CONTENT

Polymers

A chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating structural units is called polymers. The materials have unique properties depending on the type of molecules being bonded and how they are bonded. Some polymers bend and stretch, like rubber and polyester. Others are hard and tough, like epoxies and glass.

Physical properties of polymers

The physical properties of polymers are: -

- Density
- Molecular weight
- Degree of polymerization
- Molar volume
- Crystallinity of material
- Melting point
- Cloud point
- Pour point
- Specific gravity
- Viscosity
- Water absorption

Degree of polymerization

The term degree of polymerization refers to the number of repeating units in the polymer molecule. Degree of polymerization= Mn / Mo

Where: Mn= No average molecular weight

Mo= Molecular weight of the repeat unit

Polymerization and its types

Polymerization is a process of reacting monomer molecule together in a chemical reaction to form polymer chains or threedimensional networks. **Types of polymerization**

- Chain-Growth or Addition Polymerization
- Step-Growth or Condensation Polymerization

Chain-Growth or Addition Polymerization

Polymerization that occurs through the coupling of monomers using their multiple bonds is called **addition polymerization**. The simplest example involves the formation of polyethylene from ethylene molecules. In this reaction, the double bond in each ethylene molecule opens up, and two of the electrons originally in this bond are used to form new carbon-carbon single bonds with two other ethylene molecules.

Some common commercial addition polymers are:

- Polyethylene - films, packaging, bottles

Step-Growth or Condensation Polymerization

The chemical mechanism that cells use to make and break polymers are basically the same in all cases. Monomers are connected by a reaction in which two molecules are covalently bonded to each other through loss of a water molecule; this is called a **condensation polymerization** because the lost molecule is water.

Some common polymers in life are:

- All proteins made from amino acids

Classification of Polymers

Polymers cannot be classified under one category because of their complex structures, different behaviours, and vast applications. We can, therefore, classify polymers based on the following considerations.

Classification of Polymers based on the Source of Availability

- **Natural Polymers:**

They occur naturally and are found in plants and animals. For example, proteins, starch, cellulose, and rubber. To add up, we also have biodegradable polymers which are called biopolymers.

- **Semi-synthetic Polymers:**

They are derived from naturally occurring polymers and undergo further chemical modification. For example, cellulose nitrate, cellulose acetate.

- **Synthetic Polymers:**

These are man-made polymers. Plastic is the most common and widely used synthetic polymer. It is used in industries and various dairy products. For example, nylon-6, 6, polyether's etc.

Classification Based on Molecular Forces

- **Elastomers:** These are rubber-like solids weak interaction forces are present. For example, Rubber.

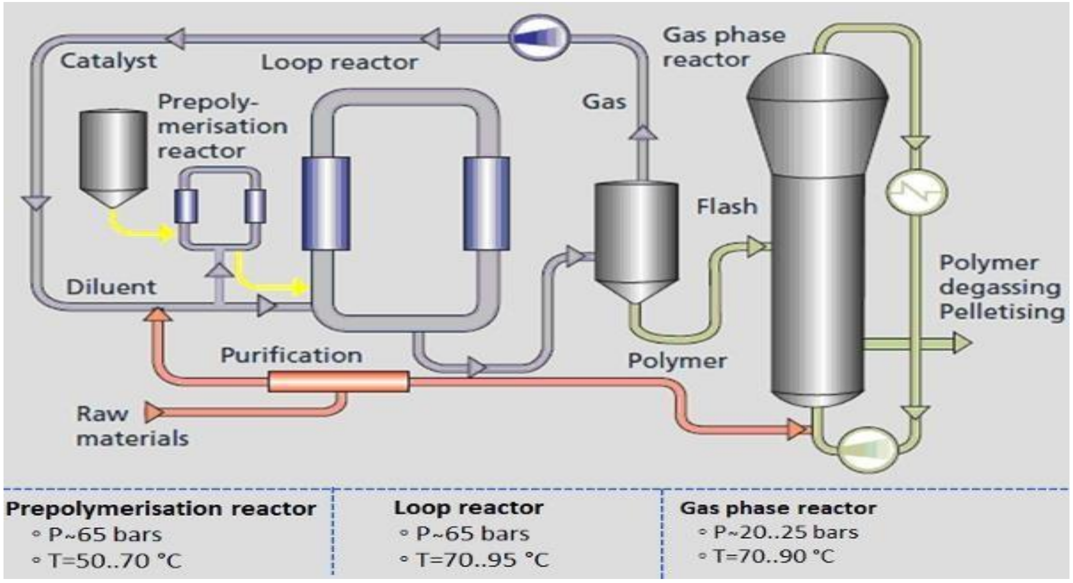
- **Fibres:** Strong, tough, high tensile strength and strong forces of interaction are present. For example, nylon -6, 6.
- **Thermoplastics:** These have intermediate forces of attraction. For example, polyvinyl chloride.
- **Thermosetting polymers:** These polymers greatly improve the material's mechanical properties. It provides enhanced chemical and heat resistance. For example, phenolics, epoxies, and silicones.

