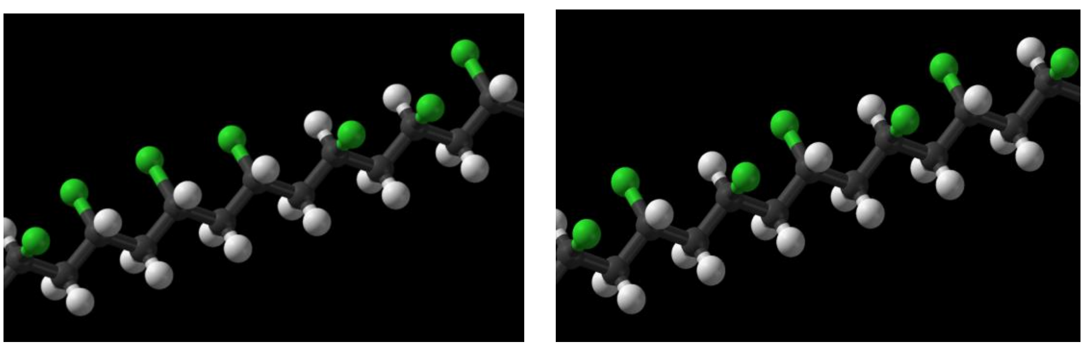
Poly(methyl methacrylate) - (PMMA)

Poly(methyl methacrylate), more often called PMMA, is a commonly used low cost thermoplastic polymer with boundless applications to everyday life. PMMA is the most commercially important acrylic polymer and is sold under several trade names including Plexiglas® and Acrylite®. High transparency makes PMMA an ideal replacement for glass where impact or weight is a serious concern. PMMA is compatible with human tissue making it an important material for transplants and prosthetics, especially in the field of ophthalmology because of its transparent properties.

PMMA is formed through block, emulsion or suspension polymerization of methacrylic acid. PMMA was thought to be an atactic polymer through the first half of the 20th century. This means that the substituents of the molecular chain alternate randomly along the chain, which is illustrated in Figure 1A below. Since the development of modern equipment and techniques, it has been determined that the molecular chains are mostly syndiotactic (Figure 1B), meaning the molecular chain's substituents alternate uniformly. Final processing of PMMA is accomplished through injection molding or extrusion at melt temperatures ranging from 200-230 ºC.



(A) (B)

Figure 1: (A) Atactic structure, with randomly alternating substituents along the molecular chain. (B) Syndiotactic structure, with uniform alternating substituents along the molecular chain.

(Need New Image)

Pendent groups form when a cluster of atoms bonds off of the backbone of the polymer chain. The bulky pendent groups on the polymer repeating unit of PMMA (Figure 2) induce several interesting properties. Crystallization is blocked by the pendent groups because the molecules can not get close to form crystalline bonds. This causes PMMA to be amorphous. Pendent groups snag on adjacent groups nearly eliminating slip between polymer chains. This causes PMMA to be rigid, brittle, have a high glass transition temperature and little mold shrinkage.

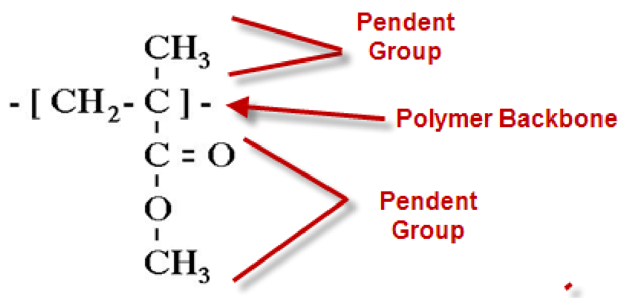


Figure 2:Bulky Pendent Groups on Polymer Repeating Unit for PMMA
(Need New Image)

Mechanical and optical property degradation caused by UV exposure is minimal with PMMA. This is because PMMA absorbs only trace amounts of light and UV radiation due to its transparency. This small amount of absorbed radiation lacks the energy necessary to break down the molecular bonds within the material. This is a unique property for a polymer, and makes it especially well suited for long term weather resistance.

PMMA has great scratch resistance when compared with similar polymers like polycarbonate, however its scratch resistance still can not compete with glass. This is inconvenient because the majority of PMMA parts utilize its optical properties, yet there are protective coatings which can be applied to mitigate this problem.

Most PMMA is used in low cost applications were transparency and weather resistance is required. Some examples of these applications are headlights and taillights on passenger automobiles, illuminated signs and street lamp housings. The polymer has also been used widely in aircraft windows as a glass replacement since WWII because of its low density and superior toughness. It is still used as a glass substitute on a wide range of sub-sonic aircraft today and has expanded to other weight sensitive applications such as race cars, motorcycles and off-road vehicles.

PMMA is often used in various implants because of its compatibility with human tissue. Because of its transparency and bio-compatibility, PMMA is important in optometry for replacing the intraocular lens of cataract patient. PMMA is used as bone cement in orthopedic surgery. The modulus of elasticity is similar to natural bone giving it a more natural feeling for the patient than metallic alternatives. The benefits of utilizing PMMA within the body are countered with the exotherm that occurs while curing the acrylic. This generation of heat has the potential to damage surrounding tissue.

The unique properties, low cost and bio-compatibility of PMMA combine to make it the most commercially important acrylic available to date. Optical and mechanical properties are directly influenced by the microstructure of PMMA. The biocompatibility of PMMA has made it an important material for implants. The unique properties and wide range of applications ensure that PMMA will continue to be an essential polymer.

References:

[1] Brydson, *Plastics Materials*, Butterworths, 1989
[2] Campo, E. Alfredo, *the Complete Part Design Handbook*, Hanser, 2006
[3] Osswald, et al, *International Plastics Handbook*, Hanser, 2006
[4] Strong, *Plastics Materials and Processing*, Prentice Hall, 2000