Rubber is an example of an elastomer type polymer, where the polymer has the ability to return to its original shape after being stretched or deformed. The rubber polymer is coiled when in the resting state. The elastic properties arise from its ability to stretch the chains apart, but when the tension is released the chains snap back to the original position. The majority of rubber polymer molecules contain at least some units derived from conjugated diene monomers (see Polymerization of Conjugated Dienes). Such conjugated diene monomers have a constructive backbone of at least four carbon atoms with a double-single-double bond reactive core (C=C-C=C). Most if not practically all such dienes undergo 1,4-addition to the polymer chain, where 1 and 4 refer to the 1st and 4th carbons of the backbone unit, which become single-bonded to the rest of the polymer chain. The diene's double bonds turn into single bonds, and the single bond between them turns into a Z or E configured double bond, depending on the polymerization conditions. The unit's backbone thus becomes like this (-C-C=C-C-). Rubber gets its elasticity when the formed double bond gets the Z configuration. For 1,3-butadiene, Z is equivalent to a cis and E is equivalent to a trans configuration.

**Natural Rubber**

Natural rubber is an addition polymer that is obtained as a milky white fluid known as latex from a tropical rubber tree. Natural rubber is from the monomer isoprene (2-methyl-1,3-butadiene), which is a conjugated diene hydrocarbon as mentioned above. In natural rubber, most of the double bonds formed in the polymer chain have the Z configuration, resulting in natural rubber's elastomer qualities.

Charles Goodyear accidentally discovered that by mixing sulfur and rubber, the properties of the rubber improved in being tougher, resistant to heat and cold, and increased in elasticity. This process was later called vulcanization after the Roman god of fire. Vulcanization causes shorter chains to cross link through the sulfur to longer chains. The development of vulcanized rubber for automobile tires greatly aided this industry.

**Synthetic Rubber**

Important conjugated dienes used in synthetic rubbers include isoprene (2-methyl-1,3-butadiene), 1,3-butadiene, and chloroprene (2-chloro-1,3-butadiene). Polymerized 1,3-butadiene is mostly referred to simply as polybutadiene. Polymerized chloroprene was developed by DuPont and given the trade name Neoprene. In a number of cases, monomers which are not dienes are also used for certain types of synthetic rubber, often copolymerized with dienes. Some of the most commercially important addition polymers are the copolymers. These are polymers made by polymerizing a mixture of two or more monomers. An example is *styrene-butadiene rubber* (SBR) - which is a copolymer of 1,3-butadiene and styrene which is mixed in a 3 to 1 ratio, respectively.

SBR rubber was developed during World War II when important supplies of natural rubber were cut off. SBR is more resistant to abrasion and oxidation than natural rubber and can also be vulcanized. More than 40% of the synthetic rubber production is SBR and is used in tire production. A tiny amount is used for bubble-gum in the unvulcanized form. *Nitrile rubber* is copolymerized from butadiene and acrylonitrile (H₂C=CH-CN). *Butyl rubber* is copolymerized from isobutylene [which is methylpropene H₂C=C(CH₃)₂] and a small percentage of isoprene. *Silicone rubber* and other compounds, chemically called polysiloxanes, are not from conjugated dienes but have repeating units like -O-SiR₂- where R is some organic radical group like methyl.
Needle Through a Balloon

The polymer rubber chains exist in random loose clumps in the unstretched state. At the nipple end of the balloon, there is lots of rubber and therefore many, many polymer chains - still loosely coiled. These chains can be pierced without popping the balloon because the chains can still be stretched. This is because they allow the skewer in between the chains without breaking the chains or the bonds that connect them. But on the sides of the balloon, these chains are stretched almost to their limit and very far apart. The piercing is too much for the stretched chains and they break apart, and the balloon pops.

Contributors

• Charles Ophardt, Professor Emeritus, Elmhurst College; Virtual Chembook
• Henry A. Padleckas