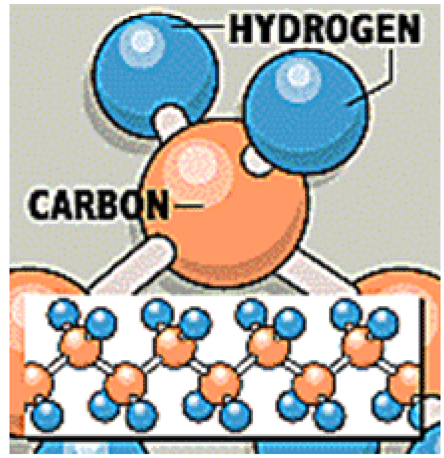
History of Polymer and Plastics for Students

History of Plastics and Polymers



Plastics are polymers. What is a polymer? The most simple 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 made of carbon, hydrogen, oxygen, and/or silicon. To make the chain, many links or "mers" are hooked or polymerized together. Polymerization can be demonstrated by linking strips of construction paper together to make paper garlands or hooking together hundreds of paper clips to form chains.

Polymers have been with us since the beginning of time. Natural polymers include such things as tar and shellac, tortoise shell and horns, as well as tree saps that produce amber and latex. These polymers were processed with heat and pressure into useful articles like hair ornaments and jewelry. 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 semi-synthetic polymer produced was Bakelite in 1909 and was soon followed by the first synthetic fiber, rayon, which was developed in 1911.

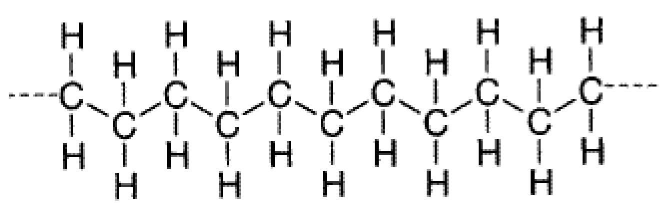
Did you know?...

Polyethylene (there are two types--high density polyethylene or HDPE, and low density polyethylene or LDPE) played a key supporting role during World War II as a critical material which insulated radar electronics.

Even with these developments, it was not until World War II that significant changes took place in the polymer industry. Prior to World War II, natural substances were generally available; therefore, synthetics that were being developed were not a necessity. Once the world went to war, our natural sources of latex, wool, silk, and other materials were cut off, making the use of synthetics critical. During this time period, we saw the use of nylon, acrylic, neoprene, SBR, polyethylene, and many more polymers take the place of natural materials that were no longer available. Since then, the polymer industry has continued to grow and has evolved into one of the fastest growing industries in the U.S. and in the world.

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. The diagram of polyethylene at right shows the simplest polymer structure.



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.

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Polyvinyl chloride (PVC) contains chlorine. Nylon contains nitrogen and oxygen. Teflon contains fluorine. Polyester and polycarbonates contain oxygen. Vulcanized rubber and thiokol contain sulfur. There are also some polymers that, instead of having a carbon backbone, have a silicon or silicon-oxygen backbone. These are considered inorganic polymers. One of the most famous silicon-based polymers is Silly Putty™.

How spaghetti noodles look on a plate is similar to how polymers can be arranged if they are amorphous

Molecular Arrangement of Polymers

Think of how spaghetti noodles look on a plate. This is similar to how polymers can be arranged if they are amorphous. 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, Plexiglas™, headlights, and contact lenses. Controlling and quenching the polymerization process can result in amorphous organization.

Obviously, not all polymers are transparent. The polymer chains in objects that are translucent and opaque are in a more 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.

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 to expand 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 recycling. The other group, the thermosets, cannot be remelted. Once these polymers are formed, reheating will cause the material to scorch. Every polymer has very distinct characteristics, but most polymers have the following general attributes.

1. *Polymers can be very resistant to chemicals.* Consider all the cleaning fluids in your home that are packaged in plastic. Reading the warning labels that describe what happens when the chemical comes in contact with skin or eyes or is ingested will emphasize the chemical resistance of these materials.
2. *Polymers can be both thermal and electrical insulators.* A walk through your house will reinforce this concept, as you consider all the appliances, cords, electrical outlets, and wiring, that are made or covered with polymeric materials. Thermal resistance is evident in the kitchen with pot and pan handles made of polymers, the coffee pot handle, the foam core of refrigerators and freezers, insulated cups, coolers, and microwave cookware. The thermal underwear that many skiers wear is made of polypropylene and the fiberfill in winter jackets is acrylic.

3. *Generally, polymers are very light in mass with varying degrees of strength.* Consider the range of applications, from dime store toys to the frame structure of space stations, or from delicate nylon fiber in pantyhose to Kevlar™, which is used in bulletproof vests.
4. *Polymers can be processed in various ways to produce thin fibers or very intricate parts.* Plastics can be molded into bottles or the body of a car or be mixed with solvents to become an adhesive or a paint. Elastomers and some plastics stretch and are very flexible. Other polymers can be foamed like polystyrene (Styrofoam™) and urethane, to name just two examples. Polymers are materials with a seemingly limitless range of characteristics and colors. Polymers have many inherent properties that can be further enhanced by a wide range of additives to broaden their uses and applications.

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 does glass, paper, or aluminum. Plastics make up 9.9 percent of our trash by weight compared to paper, which constitutes 39 percent. Glass and metals make up 13 percent by weight. In 1997, Americans produced 217 million tons of trash.

Did you know?...

The plastics we all know as Silly Putty were invented by an engineer in the 1940s -- he originally called it Nutty Putty because of its ability to stretch to many times its original size

Applications for recycled plastics are growing every day. 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.

Workers at a recycling plant sort different of types plastics

A solution 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). Incineration of polymers produces heat energy. The heat energy produced by the burning plastics not only can be converted to electrical energy but 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.

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.

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