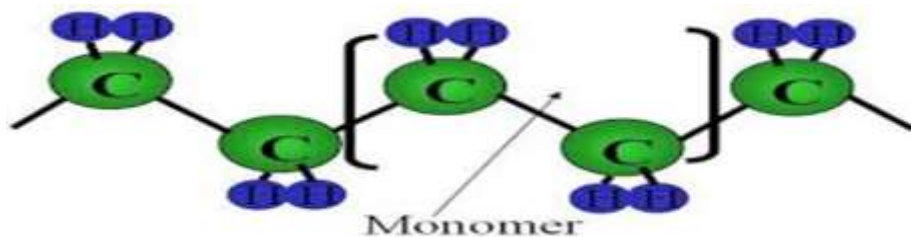


POLYMER CHEMISTRY

Polymers

- A polymers are macromolecule with high molecular mass compound ranging from 5000 to one million
- Formed by combination of one or more low molecular weight compounds. The smallest unit from which polymer is obtained is called monomer.
- The process by which polymers are obtained is called polymerization
- For e.g. polyethylene is obtained by repeating ethylene unit as a result of polymerization.



Polymers form very important components in our daily life. The polymers are highly useful in domestic industrial & medical fields. The following are the reasons for the extensive use of polymers.

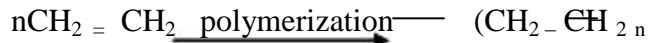
- 1) Most of the polymers are non-toxic & safe to use
- 2) They have low densities (light in weight) so transportation polymers will be easy.
- 3) They possess good mechanical strength.
- 4) These are resistant to corrosion and will not absorb moisture when exposed to the atmosphere.
- 5) These can function as good thermal & electrical insulators.
- 6) These can be moulded and fabricate easily.
- 7) They possess aesthetic colors

But the limitations for the use of polymers are

1. Some polymers are combustible.
2. The properties of polymers are time dependent
3. Some of them cannot withstand high temperature.

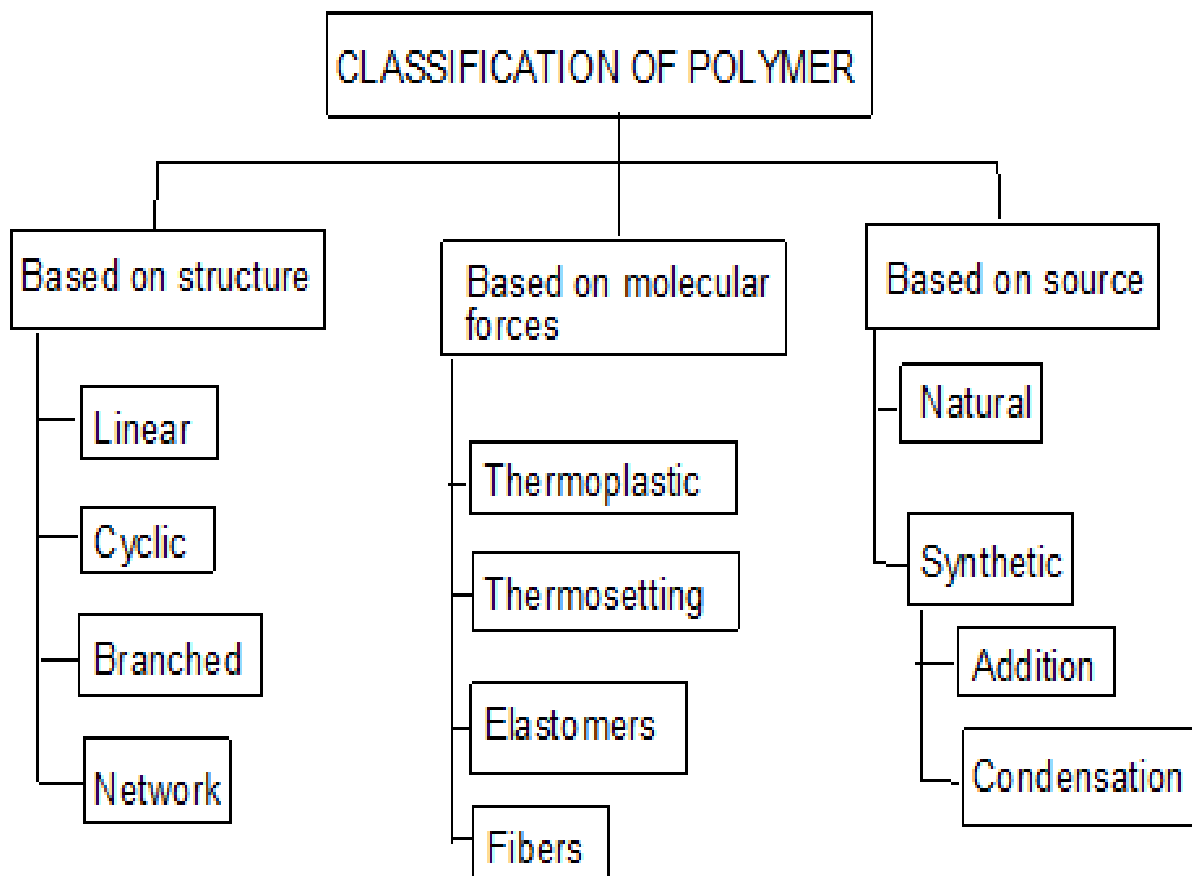
It is also interesting to note that many carbohydrates, Proteins & enzymes, DNA & RNA are natural polymers. Polymers can be defined as the large molecules (macro molecular) formed by the linkage of small molecules called monomers. (In Greek language poly means many & mer means units)

E.g.:- poly ethylene



Thus the repeated unit of polymer is called monomer. The number of repeating units in a polymer chain is called degree of polymerization. For e.g.:- if 100 molecules of ethylene polymerize to give the polymer chain, the degree of polymerization is 100.

CLASSIFICATION OF POLYMERS



Classification based on source

- Naturally occurring Polymers: These occur in plants and animals and are very essential for life e.g. starch, cellulose, amino acids, etc.
- Synthetic polymers: These polymers are prepared in laboratory they are man made polymers e.g. plastics, synthetic rubbers, etc.
- Semi synthetic polymers: These are derived from naturally occurring polymers by chemical modification. e.g. vulcanized rubber, Cuprammonium silk and Cuprammonium rayon, etc.

Polymers are classified into four categories based on magnitude of intermolecular forces

- Elastomers: In these polymers, chain are held by weakest intermolecular forces which permits the polymers to be stretched. The polymer regains its original position when forces are released.

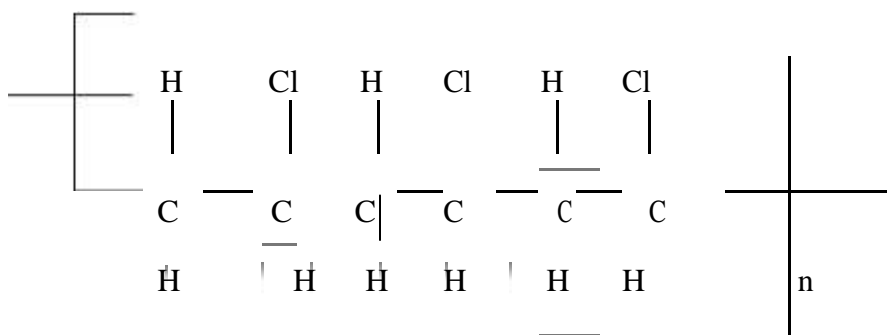
- **Fibers:** In these polymers the inter molecular forces are strong due to hydrogen bonding, cross linking , cyclic structure
- **Thermoplastics:** These are polymers for which inter molecular forces between elastomers and fibers. Due to this they can be easily molded by heating.
- **Thermosetting polymers:** Thermosetting polymers undergo chemical changes and cross linking on heating and become permanently hard and infusible.

Tacticity:-

The arrangement of functional groups on carbon backbone of the polymer is called Tacticity.

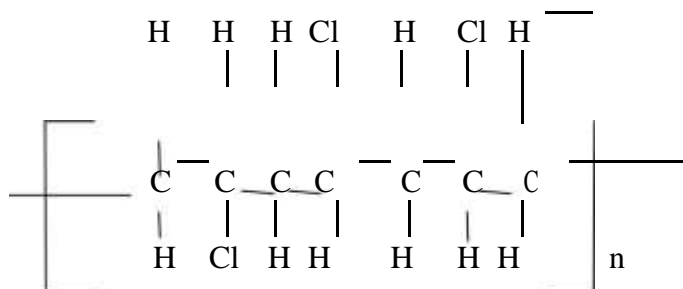
It is mainly divided into 3 types.

