Borosilicate glass

Description

Image

Caption

1. Borosilicate glass (Pyrex) is used for ovenware and chemical equipment. © iStockphoto 2. Teapot designed by Wilhelm Wagenfeldt in 1931. © Chris Lefteri

The material

Borosilicate glass is soda lime glass with most of the lime replaced by borax, B203. It has a higher melting point than soda lime glass and is harder to work; but it has a lower expansion coefficient and a high resistance to thermal shock, so it is used for glassware and laboratory equipment.

Compositional summary

74% SiO2/1% Al2O3/15% B2O3/4% Na2O/6% PbO

General properties

Density	137	-	144	lb/ft^3
Price	* 2.04	-	3.39	USD/lb
Date first used	1893			

Mechanical properties

Young's modulus	8.85	-	9.28	10^6 psi
Shear modulus	* 3.71	-	3.9	10^6 psi
Bulk modulus	* 4.86	-	5.15	10^6 psi
Poisson's ratio	0.19	-	0.21	
Yield strength (elastic limit)	* 3.19	-	4.64	ksi
Tensile strength	3.19	-	4.64	ksi
Compressive strength	* 38.3	-	55.7	ksi
Elongation	0			% strain
Hardness - Vickers	* 83.7	-	92.5	HV
Fatigue strength at 10^7 cycles	* 3.84	-	4.25	ksi
Fracture toughness	* 0.455	-	0.637	ksi.in^0.5

Mechanical loss coefficient (tan delta)	4.6e-5	-	6.2e-5	

Thermal properties

Glass temperature	842	-	1.12e3	°F
Maximum service temperature	446	-	860	°F
Minimum service temperature	-460			°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	* 0.578	-	0.751	BTU.ft/h.ft^2.F
Specific heat capacity	* 0.182	-	0.191	BTU/lb.°F
Thermal expansion coefficient	1.78	-	2.22	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.16e21	-	3.16e22	µohm.cm
Dielectric constant (relative permittivity)	4.65	-	6	
Dissipation factor (dielectric loss tangent)	0.01	-	0.017	
Dielectric strength (dielectric breakdown)	* 305	-	356	V/mil

Optical properties

Transparency	Optical Quality			
Refractive index	1.47	-	1.48	

Processability

Castability	2	-	3	
Moldability	4	-	5	
Weldability	3	-	4	

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)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	

	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Acceptable
Sodium hydroxide (60%)	Limited use

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Limited use
O2 (oxygen gas)	Excellent
Sulfur dioxide (gas)	Excellent

Durability: built environments

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

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Excellent
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	*	2.96e3	-	3.27e3	kcal/lb
CO2 footprint, primary production	*	1.65	-	1.83	lb/lb
Water usage	*	1.69	-	1.87	gal(US)/lb
Eco-indicator 99		174			millipoints/kg

Material processing: energy

Glass molding energy	*	804	-	973	kcal/lb
Grinding energy (per unit wt removed)	*	2.42e3	-	2.67e3	kcal/lb

Material processing: CO2 footprint

Glass molding CO2	*	0.594	-	0.718	lb/lb
Grinding CO2 (per unit wt removed)	*	1.67	-	1.85	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓				
Embodied energy, recycling	*	2.3e3	-	2.54e3	kcal/lb
CO2 footprint, recycling	*	1.67	-	1.84	lb/lb
Recycle fraction in current supply	*	18	-	23	%
Downcycle	✓				
Combust for energy recovery	✗				
Landfill	✓				
Biodegrade	✗				
Toxicity rating	Non-toxic				

A renewable resource?	✗

Environmental notes

Silica, the prime ingredient of glass, is the commonest compound in the earths crust, though it is harder to find it in a form sufficiently pure to make glass. Nonetheless, the ingredients of glass are ubiquitous, and the material is readily recycled at the end of its life.

Supporting information

Design guidelines

Borosilicate glass is harder to work, and requires higher temperatures, than soda-lime glass, but its properties are better. It is particularly its resistance to thermal shock that is good, making it the right choice for applications in which the temperature changes suddenly.

Typical uses

Ovenware, laboratory ware, piping, lenses and mirrors, sealed beam headlights, tungsten sealing, bells

Tradenames

Pyrex

Links

Reference

ProcessUniverse

Producers