Manufacture process of Polyethylene

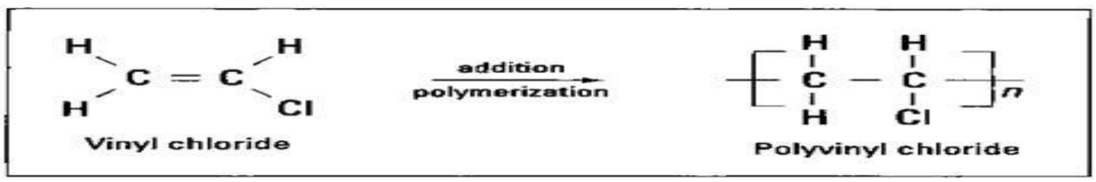
Polyethylene (PE) is the most common polymer in the world, produced 85mt / year. This is mainly due to the wide range of possible uses. Depending on its melting point, the PE is divided into several categories: low, medium and high density, each class with specific industrial applications. It occurs in the following forms: high density polyethylene (HDPE), ULDPE (ultra-low-density polyethylene), LLDPE (linear low-density polyethylene), MDPE (medium density polyethylene) HMWPE polyethylene (high molecular weight) and UHMWPE (ultra-high molecular weight).

Traditionally, the polymerization was taking place under high pressure (several hundred bars) and high temperature (up to 300°C) but over the years the energy input has been reduced by using catalytic systems. The Ziegler and metallocene catalyst families have proven to be very flexible at copolymerizing ethylene with other olefins and have become the basis for the wide range of polyethylene resins available today, including very low-density polyethylene and linear low-density polyethylene.

Polyethylene is mostly produced in slurry, gas-phase fluidized bed reactor or combination of both processes in series (such as like Spherilene and Borstar processes). Either double-tube loop reactors or autoclaves (stirred-tank reactors) are commercially employed for slurry-phase polymerization, in the presence of a catalyst system and a diluent.



Polyvinyl Chloride (PVC)

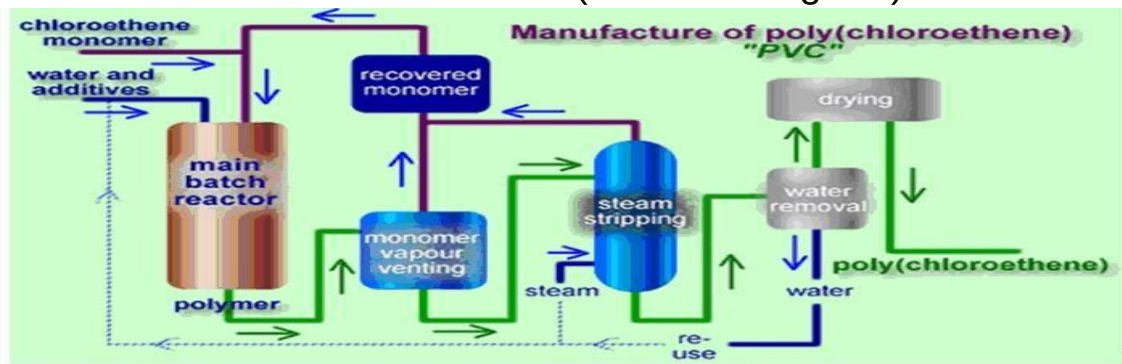


Polyvinyl Chloride (PVC) is one of the most widely used polymers in the world. Due to its versatile nature, PVC is used extensively across a broad range of industrial, technical and everyday applications including widespread use in building, transport, packaging, electrical and healthcare applications.

