- The Basics of Plastics
- The Structure of Polymers
- Polymerization and Molecular Structure
- Molecular Arrangement of Polymers
- Characteristics of Polymers
- Resin identification code

The Basics of Plastics

Plastics are polymers. What is a polymer? The simplest definition of a polymer is something made of many units. Think of a polymer as a chain. Each link of the chain is the "-mer" or basic unit that is usually made of carbon, hydrogen, oxygen, and/or silicon. To make the chain, many links or "-polymers" are hooked or polymerized together. Polymers have been with us since the beginning of time. Natural polymers include such things as tar and shellac, as well as tree saps that produce amber and latex. These polymers were processed with heat and pressure into useful products like hair ornaments and adornments . Natural polymers began to be chemically modified during the 1800s to produce many materials. The most famous of these were vulcanized rubber, gun cotton and celluloid. The first truly synthetic polymer produced was Bakelite in 1909 and was soon followed by the first synthetic fiber, rayon, which was developed in 1911.

The Structure of Polymers

Many common classes of polymers are composed of hydrocarbons. These polymers are specifically made of small units bonded into long chains. Carbon makes up the backbone of the molecule and hydrogen atoms are bonded along the backbone.
There are polymers that contain only carbon and hydrogen. Polypropylene, polybutylene, polystyrene, and polymethylpentene are examples of these.
Even though the basic makeup of many polymers is carbon and hydrogen, other elements can also be involved. Oxygen, chlorine, fluorine, nitrogen, silicon, phosphorous, and sulfur are other elements that are found in the molecular makeup of polymers. Polyvinyl chloride (PVC) contains chlorine. Nylon contains nitrogen. Teflon contains fluorine. Polyester and polycarbonates contain oxygen. There are also some polymers that, instead of having a carbon backbone, have a silicon or phosphorous backbone. These are considered inorganic polymers. One of the most famous silicon-based polymers is Silly Putty.

Polymerization and Molecular Structure

The initial compound that is used to form polymers is the "mer" or monomer. Monomers are chemically joined together in one of two ways: addition polymerization or condensation polymerization.
Addition polymerization is comprised of three basic steps: initiation, propagation, and termination. For example, during the initiation phase of the polymerization of polyethylene, the double bonds in the ethylene "mers" break and begin to bond together. A catalyst or promoter may be necessary to begin or speed up the reaction. The second phase, propagation, involves the continued addition of monomers together into chains. The final step is termination.
During termination all monomers may be used, causing the reaction to cease. A polymerization reaction can cease by quenching the reaction. Similar to quenching someone’s thirst, water can be used to quickly cool a reaction. Polymers formed by addition polymerization include acrylic, polyethylene, and polystyrene, to name a few.
Very simply, addition polymerization describes the process of "mers" joining by each one adding on to the end of the last "mer." A simple visual of the process is paper clips joined together to form a long chain. Polymers formed by addition polymerization are often thermoplastic in nature. Thermoplastics are like hot melt glue sticks that can be heated and made soft and then become

hard when cooled. Thermoplastic polymers are easily processed and reprocessed or recycled. The majority of polymers used today are thermoplastics.

The other groups of polymers are formed by condensation polymerization. During the chemical reaction of condensation polymerization, a small molecule is eliminated as the monomers join together. Common polymers in this group include nylons, some polyesters, urea formaldehyde, and urethanes. These polymers can be thermoplastic in nature or thermosetting. Once a thermoset polymer is formed, it cannot be melted and reformed. All plastics flow at some time during their processing and are solid in the finished state, but once a thermoset is processed, it is dramatically different and cannot be reformed.

The means of polymerization will affect the heat reaction of the formed polymer; likewise, the arrangement of the "mers" within the molecule will affect the physical characteristics of the formed polymer. "Mers" joined together in long chains have a linear configuration very similar to a paper clip chain, even though in actuality tetrahedral bonds give the molecule a zigzag arrangement.

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During polymerization, if the "mers" not only form straight chains but also form long side chains off the main backbone, the resulting configuration is described as branched, like a tree branch or grape stem.

A third configuration is achieved by the long chains being chemically linked together. An example would be natural rubber (isoprene) being reacted with sulfur. The sulfur bonds the chains to form a giant meshwork molecular structure that is known as vulcanized rubber. This is a cross-linked configuration.

