Description

Image

Caption

Glass ceramic can tolerate extreme thermal shock. © Kuppersbusch USA Inc.

The material

Glass ceramics are glasses that, to a greater or lesser extent, have crystallized. They are shaped while in the glassy state, using ordinary molding methods and then cooled in such a way that the additives they contain nucleate small crystals. It is sold for cooking as pyroceram and is used for high performance heat resisting applications.

Composition (summary)

SiO2/Al2O3/B2O3

General properties

Density	150	-	181	lb/ft^3
Price	* 0.939	-	5.64	USD/lb
Date first used	1957			

Mechanical properties

Young's modulus	10.9	-	13.8	10^6 psi
Shear modulus	* 4.38	-	7.09	10^6 psi
Bulk modulus	* 7.25	-	8.7	10^6 psi
Poisson's ratio	0.24	-	0.29	
Yield strength (elastic limit)	9.06	-	25.7	ksi
Tensile strength	9.06	-	25.7	ksi
Compressive strength	49.3	-	174	ksi
Elongation	0			% strain
Hardness - Vickers	230	-	720	HV
Fatigue strength at 10^7 cycles	8.71	-	24.4	ksi
Fracture toughness	1.37	-	1.55	ksi.in^0.5

Mechanical loss coefficient (tan delta)	5e-5	-	2e-4	

Thermal properties

Glass temperature	1.05e3	-	3e3	°F
Maximum service temperature	1.47e3	-	2.14e3	°F
Minimum service temperature	-460			°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	0.768	-	1.45	BTU.ft/h.ft^2.F
Specific heat capacity	0.143	-	0.215	BTU/lb.°F
Thermal expansion coefficient	1.67	-	4.11	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	2e19	-	1e21	µohm.cm
Dielectric constant (relative permittivity)	5.3	-	6.2	
Dissipation factor (dielectric loss tangent)	0.0035	-	0.0047	
Dielectric strength (dielectric breakdown)	965	-	1.02e3	V/mil

Optical properties

Transparency	Translucent		
Refractive index	1.5	-	1.55

Critical Materials Risk

High critical material risk?	No

Processability

Castability	1		
Moldability	3	-	4
Machinability	1	-	3
Weldability	1		

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%)	Excellent
Sodium hydroxide (60%)	Excellent

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)	Excellent
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 4.06e3	-	4.5e3	kcal/lb
CO2 footprint, primary production	* 2.2	-	2.43	lb/lb
Water usage	* 2.77	-	3.06	gal(US)/lb

Material processing: energy

Glass molding energy	* 1.31e3	-	1.59e3	kcal/lb
Grinding energy (per unit wt removed)	* 9.17e3	-	1.01e4	kcal/lb

Material processing: CO2 footprint

Glass molding CO2	* 0.969	-	1.17	lb/lb
Grinding CO2 (per unit wt removed)	* 6.34	-	7.01	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✖	
Recycle fraction in current supply	0.1	%
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

Glass ceramic is shaped in a two-stage process. The molding is done while the material is still a true glass, using standard glass-forming methods. The shaped product is then heat treated, causing "phase-separation" : the formation of crystalline phases. These have a very low thermal expansion coefficient, with the result that the material can withstand very sudden changes of temperature without cracking. Some grades of glass ceramic are machinable.

Typical uses

Photosensitive applications, Cookware, Lasers, Stove window glass, Telescope mirror banks, Exterior and interior cladding, Laboratory bench tops, Missile Radomes

Tradenames

Pyroceram, Macor, Shapal M-soft.

Links

Reference

ProcessUniverse

Producers