- 1) **Isotactic polymers:** Those polymers in which the functional groups are arranged on the same side are called Isotactic polymers. E.g.:- PVC

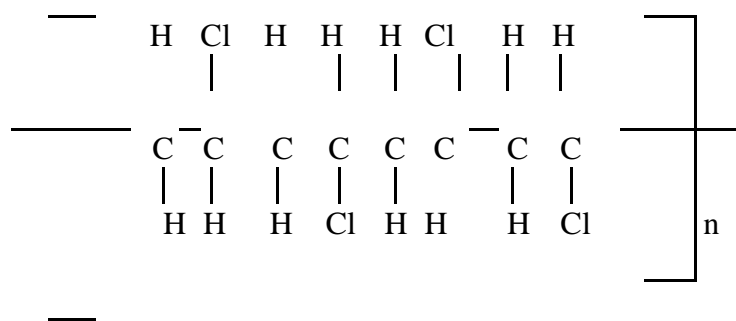


- 2) **Atactic polymers:** When there is no regular arrangement of functional groups on the backbone of the polymer chain these polymers are called atactic polymers.

E.g.: PVC (Poly Vinyl chloride)

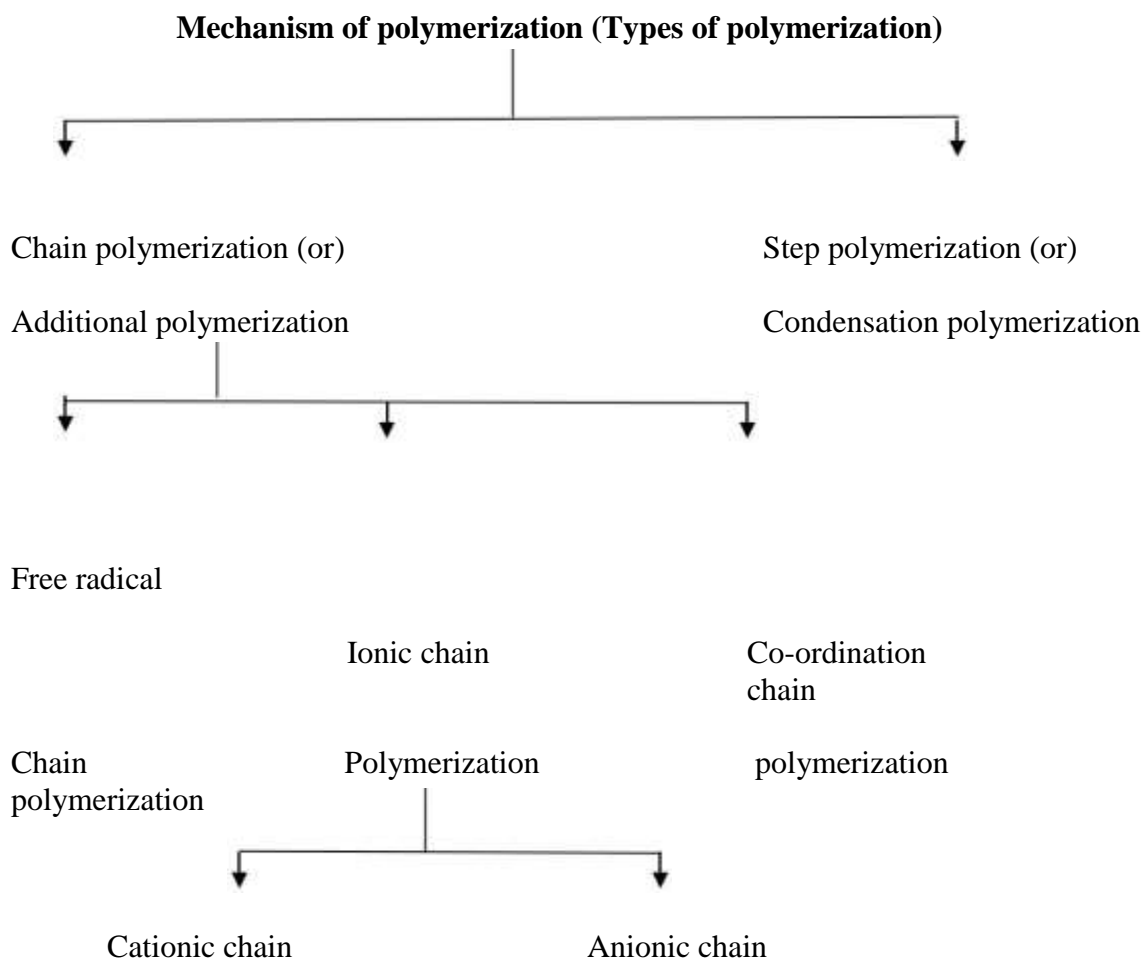


- 3) **Syndiotactic Polymers:** The polymers with alternate arrangement of functional groups are called syndiotactic polymers for e.g.:- PVC



S. No	Type	Division		
		Linear	Branched	Cross linked
1.	Structure/shape			
2.	Tacticity	Isotactic	Syndiotactic	Atactic
3.	Physical state	Amorphous		Crystalline
4.	Heat	Thermoplastic		Thermosetting
5.	Conductance	Insulators		Conductors
6.	Origin	Natural		Synthetic
7.	Environment	Biodegradable		Durable
8.	Monomer	Polar		Non-polar
9.	Number of monomers	Homo-polymer		Co-polymer
10.	Polymer chain	Homo – chain		Hetero – chain

11.	Polymerization	Addition	Condensation
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Types of Polymerisation:-

There are two types of polymerization. They are

- (1) Condensation polymerization:-** Condensation polymers are those in which two like or unlike monomers join each other by the elimination of small molecules such as H_2O , HCl , etc.

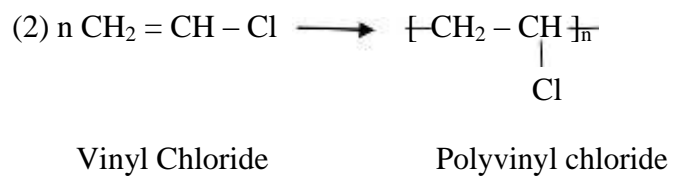
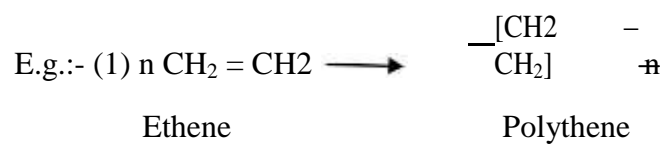
When the same kind of monomers joins, the polymer is called homopolymer.

E.g.:- Nylon -6

It is prepared by the self condensation of w-amino caproic acid which is produced from caprolactum.

(2) Chain Polymerization:- (Addition Polymerization)

Addition polymers are formed by adding monomer units without any loss of atoms or groups.



Difference between condensation of additional polymerisation:-

Condensation polymerisation	Additional polymerisation
(1) It is also known as step growth polymerisation	(1) It is also known as chain growth polymerization
(2) It takes place in monomers having reactive functional groups	(2) It takes place only in monomers having multiple bonds.
(3) It takes place with elimination of simple molecule like H_2O , NH_3 , HCl etc.,	(3) It takes place without elimination of simple molecule.
(4) Repeat units of monomers are different	(4) Repeat units & monomers are same.
(5) The polymer is formed in gradual steps	(5) Reaction is fast and polymer is formed at once.
(6) The molecular mass of polymer increases throughout the reaction	(6) There is very little change in the molecular mass throughout the reaction
(7) Product obtained may be thermosetting/thermoplastic	(7) Product obtained are thermoplastic
(8) E.g.:- Bakelite, polyester ,polyamides etc.,	(8) E.g:-Polyethylene, PVC, poly styrene.

Molecular Mass of Polymer

- The molecular mass of polymer is an important property of polymer because many important properties of properties are influenced by molecular mass. Polymers with higher molecular mass are tougher and more resistant. Their viscosities and softening temperature are also higher. Thus polymers with molecular mass are often required for particular purposes.
- Molecular mass of polymer is not a fixed or constant value like organic compound. Their molecular mass is controlled by polymerization reaction, which in turn depend upon

availability of functional group, charge carrier, life time of charge carriers. Because of random nature of growth process, the product of polymerization process is mixture of chains of different length.

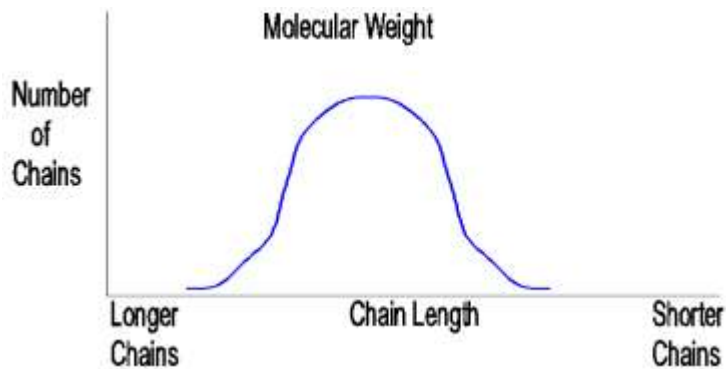
- Hence polymers are poly disperse mixture of various molecular mass polymers. Therefore molecular mass of polymers is average molecular mass

Average molecular mass of polymers can be expressed in following ways

1. Number Average Molecular Mass (M_n)
2. Weight Average Molecular Mass (M_w)
3. Z-Average Molecular Mass (M_z)
4. Viscosity average Molecular Mass (M_v)

Number average Molecular Mass (M_n)

The colligative properties of polymer solution determined, which counts number of molecules in a given volume of mass. Each molecule makes equal contribution to the colligative properties regardless of molecular mass or size. Hence molecular mass obtained by colligative properties measurement is known as number average molecular mass M_n .



