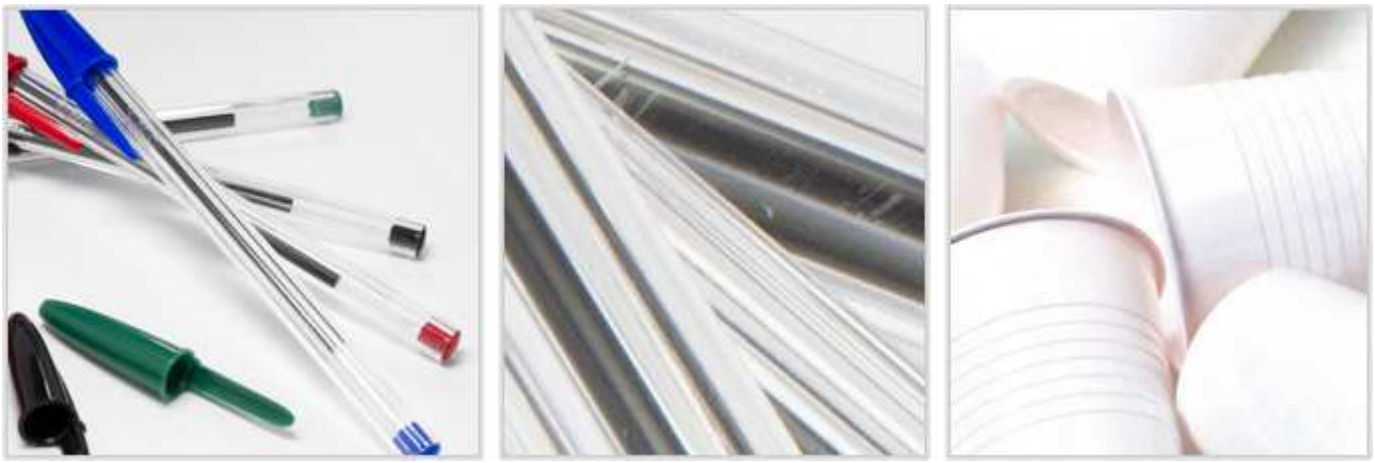
Description

Image



Caption

1. Transparent polysterene pens. © Carlos Delgado, Kadellar at en.wikipedia - (CC BY-SA 3.0) 2. Close-up of scratches on the material. © Carlos Delgado, Kadellar at en.wikipedia - (CC BY-SA 3.0) 3. Plastic cups. © Chris Lefteri

The material

Polystyrene is an optically clear, cheap, easily molded polymer, familiar as the standard "jewel" CD case. In its simplest form PS is brittle. Its mechanical properties are dramatically improved by blending with polybutadiene, but with a loss of optical transparency. High impact PS (10% polybutadiene) is much stronger even at low temperatures (meaning strength down to -12C). The single largest use of PS is a foam packaging.

Composition (summary)

(CH(C6H5)-CH2)n

General properties

Density		1.04e3	-	1.05e3	kg/m^3
Price	*	1.2	-	1.8	USD/kg
Date first used		1937			

Mechanical properties

Young's modulus		1.2	-	2.6	GPa
Shear modulus		0.5	-	0.9	GPa
Bulk modulus		2.9	-	3.1	GPa
Poisson's ratio		0.383	-	0.403	
Yield strength (elastic limit)		28.7	-	56.2	MPa
Tensile strength		35.9	-	56.5	MPa
Compressive strength		31.6	-	61.8	MPa
Elongation		1.2	-	3.6	% strain
Hardness - Vickers		8.6	-	16.9	HV
Fatigue strength at 10^7 cycles		14.4	-	23	MPa

Fracture toughness	0.7	-	1.1	MPa.m^0.5
Mechanical loss coefficient (tan delta)	0.012	-	0.0175	

Thermal properties

Glass temperature	73.9	-	110	℃
Maximum service temperature	76.9	-	103	℃
Minimum service temperature	-123	-	-73.2	℃
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.121	-	0.131	W/m.℃
Specific heat capacity	1.69e3	-	1.76e3	J/kg.℃
Thermal expansion coefficient	90	-	153	µstrain/℃

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e25	-	1e27	µohm.cm
Dielectric constant (relative permittivity)	3	-	3.2	
Dissipation factor (dielectric loss tangent)	0.001	-	0.003	
Dielectric strength (dielectric breakdown)	19.7	-	22.6	1000000 V/m

Optical properties

Transparency	Optical Quality			
Refractive index	1.57	-	1.59	

Critical Materials Risk

High critical material risk?	No

Processability

Castability	1	-	2	
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)	Limited use

Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Limited use
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Acceptable
Nitric acid (70%)	Limited use
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Acceptable
Sulfuric acid (10%)	Excellent
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	Excellent
Chloroform	Unacceptable
Crude oil	Limited use
Diesel oil	Limited use
Lubricating oil	Limited use
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Limited use
Silicone fluids	Excellent
Toluene	Unacceptable
Turpentine	Unacceptable
Vegetable oils (general)	Limited use
White spirit	Limited use

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Unacceptable
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)	Poor

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

Geo-economic data for principal component

Annual world production, principal component	1.2e7	-	1.22e7	tonne/yr
Reserves, principal component	* 3e8	-	3.1e8	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 92.1	-	102	MJ/kg
CO2 footprint, primary production	* 3.61	-	3.99	kg/kg
Water usage	* 132	-	146	l/kg
Eco-indicator 95	360			millipoints/kg
Eco-indicator 99	319			millipoints/kg

Material processing: energy

Polymer extrusion energy	* 5.8	-	6.41	MJ/kg
Polymer molding energy	* 17.9	-	19.8	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.781	-	0.863	MJ/kg
Fine machining energy (per unit wt removed)	* 3.54	-	3.91	MJ/kg
Grinding energy (per unit wt removed)	* 6.6	-	7.29	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.435	-	0.48	kg/kg

Polymer molding CO2	* 1.34	-	1.49	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0586	-	0.0647	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.265	-	0.293	kg/kg
Grinding CO2 (per unit wt removed)	* 0.495	-	0.547	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 45.3	-	50	MJ/kg
CO2 footprint, recycling	* 3.56	-	3.93	kg/kg
Recycle fraction in current supply	2.1	-	3	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 40.3	-	42.3	MJ/kg
Combustion CO2	* 3.29	-	3.45	kg/kg
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

The flammability of PS foam, and the use of CFC's as blowing agents in the foaming process was, at one time, a cause for concern. New flame retardants allow PS foams to meet current fire safety standards, and CFC blowing agents have been replaced by pentane, CO2 or HFC's which do not have a damaging effect on the ozone layer. PS can be recycled. The large volume of PS foam in packaging, much of it dumped at present, is a cause for concern. The monomer, styrene, is irritating to the eyes and throat, but none survives in the polymer.

Recycle mark

Supporting information

Design guidelines

PS comes in 3 guises: as the simple material ('general purpose PS'); as the high impact variant, blended with polybutadiene; and as polystyrene foam, the most familiar and cheapest of all polymer foams. All are FDA approved for use as food containers and packaging. General purpose PS is easy to mold. Its extreme clarity, ability to be colored, and high refractive index give it a glass-like sparkle, but it is brittle and cracks easily (think of CD cases). It is used when the optical attractiveness and the low cost are sought, and the mechanical loading is light: cosmetic compacts, transparent but disposable glasses, cassettes of all kinds. Medium and high impact polystyrenes trade their optical for their mechanical properties. Medium impact PS, translucent, appears in electrical switch gears and circuit breakers, coat hangers and combs. High impact PS - a blend of PPO and PS, is opaque, but is tough and copes better with low temperatures than most plastics; it is found in interiors of refrigerators and freezers, and in food trays such as those for margarine and yogurt. Other styrene blends, like Kraton, have low tensile strength and higher elongation than SBR or natural rubber. PS can be foamed to a very low density (roughly 1/3 of all polystyrene in foamed). These foams have low thermal conduction and are cheap, and so are used for house insulation, jackets for water boilers, insulation for disposable cups. They crush at loads that do not cause injury to delicate objects (such as TV sets or to the human body), making them good for packaging.

Technical notes

Polystyrene, PS, is - like PE and PP - a member of the polyolefin family of moldable thermoplastics. In place of one of the H-atoms of the polyethylene it has a C6H5 - benzene ring. This makes for a lumpy molecule which does not crystallize, and the resulting material is transparent with a high refractive index. The benzene ring absorbs UV light, exploited in the PS screening of fluorescent lights, but also causing the polymer to discolor in sunlight. All grades of PS have excellent electrical resistance and dielectric strength, exploited in switchgear.

Typical uses

Toys, light diffusers, lenses and mirrors, beakers, cutlery, general household appliances, video/audio cassette cases, electronic housings, refrigerator liners.

Tradenames

Aim, Bapolan, Comalloy, Dylite, Lastirol, NSC, Polystyrol, Styron, Styropor, Vestyron

Links

Reference

ProcessUniverse

Producers