Plastics

by Chris Woodford. *Last updated: September 9, 2014.*

Plastics are the most versatile materials ever invented. Indeed, the word "plastic," which derives from the Greek word *plastikos*, meaning to mold or form, has come to be used as a general description for anything particularly adaptable or flexible. Since the first plastic, celluloid, was developed as a replacement for elephant ivory in the 1860s, many different types of plastics, including nylon, polyethylene, and Teflon® have revolutionized the manufacture of commercial goods as diverse as nylon stockings and car-body parts. Although the use of plastic continues to grow and revolutionary new plastics are constantly being developed, concerns have been raised about the environmental effects of using and disposing of so much plastic material, prompting the invention of bioplastics.

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Science

Plastics are synthetic chemicals extracted mainly from petroleum and composed of **hydrocarbons** (compounds made from chains of hydrogen and carbon atoms). Most plastics are **polymers**, long molecules made up of many repetitions of a basic molecule called a monomer; in effect, the monomers are like identical railroad cars coupled together to form a very long train. Thus, as many as 50,000 molecules of ethylene (which has two carbon atoms bonded to four hydrogen atoms) can be joined end to end into a familiar polymer called polyethylene (or polythene). The process of building polymers by adding together monomers is called **additive polymerization**. Another process called **condensation polymerization** (or polycondensation) builds up polymers by removing some atoms from each monomer so they can join together in a different way. Polyesters such as Dacron® and Terylene (two different brand names for similar materials) are made by polycondensation. Whichever process is used, the chemical properties of the monomer normally govern those of the polymer that is eventually formed.

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Polymerization produces two different kinds of plastics. Sometimes, polymers form very long straight or branched chains. These are present in so-called **thermoplastics**, which always soften when heated and harden when cooled down. Examples include polyethylene and polystyrene. Polymers can also form more complex three-dimensional structures, which give plastics very different physical properties. **Thermosetting plastics**, as these are called, harden the first time they are heated when cross-links form between different plastic molecules. Thermosetting plastics never soften again no matter how many times they are heated and this makes them particularly suitable for objects that need to operate in hot environments. Epoxy resins and bakelite are examples of thermosetting plastics.

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Manufacture

Plastic goods such as hosepipes or washing-up bowls begin life as a raw material, or **resin**, produced by polymerization. Initially, the resin starts off as a powder, or as pellets or flakes, to which various other materials are added. Some of these provide color or texture, while others give the plastic particular physical properties, such as fire-resistance, slight electrical conductivity (to reduce static buildup), or added strength. Additives called **plasticizers** make a plastic flow more easily while **stabilizers** called antioxidants help to prevent it from breaking down over time, for example, through the effect of the ultraviolet radiation in sunlight.

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Once the raw material has been prepared, the final product is produced through a range of different manufacturing processes. **Extrusion** involves squeezing plastic like toothpaste through a mold and is used to make goods such as hosepipes and polyethylene sheets. **Injection molding** involves heating resin pellets until they melt, then forcing them under pressure into a mold, where they cool and harden to make objects such as plastic telephones or toy cars. A similar technique called **blow molding** makes plastic bottles by forcing a thin layer of plastic against the mold with compressed air. **Casting** is used to shape thermosetting plastics by pouring them into a mold then heating them until they set. And **calendering** involves squeezing sheets of plastic between huge rollers to make thin, flexible materials such as plastic folders.

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Uses

Starting with celluloid, invented in the 1860s, and bakelite, patented in 1909, chemists have now synthesized dozens of different "poly" plastics for almost every conceivable use (the word "poly" in front a chemical name simply indicates that a plastic has been formed by polymerization). Polyethylene gives us food wrapping, carrier bags, greenhouse materials, and plastic bottles. Polypropylene is easily drawn into strong fibers and woven into ropes and carpets. Polystyrene is a light packaging material with particularly good heat insulation properties (hence its use in styrofoam cups). Polyvinylchloride (PVC) is a cheap and versatile plastic that can be formed into a wide range of items, including imitation leather, "vinyl" records, and plastic pipes. And polytetrafluoroethylene (PTFE) or Teflon is a slippery heat- and chemical-resistant plastic used as the non-stick coating in frying pans.

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Plastic is such a dominant feature of the modern world that it seems almost impossible to imagine it being more pervasive than it already is. Yet chemists continue to pioneer improved methods of polymerization and continually produce revolutionary new plastic materials. Plastic-based composites have long been used to manufacture car components, but manufacturers such as Chrysler are now looking to produce car bodies built purely from plastics such as PET (polyethylene terephthalate)—a material commonly used to make plastic bottles. Chrysler claim the plastic shells are as crash-resistant as steel and composites, but much cheaper. Their new plastic process could reduce the number of body parts from around 80 to just 6, eliminate the need for painting (because the plastic body can be colored when it is molded), and could halve the cost of some conventional cars.

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Other new plastics promise a range of different benefits. One of the latest developments, light-emitting polymers (LEPs), could replace cathode ray tubes and expensive flat-panel LCD displays. Where today's tiny semiconductor lasers (used in appliances such as CD-players) can produce light of only certain colors, LEPs can make light of any color and are much easier to manufacture. A more controversial development has been the use of a bacteria-killing plastic called Microban® in food chopping boards and in plastic toys. The manufacturers have claimed superior resistance against bacteria, but environmental regulators and consumer watchdogs have expressed doubts and concerns. One of the most unusual new plastics is a polymer called 3GT, which has been long in development but is still not commercially marketed. It has a kind of "stretch memory," so it could be used to make seats that remember the shapes of their occupants or clothes that mold to peoples' bodies. Another amazing plastic called D3O® has an astonishing ability to absorb impacts: normally it's soft and squishy, but if you hit it very suddenly, it hardens instantly and cushions the blow. (Find out more about it in our article on energy-absorbing materials.)

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For all their benefits, plastics do present a notable problem: their sheer durability means they persist in the environment for many years, while their lightness means they can be carried great distances, for example as ocean debris. The bodies of fully a quarter of the world's seabirds are estimated to contain some sort of plastic residue. Waste plastics such as PET are now recycled into a range of useful goods, such as upholstery padding and thermal clothing. Unlike other plastics, which are produced from petroleum, polyhydroxybutyrate (PHB), sold as Biopol, is produced as a natural polymer by certain bacteria as a means of storing their energy. It breaks down harmlessly in soil, but is much more expensive than other plastics. You can read more about environmentally friendly plastics in our detailed article about bioplastics.

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