Weight average Molecular Mass (M_w)

When the molecular mass is average according to mass of molecules, weight average molecular mass is obtained. It is determined by light scattering measurement and sedimentation methods

Plastics

Plastic is a substance that can be easily formed or moulded into a desired shape.

Plastic can be formed in a desired shape by the effect of mechanical force & heat.

In the manufacture of plastic raw materials like coal, petroleum, cellulose, salt, sulphur, limestone, air, water etc are used.

Plastics as engineering materials:-

Advantages of plastics over other engineering materials.

- (1) Low fabrication cost, low thermal & electrical conductivities, high resistance to corrosion & solvents.
- (2) The stress – strain relationship of plastics is similar to that of the metals.
- (3) Plastics reduce noise & vibration in machines
- (4) Plastics are bad conductors of heat are useful for making handles used for hot objects, most plastics are inflammable.
- (5) Plastics are electrical insulators & find large scale use in the electrical industry.
- (6) Plastics are resistance to chemicals.
- (7) Plastics are clear & transparent so they can be given beautiful colours.

Types of Plastic: - (1) Thermoplastics

(2) Thermosetting plastics

Difference between thermoplastic & thermosetting resins:-

Thermoplastic resins (or) Polymers	Thermosetting resins
(1) These are produced by additional polymerization	(1) These are produced by condensation polymerization.
(2) The resins are made of long chains attached by weak Vander Waal's	(2) The resins have three dimensional network structure connected bonds.

	force of attraction	
(3)	On heating they soften and on cooling become stiff chemical nature won't change	(3) On heating they become stiff & hard. No change on cooling. Chemical nature changes.

(4) They can be remoulded	(4) They cannot be remoulded because once set means they are permanently set
(5) Scrap (waste product) can be used	(5) Scrap cannot be used
(6) The resins are soft, weak and less brittle	(6) The resins are usually hard, strong tough & more brittle
(7) These are easily soluble in some organic substances E.g.:- PVC, polyethylene etc.,	(7) Resins are not soluble in organic Solvents E.g.:- Nylon, Bakelite etc.,
(8) Contain long chain polymer with no cross linkage.	(8) They have 3D network structure.

Compounding of plastics:-

Compounding of plastics:- Compounding of plastics may be defined as the mixing of different materials like plasticizers, fillers of extenders, lubricants, pigments to the thermoplastic & thermosetting resins to increase their useful properties like strength, toughness, etc.

Resins have plasticity or binding property, but need other ingredients to be mixed with them for fabrication into useful shapes.

Ingredients used in compounding of plastics are

(1)Resins (2) Plasticizers (3) fillers (4) pigments (5) Stabilizers.

- (1) **Resins:-** The product of polymerization is called resins and this forms the major portion of the body of plastics. It is the binder, which holds the different constituents together. Thermosetting resins are usually, supplied as linear – polymers of comparatively low molecular weight, because at this stage they are fusible and hence, mouldable. The conversion of this fusible form into cross-linked infusible form takes place, during moulding itself, in presence of catalysts etc.
- (2) **Plasticizers:-** Plasticizers are substances added to enhance the plasticity of the material and to reduce the cracking on the surface.

Plasticizers are added to the plastics to increase the flexibility & toughness. Plasticizers also increase the flow property of the plastics.

e.g.:- Tricresyl phosphate, Dibutyl oxalate, castor oil

- (3) **Fillers (or) extenders:-** Fillers are generally added to thermosetting plastics to increase elasticity and crack resistance.

Fillers improve thermal stability, strength, non combustibility, water resistance, electrical insulation properties & external appearance.

E.g.:- Mica, cotton, carbon black, graphite, BaSO₄ etc.

- (4) **Dyes and pigments:-** These are added to impart the desired colour to the plastics and give decorative effect.

e.g.:- Lead chromate (yellow), ferro cyanide (blue)

- (5) **Stabilizers:-** Stabilizers are used to improve the thermal stability of plastics, e.g.:- PVC. At moulding temperature, PVC undergoes decomposition & decolourisation. So during their moulding, stabilizers are used. E.g.:- white lead, lead chromate.

FABRICATION OF PLASTICS

Giving any desired shape to the plastics (granules or powders) by using mould under the application of heat and pressure.

A proper method is to be selected depending on the shape and type of resin used.

Methods involves partial melting of resinous mass by heating.

In case of thermo-plasts molten resin is introduced in die/mould and desired shape could be achieved by compression and further cooling.

In case of thermo-sets partially polymerized mass or raw materials are introduced in the die/mould, which further cured at high temperature in the mould itself to achieve desired shape.

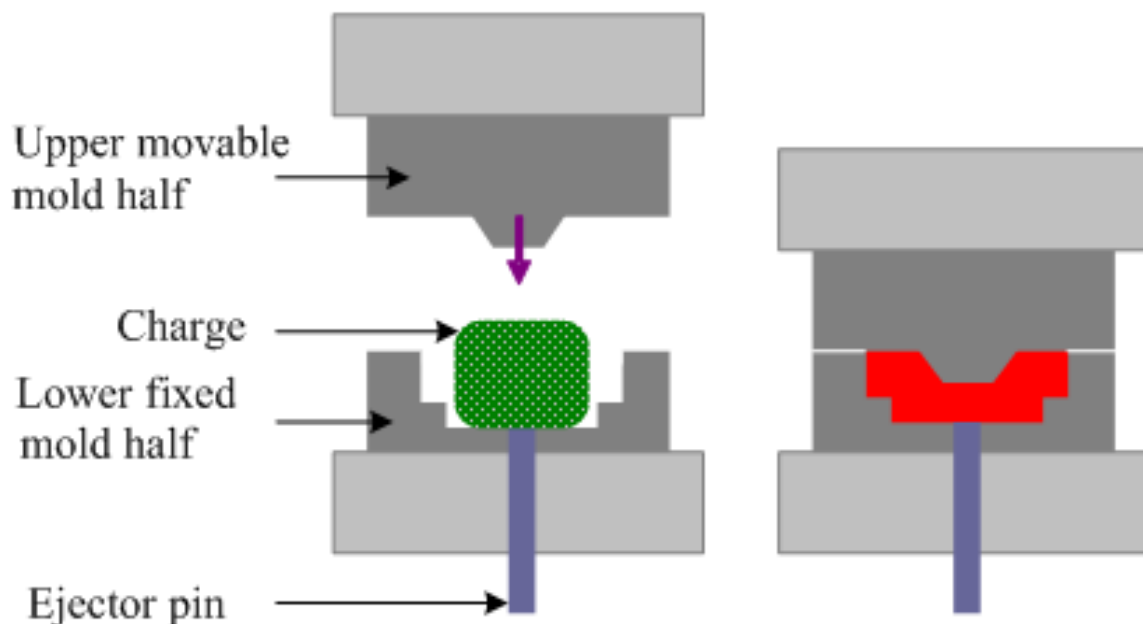
- In case of thermoplasts, curing is done at room temperature (low temperature)
- In case of thermosets, curing is done at high temperature to obtain desired cross-linking

TYPES OF FABRICATION

- | | |
|-------------------------|--|
| [I] Compression Molding | (Suitable for Thermosets / Thermoplasts) |
| [II] Injection Molding | (Suitable for Thermoplasts) |
| [III] Transfer Molding | (Suitable for Thermosets) |
| [IV] Extrusion Molding | (Suitable for Thermoplasts) |

COMPRESSION MOLDING

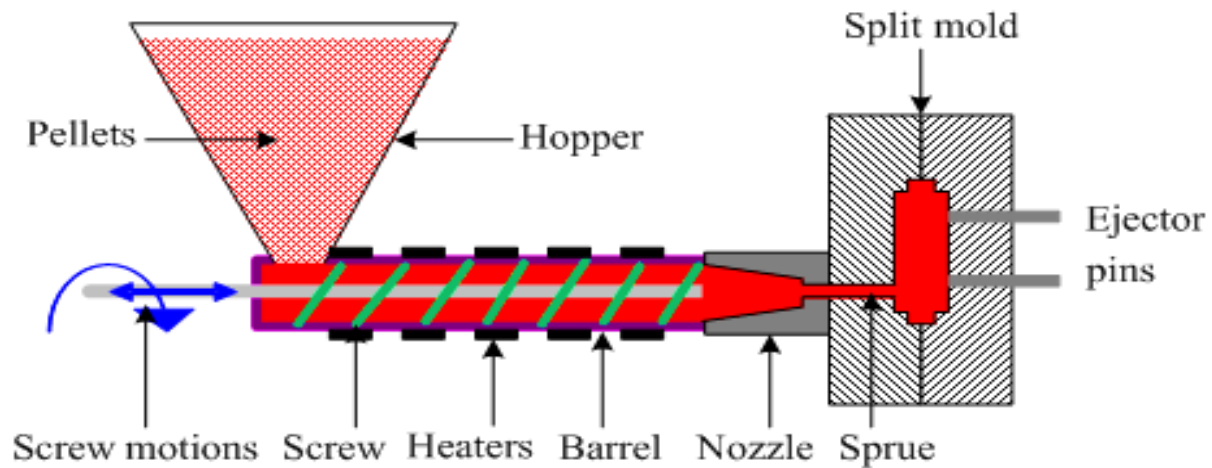
1. Common and oldest method for molding thermosetting / thermoplastic materials
2. Compression of raw materials or soften resinous mass is done in the mould/die under heat and pressure
3. Predetermined quantity of raw materials is introduced carefully in the mould, further compressed by hydraulic pressure (2000 to 10000 psi)
4. Molten or soften resinous mass gets filled in the cavity of mould.
5. Curing is done by heating (Thermosetting) or by cooling (Thermoplastics)
6. Finally moulded article is separated from the mould by opening the mould apart.
7. Applications : Electric switch boxes, Ash trays, cabinets for radio, television, computers etc.