Manufacture process of PVC

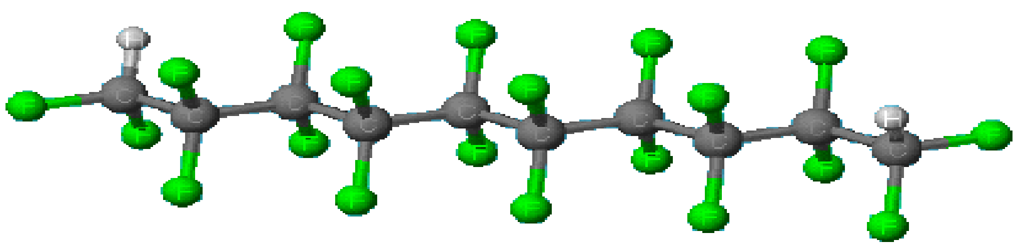
PVC is produced by polymerization of vinyl chloride monomer (VCM). The main polymerization methods include suspension, emulsion, and bulk (mass) methods. About 80% of production involves suspension polymerization. First, the raw material VCM is pressurized and liquefied, and then fed into the polymerization reactor, which contains water and suspending agents in advance. Next, the initiator is fed into the reactor, and PVC is produced under a few bars at 40 – 60°C.

The role of water is to remove and control the heat given off in the polymerization process. PVC forms as tiny particles which grow and when they reach a desired size the reaction is stopped and any unreacted vinyl chloride is distilled off and reused. The PVC is separated off and dried to form a white powder also known as PVC resin (see flow diagram).



Teflon

This is the brand name for a number of fluorinated polymers. Teflon is polytetrafluorethylene (PTFE). This is a polymer with repeating chains of –(CF2-CF2)- in it.



Teflon, $-(CF_2CF_2)-$

Manufacture process of Teflon

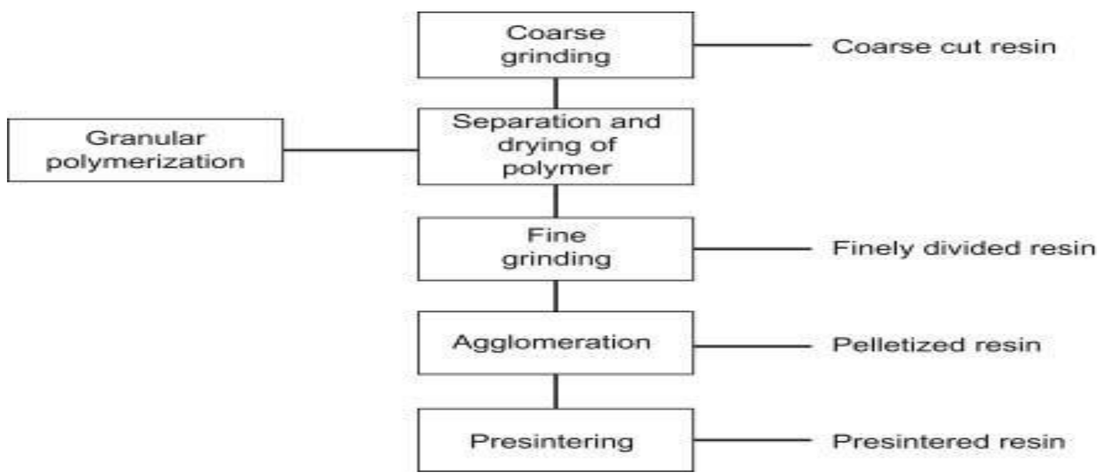
PTFE can be produced in a number of ways, depending on the particular traits desired for the end product. Many specifics of the process are proprietary secrets of the manufacturers. There are two main methods of producing PTFE. One is suspension polymerization. In this method, the TFE is polymerized in water, resulting in grains of PTFE. The grains can be further processed into pellets which can be molded. In the dispersion method, the resulting PTFE is a milky paste which can be processed into a fine powder. Both the paste and powder are used in coating applications.

Production of Teflon is a long process. The process starts, purified water is poured in a reaction chamber. There is a reaction initiator (Iron) that will form the polymer. A liquid called tetrafluoroethylene (TFE) is put in a reaction chamber through a pipe. Once TFE comes in contact with the initiator, it starts to form a polymer. This is called polymerization. This then becomes polytetrafluoroethylene (PTFE). In this substance, there are some solid grains that are formed, these grains float on top of water. As they float, the reaction chamber is shaken. Then, PTFE is put into a mill after being dried to be pulverized.

