INTRODUCTION

Plastics are ubiquitous (existing) in daily life. Major industries depend on them; neither the electronic industry nor the modern food packaging system can exist without plastics. Plastics in daily life:

- Electronic industry
- Modern food packaging
- Building
- Construction
- Household goods
- Appliances
- Transportation
- Toys
- Furniture
- Agriculture.

The **name plastics** refer to their easy processability and shaping (Greek: plastein = to form or shape).

Polymers are raw materials for plastics; they become plastics only after physical compounding and, in some cases, after chemical hardening.

Polymers are a group of:

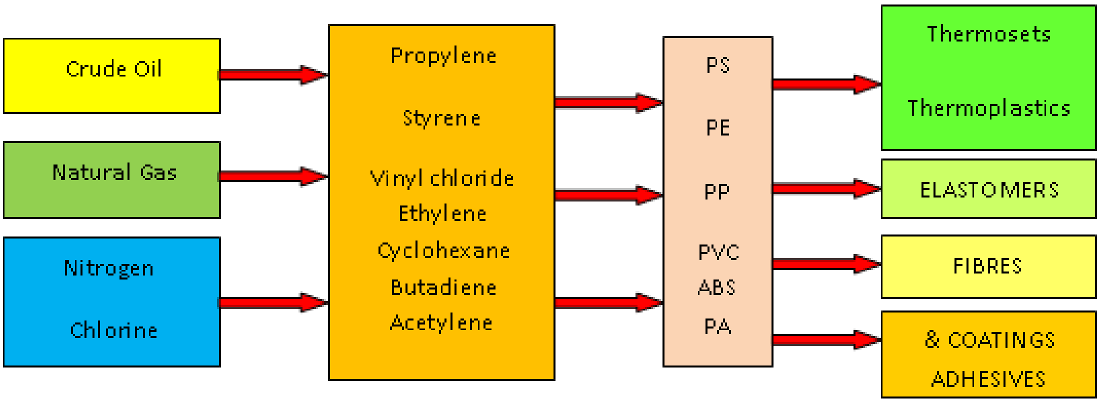
- **Organic**
- **semi organic**, or
- **inorganic**

they are chemical substances with **high molar masses**.

The **term polymer molecule** refers to a molecule composed of many units (Greek, *poly* = many, *meros* = parts), polymer molecules may thus consist of many atoms, usually a thousand or more, thereby having high molar masses 'molecular weights'.

Polymers are not only **used** as plastics but as **fibers**, **binder** in paints. Other polymers may be utilized as fibers, **elastomers** (elastic substances like rubber), **thickeners**, and **ion exchange** resins.

Raw Materials for Polymers



Characteristics of polymers:

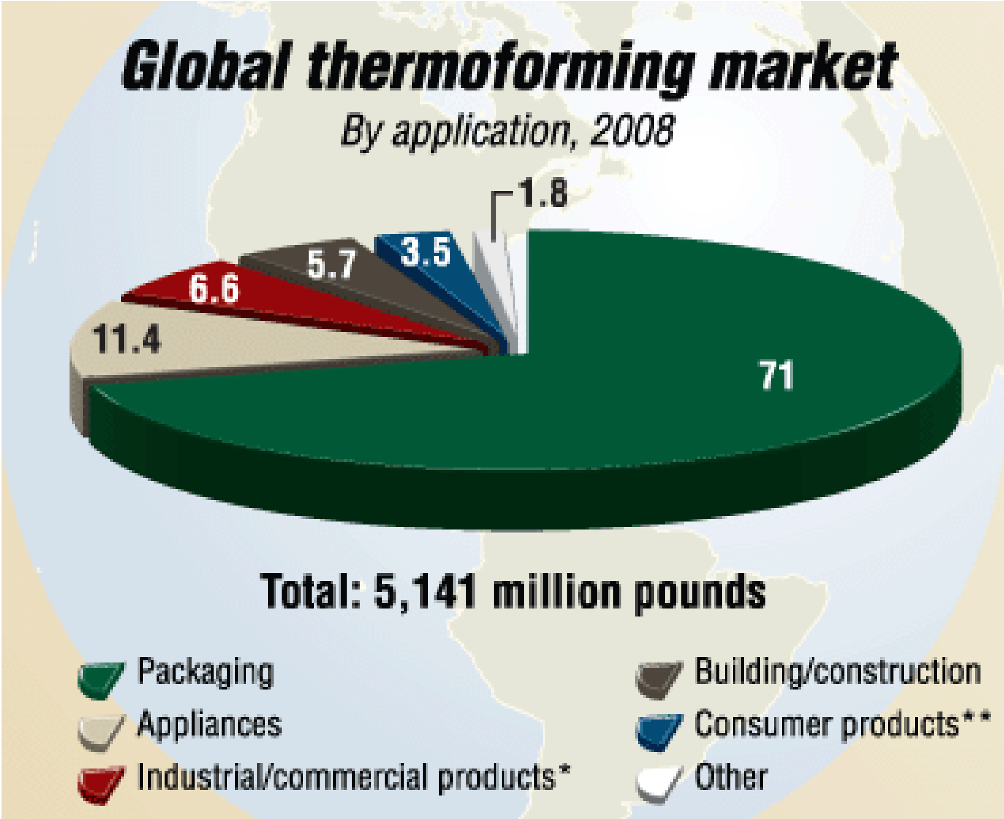
Every polymer has very distinct characteristics, but most polymers have the following general attributes:

1. Polymers can be **very resistant** to chemical.
2. Polymers can be both thermal and electrical **insulators.**
3. Polymers are very **light in weight** with varying degrees of strength.
4. Polymers can **be processed in various ways** to produce thin fibers or very intricate (complex) parts.

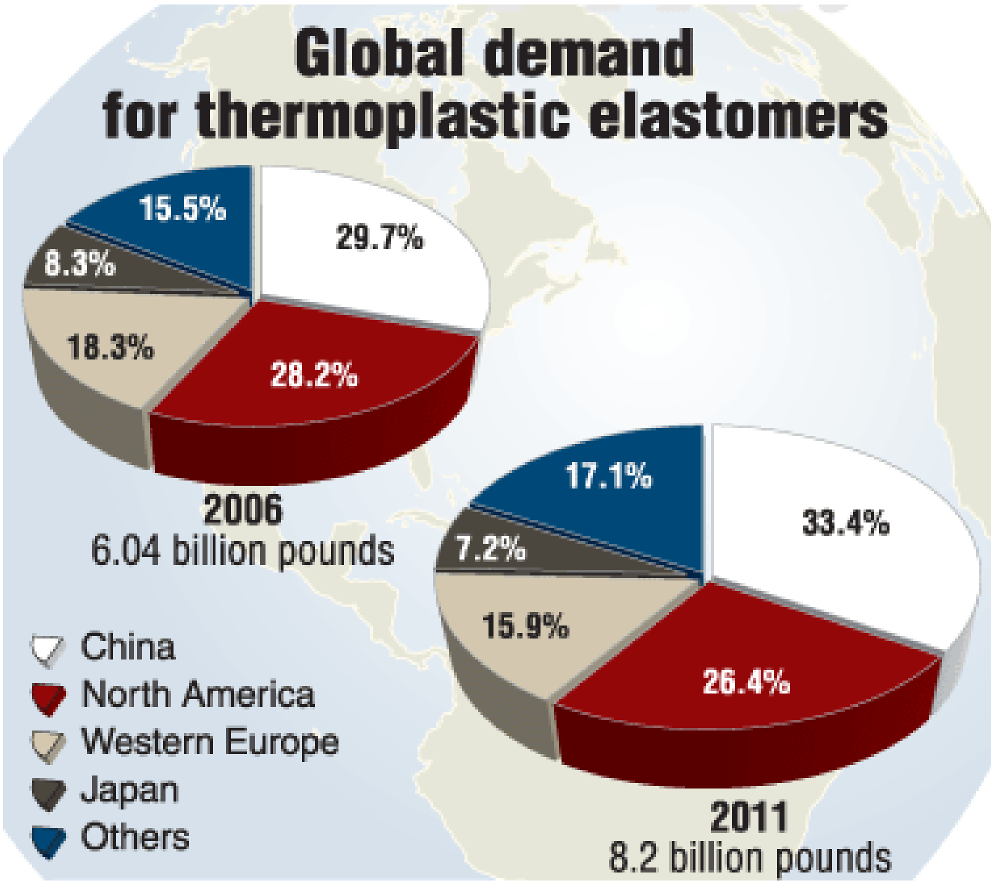
Growth of Modern Plastics

- The period 1930-1940 saw the initial commercial development of today's major thermoplastics.
- The advent of the World War II in 1939 brought plastics into great demand, largely as substitutes for materials in short supply.
- The first decade after World War II saw the development of PP and HDPE and the growth of the new plastics in many applications.
- The demand for plastics has increased steadily; plastics are now accepted by designers and engineers as basic materials along with the more traditional materials.
- Their rapid growth was due to inexpensive raw materials, easy processing, and a wide range of useful and often essential properties.

