Polymethyl methacrylate (Acrylic, PMMA)

Description

Image


Caption

1. Car rear light casing. © Chris Lefteri 2. PMMA chair. © Chris Lefteri

The material

When you think of PMMA, think transparency. Acrylic, or PMMA, is the thermoplastic that most closely resembles glass in transparency and resistance to weathering. The material has a long history: discovered in 1872, first commercialized in 1933, its first major application was as cockpit canopies for fighter aircraft during the second World War.

Composition (summary)

(CH2-C(CH3)COOCH3)n

General properties

Density		72.4	-	76.2	lb/ft^3
Price	*	1.25	-	1.3	USD/lb
Date first used		1933			

Mechanical properties

Young's modulus		0.325	-	0.551	10^6 psi
Shear modulus		0.116	-	0.198	10^6 psi
Bulk modulus		0.609	-	0.638	10^6 psi
Poisson's ratio		0.384	-	0.403	
Yield strength (elastic limit)		7.8	-	10.5	ksi
Tensile strength		7.01	-	11.5	ksi
Compressive strength		10.5	-	19	ksi
Elongation		2	-	10	% strain
Hardness - Vickers		16.1	-	21.9	HV
Fatigue strength at 10^7 cycles	*	2.2	-	4.74	ksi
Fracture toughness		0.637	-	1.46	ksi.in^0.5

Mechanical loss coefficient (tan delta)	* 0.0105	-	0.0179	

Thermal properties

Glass temperature	185	-	329	°F
Maximum service temperature	107	-	134	°F
Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0484	-	0.145	BTU.ft/h.ft^2.F
Specific heat capacity	0.355	-	0.384	BTU/lb.°F
Thermal expansion coefficient	40	-	90	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e23	-	3e24	µohm.cm
Dielectric constant (relative permittivity)	3.2	-	3.4	
Dissipation factor (dielectric loss tangent)	0.05	-	0.06	
Dielectric strength (dielectric breakdown)	399	-	551	V/mil

Optical properties

Transparency	Optical Quality			
Refractive index	1.49	-	1.56	

Critical Materials Risk

High critical material risk?	No			

Processability

Castability	3	-	5	
Moldability	4	-	5	
Machinability	3	-	4	
Weldability	5			

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Excellent

Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Limited use
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Unacceptable
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Unacceptable
Benzene	Unacceptable
Carbon tetrachloride	Limited use
Chloroform	Unacceptable
Crude oil	Acceptable
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Acceptable
Petrol (gasoline)	Excellent
Silicone fluids	Limited use
Toluene	Unacceptable
Turpentine	Unacceptable
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Unacceptable
Acetone	Unacceptable
Ethyl alcohol (ethanol)	Limited use
Ethylene glycol	Limited use
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Unacceptable

Durability: halogens and gases

Chlorine gas (dry)	Limited use

Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Acceptable
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Highly flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Acceptable
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	1.15e4	-	1.28e4	kcal/lb
CO2 footprint, primary production	*	6.46	-	7.14	lb/lb
Water usage	*	8.66	-	9.57	gal(US)/lb
Eco-indicator 99		506			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	626	-	692	kcal/lb
Polymer molding energy	*	1.91e3	-	2.1e3	kcal/lb
Coarse machining energy (per unit wt removed)	*	133	-	147	kcal/lb
Fine machining energy (per unit wt removed)	*	874	-	966	kcal/lb
Grinding energy (per unit wt removed)	*	1.7e3	-	1.87e3	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.434	-	0.479	lb/lb
Polymer molding CO2	*	1.32	-	1.46	lb/lb
Coarse machining CO2 (per unit wt removed)	*	0.0926	-	0.102	lb/lb
Fine machining CO2 (per unit wt removed)	*	0.605	-	0.669	lb/lb
Grinding CO2 (per unit wt removed)	*	1.18	-	1.3	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓				
Embodied energy, recycling	*	4.15e3	-	4.58e3	kcal/lb
CO2 footprint, recycling	*	3.01	-	3.32	lb/lb
Recycle fraction in current supply	*	0.5	-	1	%
Downcycle	✓				
Combust for energy recovery	✓				
Heat of combustion (net)	*	2.8e3	-	2.94e3	kcal/lb
Combustion CO2	*	2.15	-	2.25	lb/lb
Landfill	✓				
Biodegrade	✗				
Toxicity rating	Non-toxic				
A renewable resource?	✗				

Environmental notes

Acrylics are non-toxic and recyclable.

Recycle mark

Supporting information

Design guidelines

Acrylic, PMMA, is hard and stiff as polymers go, easy to polish but sensitive to stress concentrations. It shares with glass a certain fragility, something that can be overcome by blending with acrylic rubber to give a high-impact alloy (HIPMMA). PVC can be blended with PMMA to give tough, durable sheets. Acrylic is available as a sheet, rod or tube and can be shaped by casting or extrusion. Cell casting uses plates of glass and gasketing for a mold; it allows clear and colored panels up to 4 inches thick to be cast. Extrusion pushes melted polymer pellets through a die to give a wide variety of shapes, up to 0.25 inches thick for sheet. Clear and colored PMMA sheet lends itself to thermoforming, allowing inexpensive processing. A hybrid sheet manufacturing process, continuous casting, combines the physical benefits of cell casting and the cost efficiency of extrusion. Extruded and continuous cast sheet have better thickness tolerance than cell-cast sheet. PMMA can be joined with epoxy, alpha-cyanoacrylate, polyester or nitrile-phenolic adhesives. It scratches much more easily than glass, but this can be partially overcome with coatings.

Technical notes

Polymers are truly transparent only if they are completely amorphous - that is, non-crystalline. The lumpy shape of the PMMA molecule ensures an amorphous structure, and its stability gives good weathering resistance. PMMA is attacked by esters, ketones, acids and hydrocarbons, and has poor resistance to strong acids or bases, solvents and acetone.

Typical uses

Lenses of all types, cockpit canopies and aircraft windows, signs, domestic baths, packaging, containers, electrical components, drafting equipment, tool handles, safety spectacles, lighting, automotive tail lights, chairs, contact lenses, windows, advertising signs, static dissipation products, compact disks.

Tradenames

Acrive, Acrylite, Acryrex, Altuglas, Cyrolite, Diakon, Glasflex, Goldrex, Lucite, Lucryl, Optix, Oroglas, Perspex, Plexiglas, Plexit, Sumiplex

Links

Reference

ProcessUniverse

Producers