

Plastic

Any of numerous synthetic materials that consist of giant molecules called polymers, with extremely long chains of repeating units derived from short molecules. Plastics can be formed into products by molding or otherwise shaping.

A significant property of most plastics is that they soften when heated, so that they can be formed into shapes, then become rigid on cooling. This property derives from their physical structure, which consists of a network of polymers, the constituent units of which separate under heat sufficiently to slide apart, but on cooling become firmly entangled again.

The first **plastic** developed was celluloid, consisting of nitrocellulose softened by vegetable oils and camphor, patented in 1870 by an American printer, John W. Hyatt.

The first completely synthetic **plastic** was Bakelite, produced from phenol and formaldehyde by Leo Baekeland in 1909. Advances in basic understanding of molecular physics facilitated the subsequent development of nylon, polyethylene, and other plastics.

All plastics are manufactured by some method of polymerization, the process of forming the long chains and networks of molecules.

The two major divisions of plastics are the thermosetting resins and thermoplastic resins. Thermosetting resins become insoluble and infusible on heating.

Among thermosetting resins are the phenolic resins, furan resins, aminoplastics, alkyds and polyesters of unsaturated acids, epoxy resins, polyurethanes, and silicones.

Thermoplastic resins, which can be melted and solidified repeatedly, unlike thermosetting resins, include cellulose derivatives, addition polymers (polyethylene, polypropylene, vinyls, acrylics, fluorocarbon resins, and polystyrenes), and condensation polymers (nylons, polyethylene terephthalate, polycarbonates, and polyamides).

Other types of resins include oil-soluble or modified resins, plastics such as casein and lignin extracted from natural products, and special-application synthetics such as resins used as adhesives and as additives to paper and textiles.

Raw materials for plastics include coal and cellulose, but by far the chief source is petroleum. Plastics are shaped by a variety of means, including extrusion, blow-molding, calendering between rollers, thermosetting in hydraulic presses, injection molding, rotational molding using centrifugal action, thermoforming, vacuum molding, laminating by press, and casting. Foamed plastics are produced by forming gas bubbles in the molten material.

Plastic products are further shaped and finished by means ranging from mechanical through laser machining, ultrasonic welding, and radiation processing.

Because of their easy manipulation, economical manufacture, low specific gravity, and resistance to corrosion, plastics have replaced metal, wood, glass, and other materials in many applications. An immense array of **plastic** industrial and consumer goods is available. *See also* resin.

Carbon-chain polymers

Polyolefins and related polymers

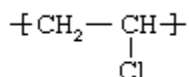
Polyvinyl chloride (PVC)

A synthetic resin belonging to the family of polymeric organic compounds, manufactured by treating **vinyl chloride** (*q.v.*) with a peroxide catalyst, usually in aqueous suspension or emulsion. After mixing with plasticizers, stabilizers, and pigments, the resin may be fabricated by techniques such as calendering, molding, or extrusion into flexible articles such as raincoats, shower curtains, and packaging films. The resin is not plasticized for use in making rigid products such as water pipe, plumbing fittings, and phonograph records.

For use in making piping or structural panels that require high resistance to impact, polyvinyl chloride often is blended with small proportions of rubbery synthetic polymers. Resins more easily plasticized than polyvinyl chloride can be prepared by adding various proportions of vinyl acetate to vinyl chloride before polymerizing the mixture; stiffer resins result from treatment of polyvinyl chloride with chlorine.

Second only to PE in production and consumption, **PVC** is manufactured by bulk, solution, suspension, and emulsion polymerization of vinyl chloride monomer, using free-radical initiators.

Vinyl chloride ($\text{CH}_2=\text{CHCl}$) is most often obtained by reacting ethylene with oxygen and hydrogen chloride over a copper catalyst. It is a carcinogenic gas that must be handled with special protective procedures. As a polymer repeating unit, its chemical structure is:



PVC was first prepared by the German chemist Eugen Baumann in 1872, but it was not patented until 1913, when Friedrich Heinrich August Klatte used sunlight to initiate the polymerization of vinyl chloride.

Commercial application of this plastic was limited by its extreme rigidity. In 1926, while trying to dehydrohalogenate **PVC** in a high-boiling solvent in order to obtain an unsaturated polymer that might bond rubber to metal, Waldo Lonsbury Semon, working for the B.F. Goodrich Company in the United States, serendipitously obtained what is now called plasticized **PVC**.

The discovery of this flexible, inert product was responsible for the commercial success of the polymer. Another route to a flexible product was copolymerization: in 1930 the Union Carbide Corporation introduced the trademarked polymer Vinylite, a copolymer of vinyl chloride and vinyl acetate that became the standard material of long-playing phonograph records.

Pure **PVC** finds application in the construction trades, where its rigidity and low flammability are useful in pipe, conduit, siding, window frames, and door frames. In combination with plasticizer (sometimes in concentrations as high as 50 percent), it is familiar to consumers as floor tile, garden hose, imitation leather upholstery, and shower curtains.

Polyvinylidene chloride (PVDC)

Vinylidene chloride (chemical formula $\text{CH}_2=\text{CCl}_2$, polymer repeating unit structure $-\text{[CH}_2\text{-CCl}_2\text{-]}$) can be made directly from ethylene and chlorine or by the further chlorination of vinyl chloride with subsequent removal of hydrogen chloride by alkali treatment.

It is polymerized in suspension or emulsion processes, using free-radical initiators.

The outstanding property of vinylidene chloride is its low permeability to water vapour and gases—a property that makes it ideal for food packaging.

Copolymers of vinylidene chloride and other monomers are also marketed.

The best known is saran, a trade name for a copolymer consisting of about 87 percent vinylidene chloride and 13 percent vinyl chloride. Saran is extruded into transparent films for use as a food wrap.