INJECTION MOLDING

- This method is especially used for thermoplastic materials
- Powder or granular resin is heated in a cylinder and injected at a controlled rate in a mould with the help of piston plunger or screw.
- Piston plunger or screw is used to force the material in mould.
- Pressure upto 2000 kg/cm^2 (100 psi) is used
- Once the article is formed mould is cooled and half mould is opened to remove the finished article.

- Disadvantage of the method is formation of air bubbles or cavities in the articles
- **Applications:** Smaller but large volume articles such as, pen caps, bottle caps, cups, containers, mechanical parts

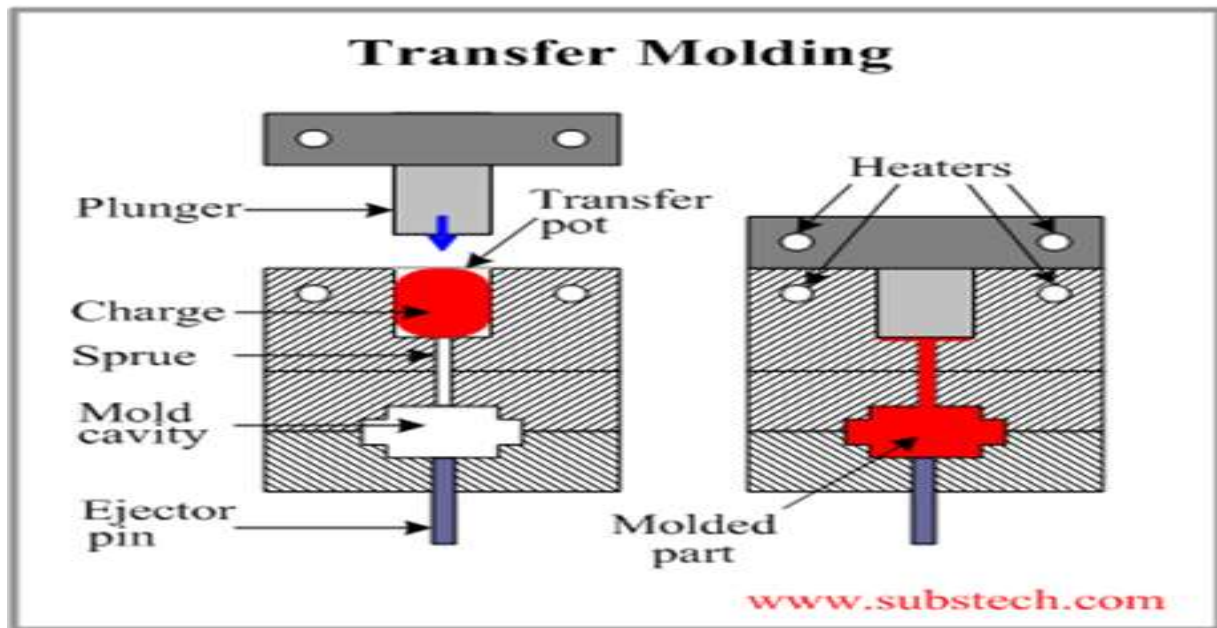


TRANSFER MOLDING

- The method combines features of both Compression Molding (hydraulic pressing of molding materials - thermosets) and Injection Molding (ram-plunger and filling the mold through a sprue).
- The method is used especially for molding thermosetting resins (thermosets)
- Products with relatively intricate designs could be fabricated with this method
- Powdered raw materials are heated at certain low temperature to soften and then introduced through an orifice or sprue in the mould
- Then it is cured in the mould at high temperature for certain time
- Finally the moulded article is removed by separation of mould

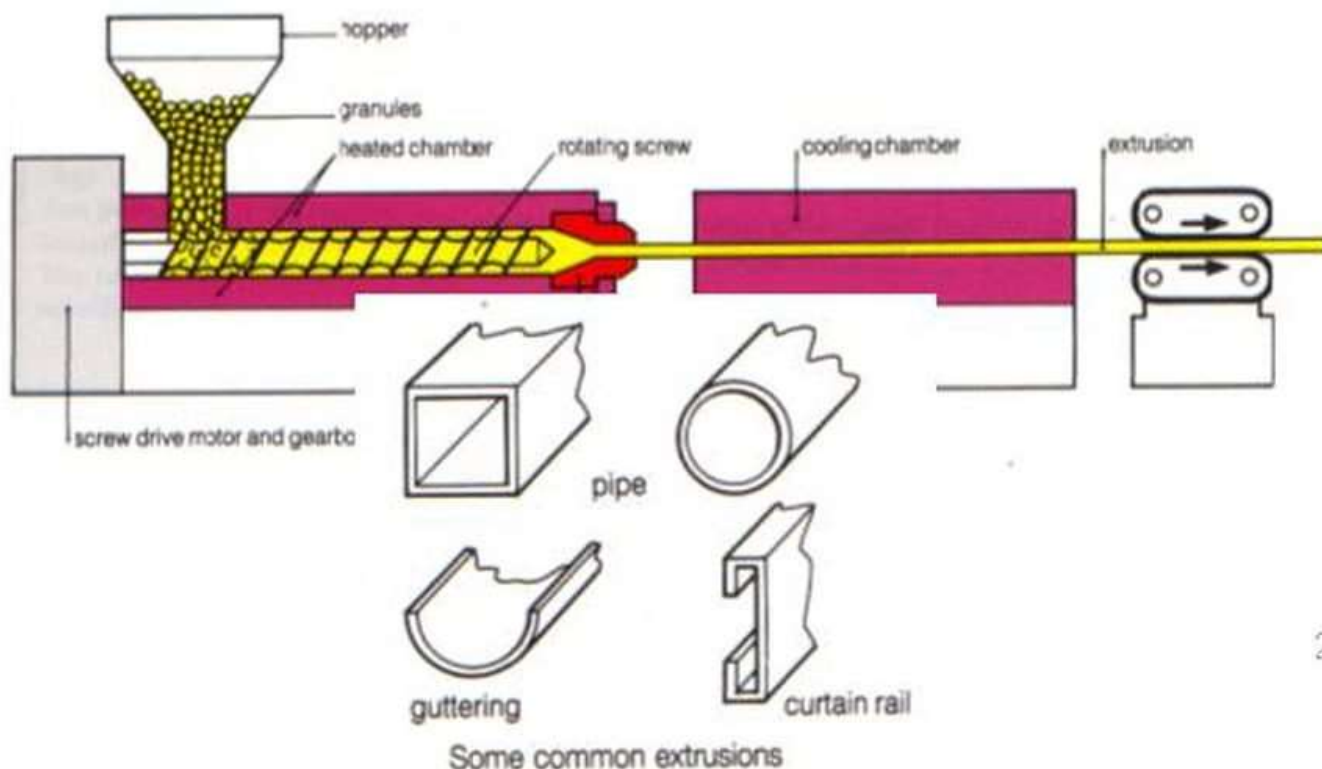
Advantages:

Articles with intricate shapes could be designed
 Aerospace and automobile parts, car body, helmets
 The articles produced are blister free
 Fine wires and glass fibers can be inserted in the mould
 Even thick pieces can be cured completely and uniformly



Extrusion Molding

Whenever continuous molding of material like wires, cables, and sheets is required extrusion molding is used. The thermoplastic materials are molded by this method. They undergo continuous molding to form articles of uniform cross section. In this method, the thermoplastic material are heated to plastic condition and pushed by means of screw conveyor in to a mould cavity having required outer shape of articles to be manufactured. Here the plastic mass gets cooled due to atmospheric exposure. A long conveyor carries away the cooled products continuously.



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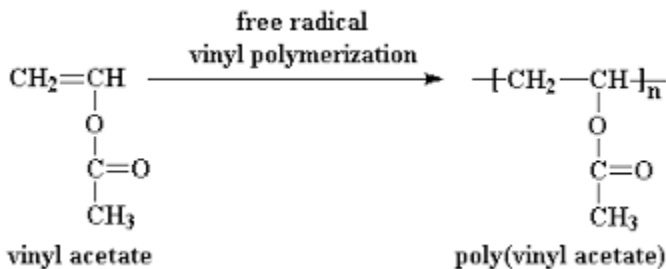
Preparation, Properties and uses of IMPORTANT POLYMERS:

POLY VINYL ACETATE (PVAc):

Polyvinyl acetate is a substance produced through the combining of many units of monomeric vinyl acetate ($\text{CH}_3\text{COOCH}=\text{CH}_2$). The number of units so combined is typically between 100 and 5,000. This translates to an average molecular weight of between 850 and 40,000. Polyvinyl acetate may be used as is or modified through chemical reactions to produce other important polymeric substances

Preparation:

Monomeric vinyl acetate was once prepared by reacting acetylene with anhydrous acetic acid in the presence of a mercurous sulfate catalyst; poly vinyl acetate is prepared by free radical vinyl polymerization as follows



Properties:

Polyvinyl acetate is an amorphous polymer, not a crystalline one. The hardest of the polyvinyl esters, polyvinyl acetate offers good adhesion to most surfaces. Unlike some other thermoplastics, it will not turn yellow. Polyvinyl acetate does not cross-link, thus becoming insoluble, and it can be dissolved in many solvents other than water. One slow-drying formulation combines 5 to 15 percent polyvinyl acetate with ethyl alcohol (ethanol). A fast-drying counterpart combines the same amount of polyvinyl acetate with acetone (dimethyl ketone).

USES:

Emulsified polyvinyl acetate is used in water-based adhesives, including pastes and glues. One of the uses for emulsified polyvinyl acetate is in bookbinding. Depending upon the necessary lifetime of the book, the polyvinyl acetate chosen will either be copolymeric or homopolymeric. Polyvinyl acetate offers acceptable gap-filling capability. It may be used as a resinous component of latex paints, offering compatibility with a wide-range of other paint chemicals. Polyvinyl acetate may be used in the lamination of metal foils. Non-emulsified, or waterless, polyvinyl acetate is useful as a thermosetting adhesive.

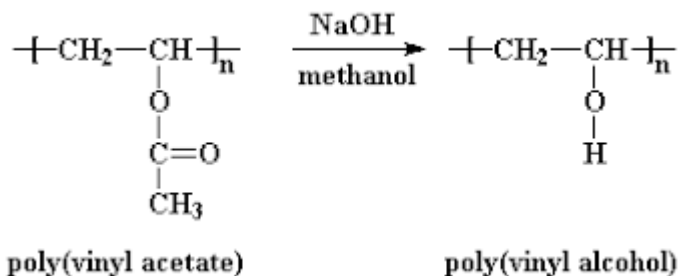
Poly Vinyl Alcohol (PVA):

Polyvinyl alcohol, also known as *PVOH*, *PVA*, or *PVAL*, is a synthetic polymer that is soluble in water. It is effective in film forming, emulsifying, and has an adhesive quality. It has no odor and is not toxic, and is resistant to grease, oils, and solvents. It is ductile but strong, flexible, and functions as a high oxygen and aroma barrier.

Preparation:

- Unlike most vinyl polymer, PVA is not prepared by polymerization of the corresponding monomer
- Polyvinyl alcohol was first prepared in 1924 by hydrolyzing polyvinyl acetate in ethanol with potassium hydroxide.
- Polyvinyl alcohol is produced commercially from polyvinyl acetate, usually by a continuous process. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of anhydrous sodium methylate or aqueous sodium hydroxide. The physical characteristics and its specific functional uses depend on the degree of polymerization and the degree of hydrolysis. Polyvinyl alcohol is classified into two

classes namely: partially hydrolyzed and fully hydrolyzed. Partially hydrolyzed PVA is used in the foods.

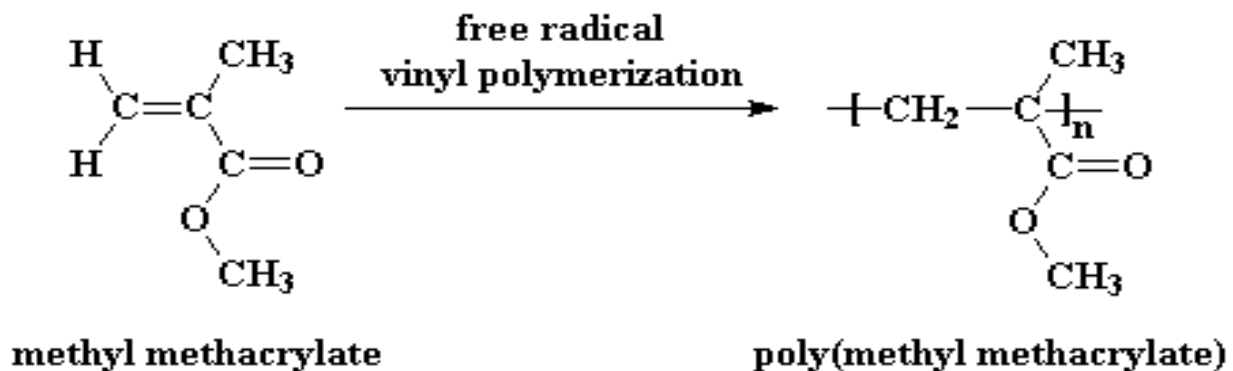


POLYMETHYL METHACRYLATE (PMMA)

Poly(methyl methacrylate) (PMMA), also known as acrylic or acrylic glass as well as by the trade names Crylux, Plexiglas, Acrylite, Lucite, and Perspex among several others (see below), is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass. The same material can be used as a casting resin, in inks and coatings, and has many other uses.

PREPARA:

PMMA is routinely produced by emulsion polymerization, solution polymerization, and bulk polymerization. Generally, radical initiation is used



Properties:

PMMA is a strong, tough, and lightweight material. It has a density of 1.17–1.20 g/cm³,^{[1][20]} which is less than half that of glass.^[1] It also has good impact strength, higher than both glass and polystyrene; however, PMMA's impact strength is still significantly lower than polycarbonate

PMMA transmits up to 92% of visible light (3 mm thickness), and gives a reflection of about 4% from each of its surfaces due to its refractive index (1.4905 at 589.3 nm).^[3] It filters ultraviolet (UV) light at wavelengths below about 300 nm

PMMA swells and dissolves in many organic solvents; it also has poor resistance to many other chemicals due to its easily hydrolyzed ester

Uses:

Being transparent and durable, PMMA is a versatile material and has been used in a wide range of fields and applications such as rear-lights and instrument clusters for vehicles, appliances, and lenses for glasses. PMMA in the form of sheets affords to shatter resistant panels for building windows, skylights, bulletproof security barriers, signs & displays, sanitary ware (bathtubs), LCD screens, furniture and many other applications. It is also used for coating polymers based on MMA provides outstanding stability against environmental conditions with reduced emission of VOC. Methacrylate polymers are used extensively in medical and dental applications where purity and stability are critical to performance.

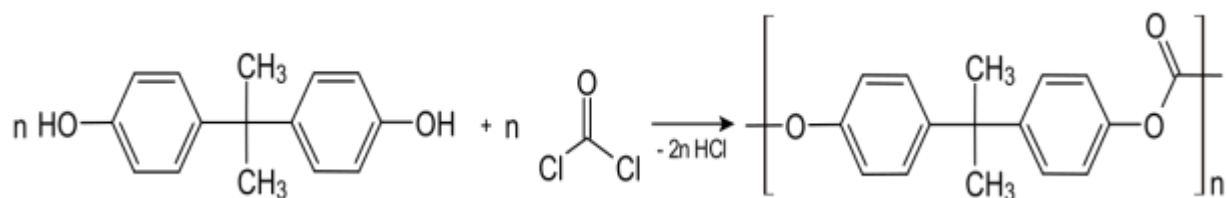
POLY CARBONATES (PC)

Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent. They are easily worked, molded, and thermoformed.