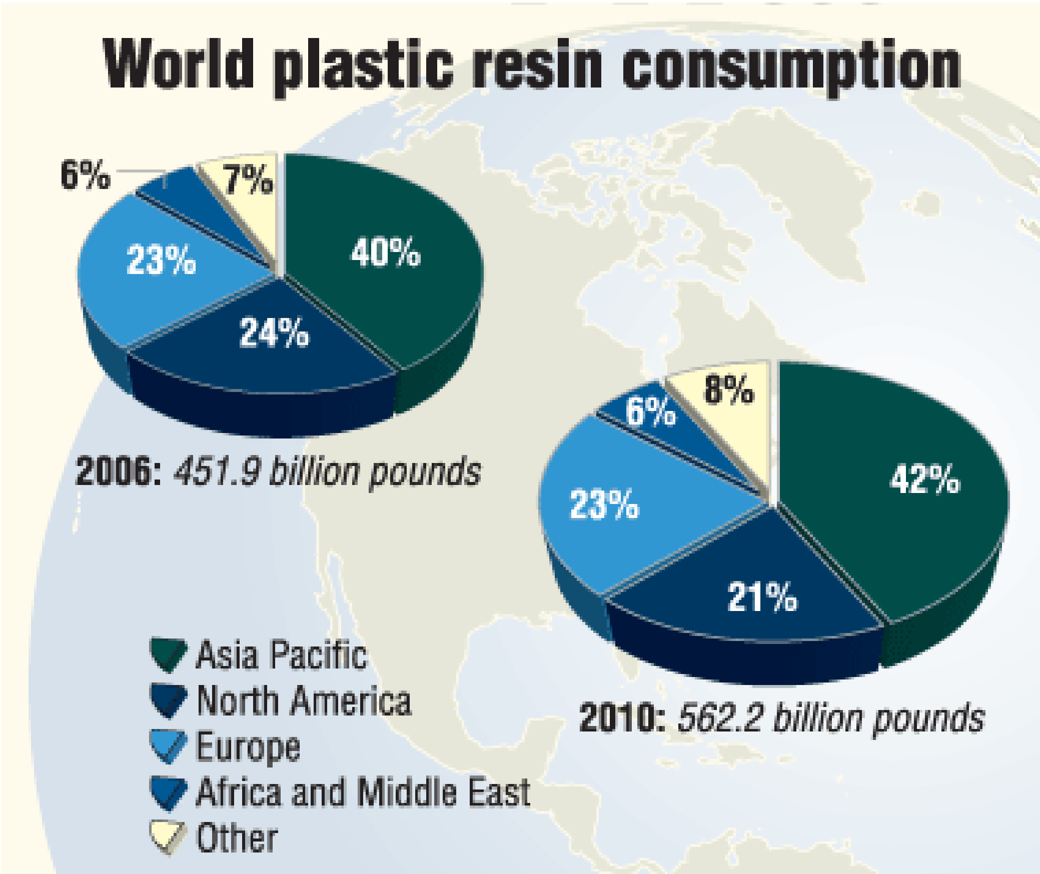
The following figure shows the world consumption of plastics by sectors. Packaging uses 71% of all thermoformed plastics.



The following chart shows the global demand for thermoplastic elastomers:



The following chart shows the world plastic resin consumption:



Classification of Polymers:

1. **Natural Polymers**: exist in nature such as:

- **Nucleic acid**: the acids found in the cell nucleus.
- **Casein**: the most important protein of milk and cheese, (Latin, caseus = cheese).
- **Cellulose**: the polymeric sugar of the plant cell.

Some of these naturally polymers are used by man as materials without further chemical transformation, example: cellulose for paper.

2. **Synthesized Polymers**: most polymers are, however, synthesized from molecules with low molar masses, the so-called monomers. These processes are called polymerization, example are the preparation of:

- **Polyethylene** from ethylene.
- **Polyvinylchloride** from vinyl chloride.
- **Polypropylene** from propylene.
- **Polystyrene** from styrene.

Thermoplastics or Thermosetting:

Components and products are increasingly being made from plastic (polymer) materials and there is a wide choice of manufacturing techniques available. Some of the advantages of manufacturing with polymers are as follows.