Polyethylene has the simplest "mer" structure. Even though the backbone of other polymers will be similarly formed by a broken bond between two carbons, the remaining carbons in the "mer" will form a functional group whose orientation about the backbone will affect the physical nature of the resulting polymer. For example, propylene is the "mer" that will form polypropylene:

Polymerization will be initiated by the double bond breaking and the "-mers" joining together. Therefore, the methyl group on the propylene "-mer" has the potential to be located at various points along the backbone. If the methyl group (CH3) is oriented repeatedly on one side of the chain on alternating carbons, it is called isotactic.

Ninety to ninety-five percent of all polypropylene polymers have this configuration.

Molecular Arrangement of Polymers

Think of how spaghetti noodles look on a plate. This is similar to how polymers can be arranged if they lack a specific for or are amorphous. Controlling and quenching the polymerization process can result in amorphous organization. An amorphous arrangement of molecules has no long-range order or form in which the polymer chains arrange themselves. Amorphous polymers are generally transparent. This is an important characteristic for many applications such as food wrap, plastic windows, headlights, and contact-lenses. Obviously not all polymers are transparent.

The polymer chains in objects that are translucent and opaque are in a crystalline arrangement. By definition a crystalline arrangement has atoms, ions, or in this case, molecules in a distinct pattern. You generally think of crystalline structures in salt and gemstones, but not in plastics. Just as quenching can produce amorphous arrangements, processing can control the degree of crystallinity. The higher the degree of crystallinity, the less light can pass through the polymer. Therefore, the degree of translucence or opaqueness of the polymer is directly affected by its crystallinity.

Scientists and engineers are always producing better materials by manipulating the molecular structure that affects the final polymer produced. Manufacturers and processors introduce various fillers, reinforcements, and additives into the base polymers, expanding product possibilities.

Characteristics of Polymers

Polymers are divided into two distinct groups: thermoplastics and thermosets. The majority of polymers are thermoplastic, meaning that once the polymer is formed it can be heated and reformed over and over again. This property allows for easy processing and facilitates recycling. The other group, the thermosets, can not be re-melted. Once these polymers are formed, reheating will cause the material to scorch.

In addressing all the superior attributes of polymers, it is equally important to discuss some of the difficulties associated with the material. Plastics deteriorate but never decompose completely, but neither do glass, paper, or aluminum. Plastics make up 9.5 percent of our trash by weight compared to paper, which constitutes 38.9 percent. Glass and metals make up 13.9 percent by weight.

Applications for recycled plastics are growing every day. Recycled plastics can be blended with virgin plastic (plastic that has not been processed before) to reduce cost without sacrificing properties. Recycled plastics are used to make polymeric timbers for use in picnic tables, fences, and outdoor toys, thus saving natural lumber. Plastic from 2-liter bottles is even being spun into fiber for the production of carpet. An option for plastics that are not recycled, especially those that are soiled, such as used microwave food wrap or diapers, can be a waste-to-energy system (WTE). The controlled combustion of polymers produces heat energy. The heat energy produced by the burning plastics not only can be converted to electrical energy but also helps burn the wet trash that is present. Paper also produces heat when burned, but not as much as plastics. On the other hand, glass, aluminum and other metals do not release any energy when burned. To better understand the incineration process, consider the smoke coming off a burning object and then ignite the smoke with a Bunsen burner. Observe that the smoke disappears. This is not an illusion, but illustrates that the by-products of incomplete burning are still flammable. Incineration burns the material and then the by-products of the initial burning. Polymers affect every day of our life. These materials have so many varied characteristics and applications that their usefulness can only be measured by our imagination. Polymers are the materials of past, present, and future generations.

Resin identification code

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 at the urging of recyclers around the country. A growing number of communities were implementing recycling programs in an effort to decrease the volume of waste subject to rising tipping fees at landfills. In some cases, these programs were driven by state-level recycling mandates.

The SPI code was developed to meet recyclers' needs while providing manufacturers with a consistent, uniform system that could apply nationwide. Because municipal recycling programs traditionally targeted packaging—primarily containers—the SPI coding system offers a means of identifying the resin content of bottles and containers commonly found in the residential waste stream.

Recycling firms have varying standards for the plastics they accept. Some firms may require that the plastics be sorted by type and separated from other recyclables; some may specify that mixed plastics are acceptable if they are separated from other recyclables; while others may accept all material mixed together. If you are unsure if your plastic material is recyclable, please contact Filmco for a detailed evaluation and proposal.

Learn more about plastic

Symbol	Acronym	Full name and uses
1	PET	Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.
2	HDPE	High-density polyethylene - Milk and washing-up liquid bottles
3	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
4	LDPE	Low density polyethylene - Carrier bags and bin liners.
5	PP	Polypropylene - Margarine tubs, microwave-able meal trays.
6	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
7	Other	Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.