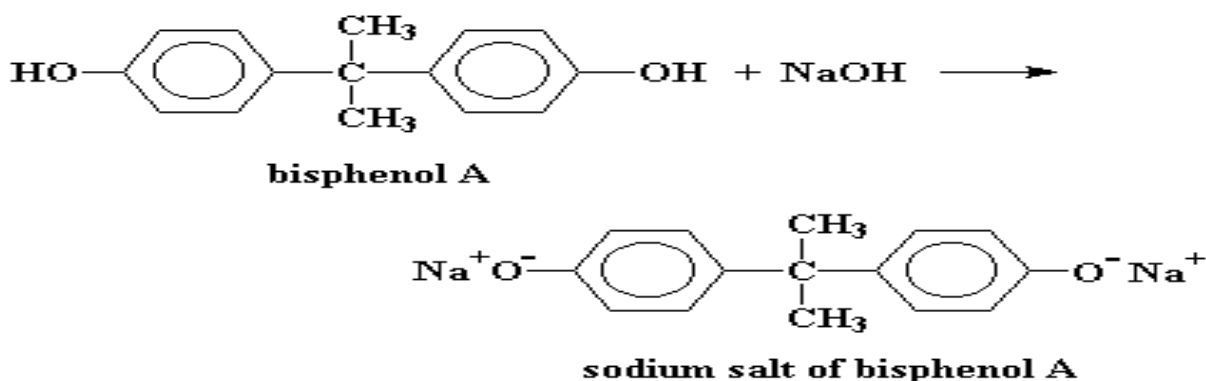
Preparation:

The main polycarbonate material is produced by the reaction of bisphenol A (BPA) and phosgene COCl_2

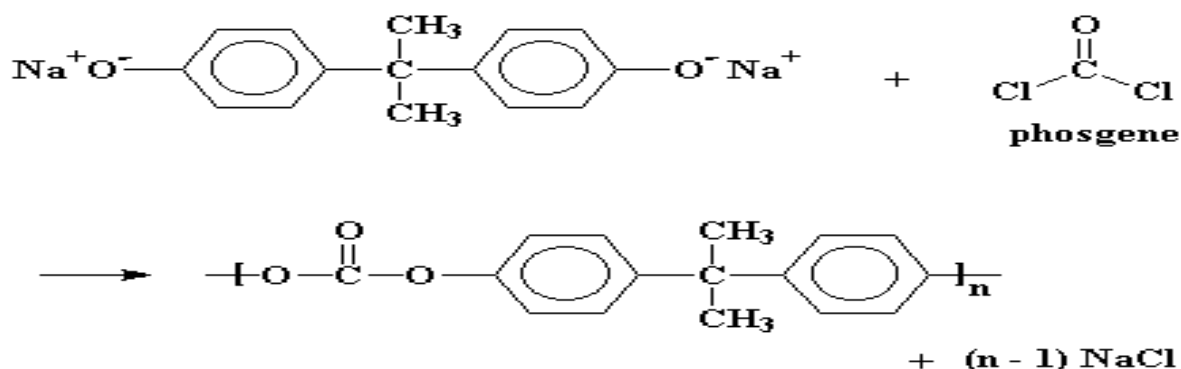
2. The overall reaction can be written as follows:



The first step of the synthesis involves treatment of bisphenol A with sodium hydroxide, which deprotonates the hydroxyl groups of the bisphenol A



The diphenoxide ($\text{Na}_2(\text{OC}_6\text{H}_4)_2\text{CMe}_2$) reacts with phosgene to give a chloroformate, which subsequently is attacked by another phenoxide. The net reaction from the diphenoxide is:



Properties:

Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch-resistance.

The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature.

Polycarbonate has a glass transition temperature of about 147 °C (297 °F; 420 K)

Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking.

Uses:

ELECTRONICS:

Polycarbonate is mainly used for electronic applications that capitalize on its collective safety features. Being a good electrical insulator and having heat-resistant and flame-retardant properties, it is used in various products associated with electrical and telecommunications hardware. It can also serve as a dielectric in high-stability capacitors

CONSTRUCTION:

The second largest consumer of polycarbonates is the construction industry, e.g. for domelights, flat or curved glazing, and sound walls, which all use extruded flat solid or multiwall sheet, or corrugated sheet.

DATA STORAGE:

A major application of polycarbonate is the production of Compact Discs, DVDs. These discs are produced by injection molding polycarbonate into a mold cavity that has on one side a metal stamper containing a negative image of the disc data, while the other mold side is a mirrored surface.

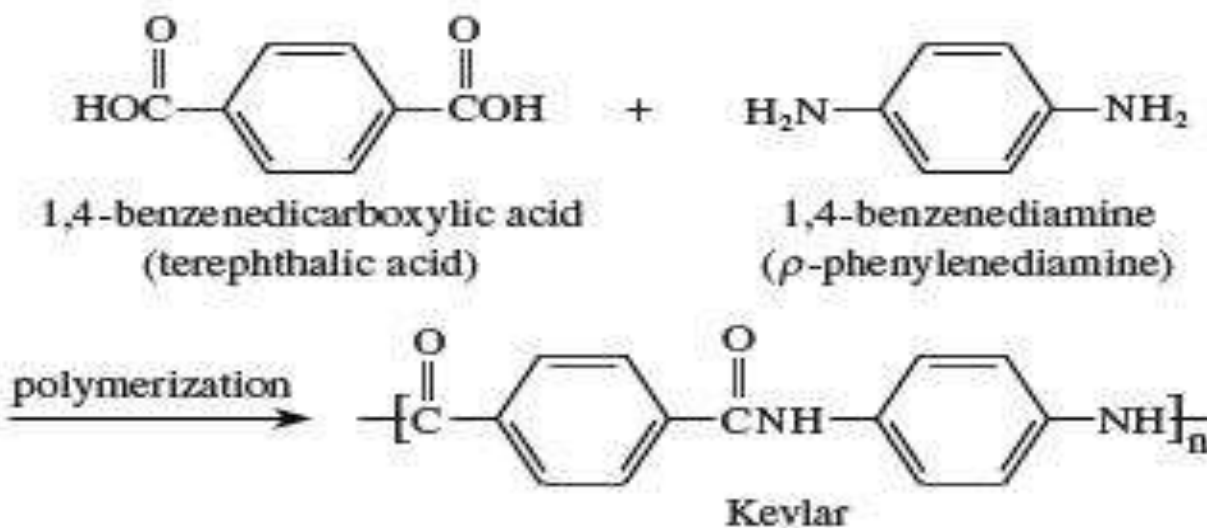
Due to its low weight and high impact resistance, polycarbonate is the dominant material for making automotive headlamp lenses.

Poly-Paraphenylene Terephthalamide (KEVLAR):

Poly-paraphenylene terephthalamide – branded Kevlar is a heat-resistant and strong synthetic fiber.

Preparation:

Kevlar is synthesized in solution from the monomers 1,4-phenylene-diamine (*para*-phenylenediamine) and terephthaloyl chloride in a condensation reaction yielding hydrochloric acid as a byproduct.



Properties:

When Kevlar is spun, the resulting fiber has a tensile strength of about 3,620 MPa,^[14] and a relative density of 1.44.

Kevlar maintains its strength and resilience down to cryogenic temperatures (-196 °C); in fact, it is slightly stronger at low temperatures.

Kevlar's structure consists of relatively rigid molecules which makes them exceptional strong. They are high tensile strength-to-weight ratio; by this measure it is 5 times stronger than steel.

USES:

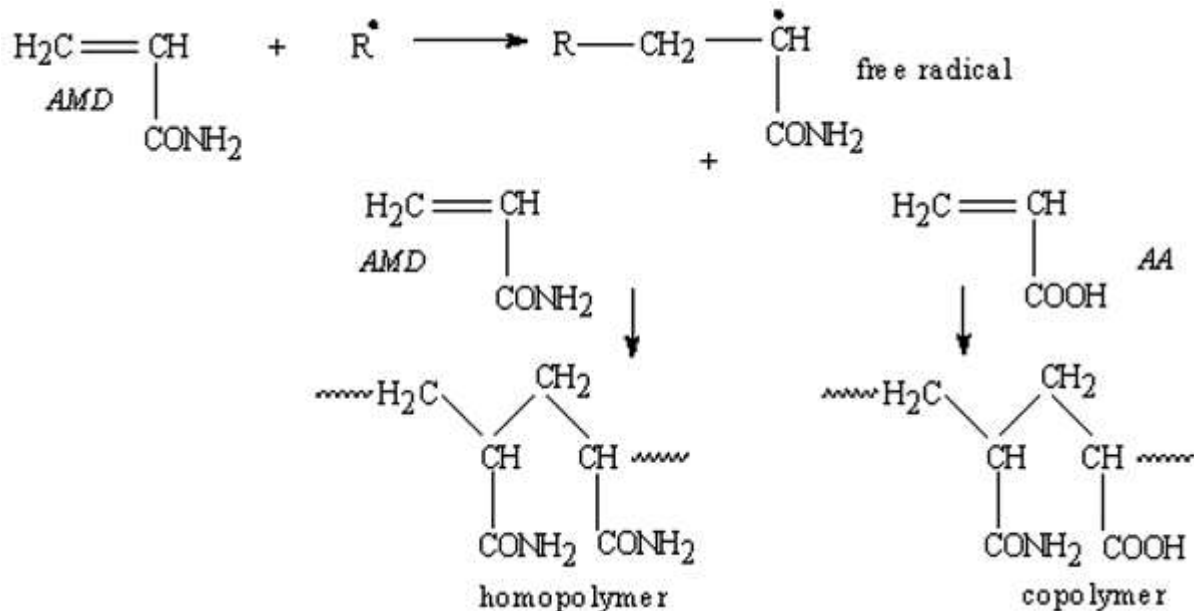
Kevlar has many applications, ranging from bicycle tires and racing sails to bulletproof vests. It is also used to make modern marching drumheads that withstand high impact.