- With many polymers manufacturing processes the energy requirements are small compared with that of metals.
- The amount of polymer used can be accurately determined with very small or negligible amounts of waste.
- When casting polymers shrinkage voids are less of a problem than with metals due to the fact that they are not good conductors of heat and do not therefore exhibit large thermal gradients that could lead to uneven cooling.
- Polymers do not, in general, react with the air, and this means that incorporating features in the mould that would be necessary in the case of metals, to reduce oxidation problems, are not required in the case of plastics.

Because of these factors, manufacturing methods for polymers are cheaper than that for most metals.
The use of polymers also enables greater flexibility in the design of components. However, polymer components are not usually as strong or stiff or resistant to heat as components made from metals.

There are two basic families of polymers: thermoplastics and thermosetting plastics:

Thermoplastics:

- When a thermoplastic is heated it **first softens** (plasticisers).
- After time or as the heat is increased, **secondary bonding** (Van Der Waals bonds between the long chain molecules) **breaks down** and it becomes viscous liquid.
- After the heat is removed the liquid thermoplastic will **solidify** (a physical process) with the identical chemical and physical structure that it had before it melted.
- This property of melting and freezing via the formation and breaking down of secondary bonding is much the same as the way most metals behave.
- The shaping of a thermoplastic is thus a **reversible process**.
- They are normally composed of fairly **high molar mass molecules**.
- Examples of thermoplastics are: PP, PE, PVC, PS, nylon, acrylics (such as perspex and plexiglas).

Thermosetting resins:

- Harden through **chemical cross-linking reactions** between polymer molecules and become thermosets since their shapes and properties are set by this process.
- Thermosetting plastics, known as thermosets, undergo an **irreversible chemical change when heated**.
- The initial heating causes a thermoset to **soften**, in the same way as a thermoplastic, and then, after a time usually in the region of a few minutes, the

thermoset will **harden**, due to an irreversible chemical change known as polymerisation. This is the formation of primary **covalent bonding** – crosslinking – between the long chain molecules.

- Re-heating thermosets would **not soften** them again and they would retain their rigidity up to the point where they are destroyed by ablation (**decompose chemically**).
- One major disadvantage with thermosets is that, unlike thermoplastics, they cannot be recycled, their formation is **irreversible**.
- Thermosets are usually generated from fairly **low molar mass polymers** called prepolymers.
- Examples: epoxies, polyesters, silicones and rubbers.

Groups of Plastics:

1. **Commodity thermoplastics** are manufactured in great amounts;
   PVC, PE (HD, LD, LLD), iPP, PS.
2. **Engineering plastics** (technical plastics) are in general thermoplastics that posses improved mechanical properties compared to commodity plastics. They maintain dimensional stability and most mechanical properties above 100^oC or below 0^oC.
   PET, PC, Polyamides, polymethyl methacrylate, polyoxymethylene.
3. **High-performance plastics** are engineering plastics with even more improved mechanical properties. They comprise *liquid crystalline polymers*, *polyetherketones, polysulfones, polyphynylene sulfide*.
4. **Functional plastics**: have only one very specific use like *poly ethylene-co-vinyl alcohol* is a functional plastic that is only used as a barrier resin in packaging.
5. **Fluroplastics** are specially plastics because of their surface properties. They comprise *polytetrafluoroethylene* (PTFE, Teflon), *poly vinylidene fluoride* (PVDF), *polychlorotrifluroethylene* (PCTFE).
6. **Thermosets** are sometimes also classified as engineering or high-performance plastics. They comprise *alkyd* resins, *phenolic* resins, *amino resins*, *epoxides* (epoxies), *polyurethanes*.

Advantages of Plastics

- Corrosion resistance (polyester powder coating).
- Electrical insulation (wire coating).
- Reduced vibration noise (damping).
- Low thermal conductivity (thermal insulation).
- Durable and tough.
- Colour fastness.
- Low density ($\rho = 1000\text{-}1500\ kg/m^3$).

- Low energy to mould and shape.
- Complex shapes moulded in one piece (injection moulding).

Disadvantages of Plastics

- Low stiffness (1-4 GPa).
- Low strength (7-100 MPa).
- High thermal expansion (30-200.10^{-6} K^{-1}).
- Low heat distortion temperature (<150 ^{o}C).
- Mechanical properties vary with time and temperature.
- Disposal/recycling issues.

The following figure shows the classifications of polymers and examples on each type: