitutes, adhesives, composite matrices, and elastomers are applications of polymers used in the industrial market.

Sports

Playing field equipment, various balls, golf clubs, swimming pools, and protective helmets are often made from polymers.

1.4. Standardization.

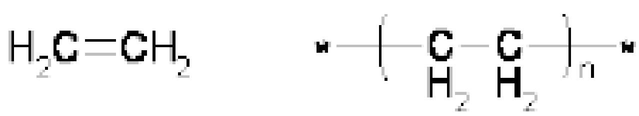
The name of a polymer is generally derived from that of the monomer by adding the prefix "poly". For the monomer name: it is composed of several words, placed in parentheses, and preceded by "poly" (prefix).

Example: poly(vinyl chloride). For copolymers, a unifix is used to describe what is known about the arrangement of the constituent units. They are designated as: the alternating polymer.

Example: Poly[styrene-Co-(methyl methacrylate)].

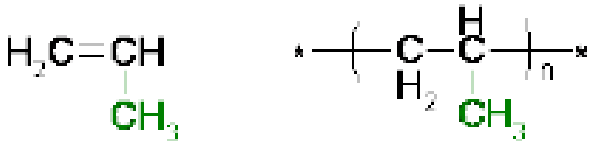
Examples of common polymers:

The most widely used polymer is polyethylene **(PE).**



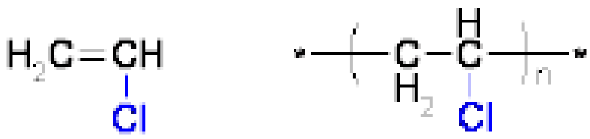
It is the packaging material par excellence.

- The second most commonly used polymer is polypropylene **(PP).**



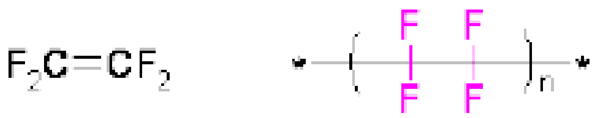
It's a hard plastic. It's found in all plumbing materials.

- Polyvinyl chloride **(PVC).**



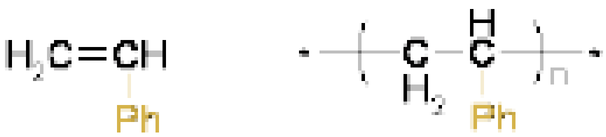
It is used in the manufacture of synthetic shoes and discs.

- Polytetrafluoroethylene **(PTFE).**



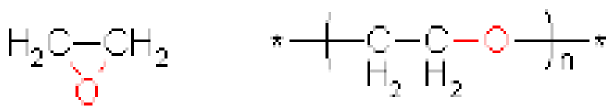
This polymer is better known as Teflon (non-stick).

- Polystyrene **(PS).**



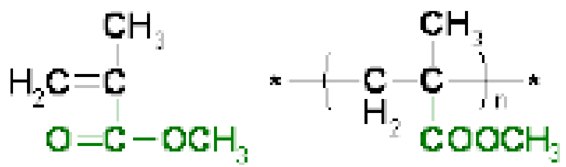
It is used for packaging.

- Polyethylene oxide **(POE).**



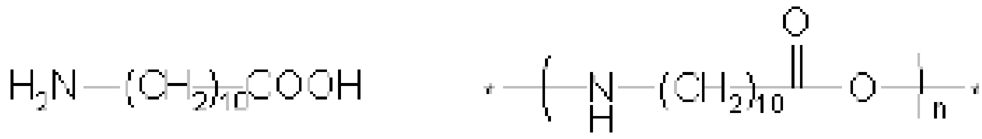
It is used in cosmetics.

- Polymethyl methacrylate **(PMMA).**



It is used in the manufacture of Plexiglas®.

- Polyamides, for example nylon.



It is used in the manufacture of synthetic fibers.