Kevlar is a well-known component of personal armor such as combat helmets, ballistic face masks, and ballistic vests.

It is used for motorcycle safety clothing, especially in the areas featuring padding such as shoulders and elbows.

Kevlar is often used in the field of cryogenics for its low thermal conductivity and high strength relative to other materials for suspension purposes.

Polyacrylamide



Properties:

Linear polyacrylamide is a water-soluble polymer.

It is typically non-ionic polymer but due to hydrolysis of some amide groups they could convert into carboxylic groups giving polyacrylamide some weak an ionic properties.

Uses

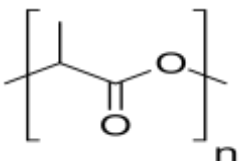
One of the largest uses for polyacrylamide is to [flocculate](#) solids in a liquid. This process applies to [water treatment](#), and processes like [paper making](#) and screen printing.

Polyacrylamide can be supplied in a powder or liquid form, with the liquid form being subcategorized as solution and emulsion polymer. Even though these products are often called 'polyacrylamide', many are actually [copolymers](#) of [acrylamide](#)

Another common use of polyacrylamide and its derivatives is in subsurface applications such as Enhanced Oil Recovery.

Polylactic acid

Polylactic acid, also known as poly(lactic acid) or polylactide (abbreviation PLA) is a thermoplastic polyester with backbone formula $(\text{C}_3\text{H}_4\text{O}_2)_n$ or $[-\text{C}(\text{CH}_3)\text{HC}(=\text{O})\text{O}-]_n$, formally obtained by condensation of lactic acid $\text{C}(\text{CH}_3)(\text{OH})\text{HCOOH}$ with loss of water (hence its name). It can also be prepared by ring-opening polymerization of lactide $[-\text{C}(\text{CH}_3)\text{HC}(=\text{O})\text{O}-]_2$, the cyclic dimer of the basic repeating unit.

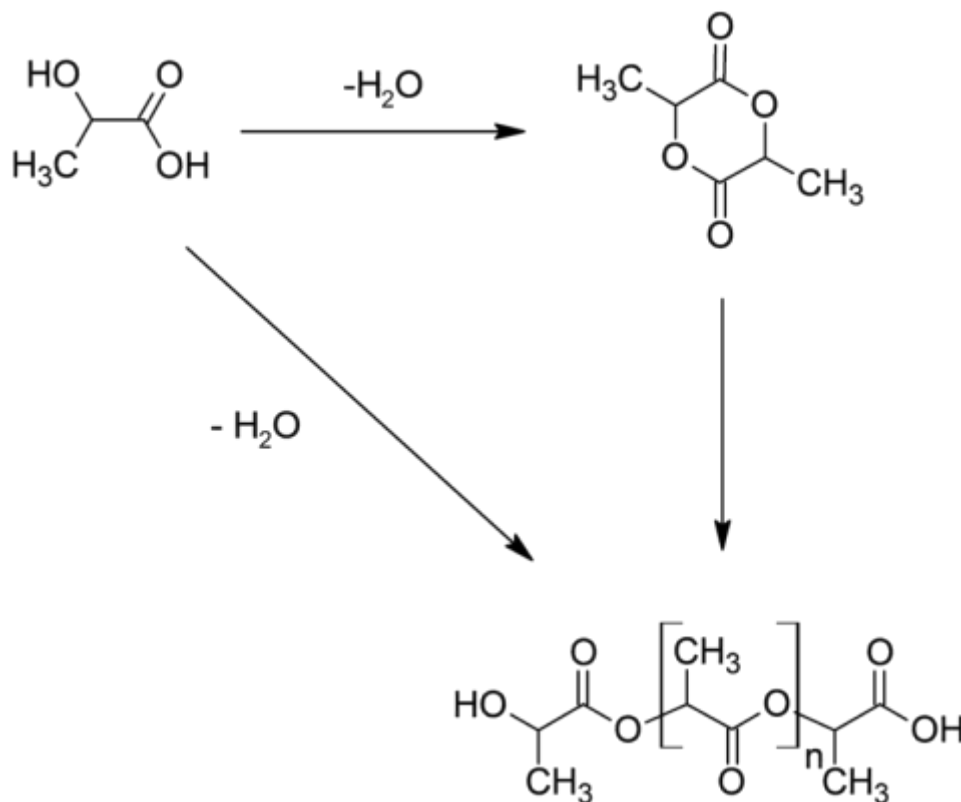


Synthesis

The monomer is typically made from fermented plant starch such as from corn, cassava, sugarcane or sugar beet pulp.

Several industrial routes afford usable (i.e. high molecular weight) PLA. Two main monomers are used: lactic acid, and the cyclic di-ester, lactide. The most common route to PLA is the ring-opening polymerization of lactide with various metal catalysts (typically tin octoate) in solution or as a suspension. The metal-catalyzed reaction tends to cause racemization of the PLA, reducing its stereoregularity compared to the starting material (usually corn starch).

The direct condensation of lactic acid monomers can also be used to produce PLA. This process needs to be carried out at less than 200 °C; above that temperature, the entropically favored lactide monomer is generated. This reaction generates one equivalent of water for every condensation (esterification) step. The condensation reaction is reversible and subject to equilibrium, so removal of water is required to generate high molecular weight species. Water removal by application of a vacuum or by azeotropic distillation is required to drive the reaction toward polycondensation. Molecular weights of 130 kDa can be obtained this way. Even higher molecular weights can be attained by carefully crystallizing the crude polymer from the melt. Carboxylic acid and alcohol end groups are thus concentrated in the amorphous region of the solid polymer, and so they can react. Molecular weights of 128–152 kDa are obtainable thus.



Properties:

- PLA polymers range from amorphous glassy polymer to semi-crystalline and highly crystalline polymer with a glass transition 60–65 °C, a melting temperature 130–180 °C, and a Young's modulus 2.7–16 GPa.[13][14][15] Heat-resistant PLA can withstand

temperatures of 110 °C.[16] The basic mechanical properties of PLA are between those of polystyrene and PET.[13] The melting temperature of PLLA can be increased by 40–50 °C and its heat deflection temperature can be increased from approximately 60 °C to up to 190 °C by physically blending the polymer with PDLA (poly-D-lactide). PDLA and PLLA form a highly regular stereocomplex with increased crystallinity. The temperature stability is maximised when a 1:1 blend is used, but even at lower concentrations of 3–10% of PDLA, there is still a substantial improvement. In the latter case, PDLA acts as a nucleating agent, thereby increasing the crystallization rate[citation needed]. Biodegradation of PDLA is slower than for PLA due to the higher crystallinity of PDLA[citation needed]. The flexural modulus of PLA is higher than polystyrene and PLA has good heat sealability.

- Racemic PLA and pure PLLA have low glass transition temperatures, making them undesirable because of low strength and melting point. A stereocomplex of PDLA and PLLA has a higher glass transition temperature, lending it more mechanical strength.

Uses:

Consumer goods

PLA is used in a large variety of consumer products such as disposable tableware, cutlery, housings for kitchen appliances and electronics such as laptops and handheld devices, and microwavable trays. (However, PLA is not suitable for microwavable containers because of its low glass transition temperature.) It is used for compost bags, food packaging and loose-fill packaging material that is cast, injection molded, or spun.[35] In the form of a film, it shrinks upon heating, allowing it to be used in shrink tunnels. In the form of fibers, it is used for monofilament fishing line and netting. In the form of nonwoven fabrics, it is used for upholstery, disposable garments, awnings, feminine hygiene products, and diapers.

PLA has applications in engineering plastics, where the stereocomplex is blended with a rubber-like polymer such as ABS. Such blends have good form stability and visual transparency, making them useful in low-end packaging applications.