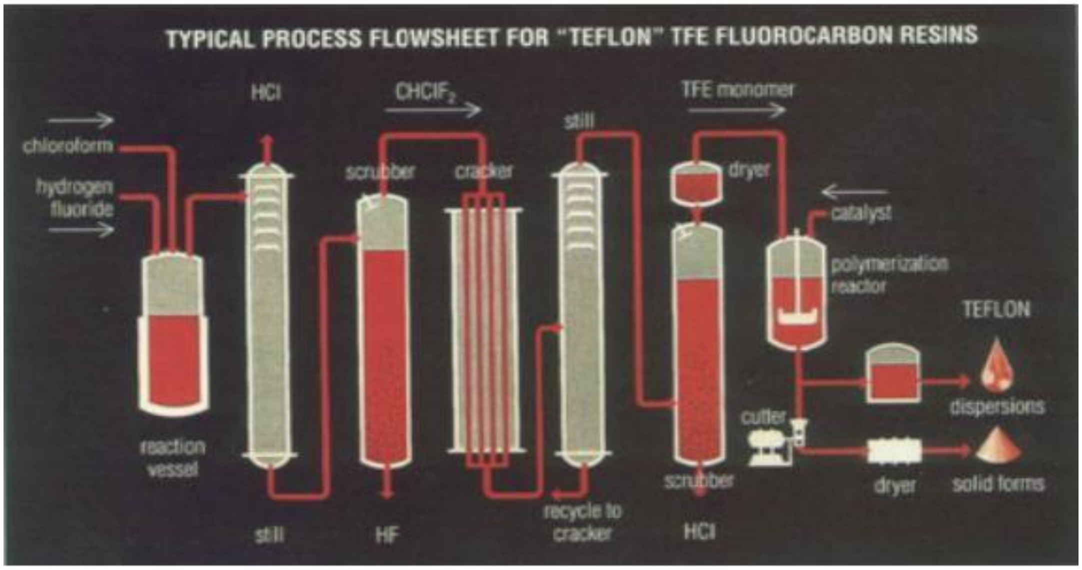
After pulverization the Teflon powder has the consistency of wheat flour yet the material is unable to be fed into a mill because it still has lumps and air bubbles, because of this the manufacturers must turn the Teflon powder into small pellets by using a process called "Agglomeration”. Agglomeration can be done in several different ways but most manufacturers prefer to used acetone (a solvent of Teflon) and tumble the Teflon in a large drum, to form small pellets of Teflon.

The Teflon pellets are `wet` so the pellets are placed in a large oven and baked until dry. The dry Teflon pellets can then be molded into any form the manufacturer may choose by using a variety of techniques. However, the Teflon is often sold to other manufacturers in bulk pre-molded into large blocks often called billets. These blocks may be up to 1.5 m tall.

To make billets, Teflon pellets are dumped in bulk into a large cylinder stainless steel mold. The mold is placed in a hydraulic press. The press' arm or ram pushes the mold and the Teflon. Later the mold is removed from the press and the Teflon is removed. Lastly the newly formed billet is put into a large oven for a process called sintering. Once the large block of Teflon is placed in the sintering oven for many hours, it gradually reaches a warm temperature around 360°C. Even though this is far above the melting point of Teflon the Teflon holds together fairly well and soon the particles collect and the material becomes gel-like fluid substance glowing a faint red. Once the Billet cools it will be shiped to other customers/manufacturers that will process it further for a finished product.



Manufacturing process of Teflon



Polymer Production Capacity

Global Production Capacity

- The global production capacity of polyethylene polymer in 2016 was 103 million tons.
- The global production capacity of PVC polymer in 2016 was 61 million tons.
- The global production capacity of Teflon polymer in 2016 was 165 million tons.

Production Capacity of India

- India’s polyethylene annual capacity was more than 3 million tons during 2016.
- India’s PVC annual capacity was more than 5 million tons during 2016.
- India’s Teflon annual capacity was more than 8.5 million tons during 2016.

Pollution control device in Polymer Industries

- Scrubbers
- Incineration

- Carbon Capture Storage device

Reference

- Outlines of Chemical Technology by Dryden
- Chemical Process Industries by Shreve
- : https://byjus.com/jee/polymers/
- : guichon-valves.com/faqs/pe-polyethylene-manufacturingprocess-of-polyethylene-pe/
- : https://guichon-valves.com/faqs/pvc-polyvinyl-chloridemanufacturing-process-of-polyvinyl-chloride-pvc/
- : http://www.madehow.com/Volume-7/Teflon.html#ixzz6HDeJFBEZ