PLA is used for automotive parts such as floor mats, panels, and covers. Its heat resistance and durability are inferior to the widely used polypropylene (PP), but its properties are improved by means such as capping of the end groups to reduce hydrolysis. Agricultural

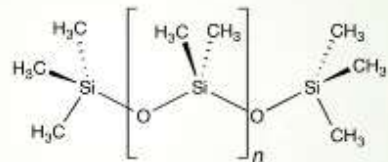
In the form of fibers, PLA is used for monofilament fishing line and netting for vegetation and weed prevention. It is used for sandbags, planting pots, binding tape and ropes .[35]

Medical

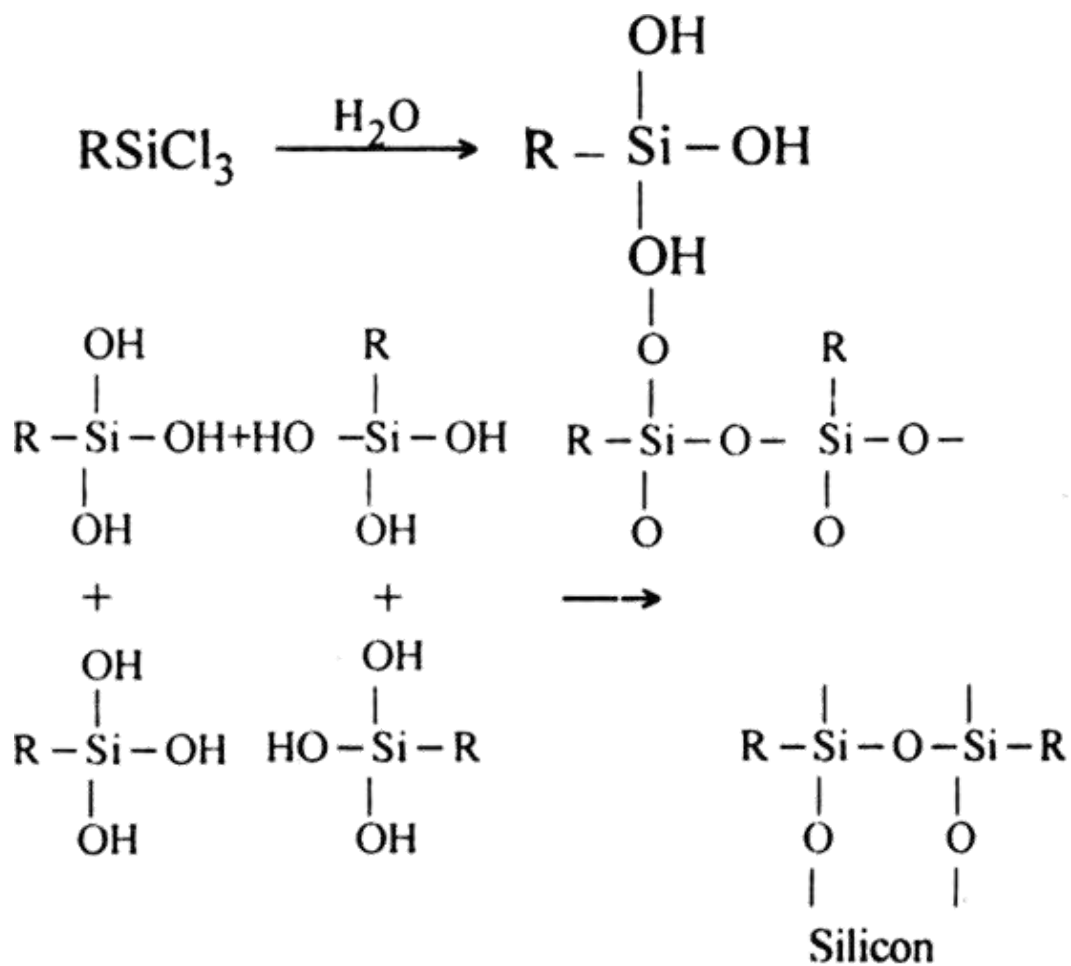
PLA can degrade into innocuous lactic acid, so it is used as medical implants in the form of anchors, screws, plates, pins, rods, and mesh.[35] Depending on the exact type used, it breaks down inside the body within 6 months to 2 years. This gradual degradation is desirable for a support structure, because it gradually transfers the load to the body (e.g. to the bone) as that area heals. The strength characteristics of PLA and PLLA implants are well documented.

Silicone Polymer:PDMS(Polydimethylsiloxane)-Polysiloxane

- By varying the -Si-O- **chain lengths, side groups, and crosslinking**, silicones can be synthesized with a wide variety of properties and compositions.
- They can vary in consistency from liquid to gel to rubber to hard plastic.
- The most common siloxane is **linear polydimethylsiloxane (PDMS)**, a silicone oil.



- The second largest group of silicone materials is based on silicone resins.
- Si-O bonds are much stronger than a typical C-O single bond. (809 kJ/mol compared to 538 kJ/mol)



Properties:

- Silicones exhibit many useful characteristics, including:[1]
- Low thermal conductivity
- Low chemical reactivity
- Low toxicity
- Thermal stability (constancy of properties over a wide temperature range of -100 to 250 °C)
- The ability to repel water and form watertight seals.
- Does not stick to many substrates, but adheres very well to others, e.g. glass
- Does not support microbiological growth
- Resistance to oxygen, ozone, and ultraviolet (UV) light. This property has led to the widespread use of silicones in the construction industry (e.g. coatings, fire protection, glazing seals) and the automotive industry (external gaskets, external trim).
- Electrical insulation properties. Because silicone can be formulated to be electrically insulative or conductive, it is suitable for a wide range of electrical applications.

Uses:

Applications of silicone polymers Health care applications

- Moulded parts - drainage accessories, external feeding, laboratory tubing, respiratory masks, drug delivery devices etc.

-Dental impression materials, Extrusion and tubing - blood handling equipments, urological applications etc.

-Breast implants

Cosmetics & Toiletries

-Hair care products mainly conditioning and hair styling products, but siloxanes may also be used in shampoos and colors.

-Skin care products such as body care, facial care and sun screen products.

-Shaving products such as pre shave and after-shave lotion and shaving foam.

-Liquid soap and shower gels.

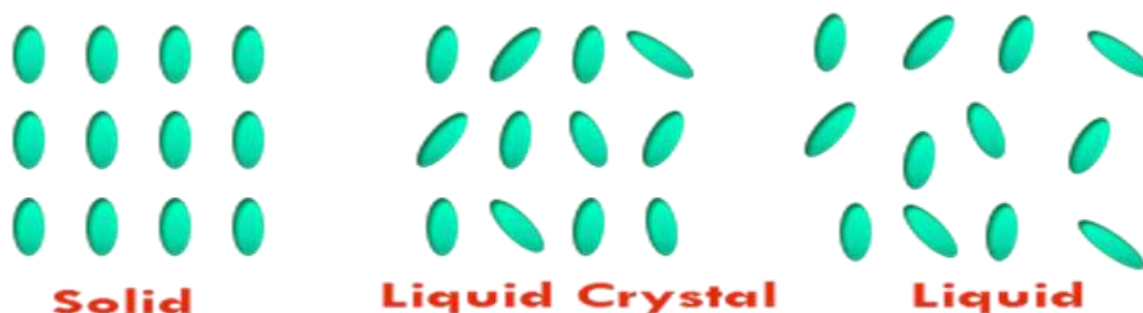
Sealants used for construction

-One component RTV silicones: mainly used in the construction industry for sealants around windows and doors, in bathrooms, expansion joints between dissimilar materials.

Liquid-crystal polymers (LCPs)

An Austrian botanist named Friedrich Reinitzer studied a material called as cholesteryl benzoate which showed two distinct melting points. He noticed the change of crystal structure to hazy

liquid by increase the temperature of solid sample. Later on further heating, the hazy liquid converted to transparent liquid. Reinitzer discovered a new phase of matter that is called as liquid crystal phase. Such materials show unique properties and have several new applications in modern technology. Liquid-crystal polymers (LCPs) are a class of aromatic polymers. They are extremely unreactive and inert, and highly resistant to fire. Liquid crystallinity in polymers may occur either by dissolving a polymer in a solvent (lyotropic liquid-crystal polymers) or by heating a polymer above its glass or melting transition point (thermotropic liquid-crystal polymers). Liquid-crystal polymers are present in melted/liquid or solid form. In solid form the main example of lyotropic LCPs is the commercial aramid known as Kevlar. Chemical structure of this aramid consists of linearly substituted aromatic rings linked by amide groups. In a similar way, several series of thermotropic LCPs have been commercially produced by several companies. The orientation of molecules in liquid crystal state is intermediate liquid and solid phases. This intermediate state I called as mesogenic state or liquid crystal state.



In such materials the properties of a material depend on the direction in which they are measured. The liquid crystalline structure has positional order, orientational order and bond orientational order.

Properties

1. Typically, LCPs have a high mechanical strength at high temperatures, extreme chemical resistance, inherent flame retardancy, and good weatherability.
 2. Liquid-crystal polymers come in a variety of forms from sinterable high temperature to injection moldable compounds.
 3. LCPs can be welded, though the lines created by welding are a weak point in the resulting product.
 4. LCPs have a high coefficient of thermal expansion.
 5. LCPs are exceptionally inert.
 6. They resist stress cracking in the presence of most chemicals at elevated temperatures, including aromatic or halogenated hydrocarbons, strong acids, bases, ketones, and other aggressive industrial substances.
 7. Hydrolytic stability in boiling water is excellent.
- Environments that deteriorate the polymers are high-temperature steam, concentrated sulfuric acid, and boiling caustic materials.

Uses

1. Because of their various properties, LCPs are useful for electrical and mechanical parts, food containers, and any other applications requiring chemical inertness and high strength.
2. LCP is particularly good for microwave frequency electronics due to low relative dielectric constants, low dissipation factors, and commercial availability of laminates.

3. Packaging microelectromechanical systems (MEMS) is another area that LCP has recently gained more attention.
4. The superior properties of LCPs make them especially suitable for automotive ignition system components, heater plug connectors, lamp sockets, transmission system components, pump components, coil forms and sunlight sensors and sensors for car safety belts.