Description

Image

Caption

Epoxies paints are exceptionally stable and protective, and take color well.

The material

Epoxies are thermosetting polymers with excellent mechanical, electrical and adhesive properties and good resistance to heat and chemical attack. They are used for adhesives (Araldite), surface coatings and, when filled with other materials such as glass or carbon fibers, as matrix resins in composite materials. Typically, as adhesives, epoxies are used for high-strength bonding of dissimilar materials; as coatings, they are used to encapsulate electrical coils and electronic components; when filled, they are used for tooling fixtures for low-volume molding of thermoplastics.

Composition (summary)

(O-C6H4-CH3-C-CH3-C6H4)n

General properties

Density		1.11e3	-	1.4e3	kg/m^3
Price	*	2.26	-	2.92	USD/kg
Date first used		1947			

Mechanical properties

Young's modulus		2.35	-	3.08	GPa
Shear modulus		0.84	-	1.1	GPa
Bulk modulus		3.8	-	4	GPa
Poisson's ratio		0.38	-	0.42	
Yield strength (elastic limit)		36	-	71.7	MPa
Tensile strength		45	-	89.6	MPa
Compressive strength		39.6	-	78.8	MPa
Elongation		2	-	10	% strain
Hardness - Vickers		10.8	-	21.5	HV
Fatigue strength at 10^7 cycles	*	22.1	-	35	MPa

Fracture toughness	0.4	-	2.22	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.0095	-	0.027	

Thermal properties

Glass temperature	66.9	-	167	°C
Maximum service temperature	140	-	180	°C
Minimum service temperature	-123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.18	-	0.5	W/m.°C
Specific heat capacity	1.49e3	-	2e3	J/kg.°C
Thermal expansion coefficient	58	-	117	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e20	-	6e21	µohm.cm
Dielectric constant (relative permittivity)	3.4	-	5.7	
Dissipation factor (dielectric loss tangent)	7e-4	-	0.015	
Dielectric strength (dielectric breakdown)	11.8	-	19.7	1000000 V/m

Optical properties

Transparency	Transparent		
Refractive index	1.54	-	1.6

Critical Materials Risk

High critical material risk?	No

Processability

Castability	4	-	5
Moldability	4	-	5
Machinability	3	-	4
Weldability	1		

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable

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

Durability: alkalis

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

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

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

Durability: flammability

Flammability	Slow-burning

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Limited use
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		1.2e5	-	1.25e5	tonne/yr
Reserves, principal component	*	3.7e6	-	3.8e6	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	127	-	140	MJ/kg
CO2 footprint, primary production	*	6.83	-	7.55	kg/kg
Water usage	*	26.6	-	29.4	l/kg

Material processing: energy

Polymer molding energy	*	21	-	23.1	MJ/kg
Coarse machining energy (per unit wt removed)	*	1.49	-	1.65	MJ/kg
Fine machining energy (per unit wt removed)	*	10.6	-	11.7	MJ/kg
Grinding energy (per unit wt removed)	*	20.8	-	22.9	MJ/kg

Material processing: CO2 footprint

Polymer molding CO2	*	1.68	-	1.85	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.112	-	0.123	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.796	-	0.88	kg/kg
Grinding CO2 (per unit wt removed)	*	1.56	-	1.72	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle		✖			
Recycle fraction in current supply		0.5	-	1	%
Downcycle		✔			
Combust for energy recovery		✔			
Heat of combustion (net)	*	30	-	31.5	MJ/kg
Combustion CO2	*	2.42	-	2.54	kg/kg
Landfill		✔			
Biodegrade		✖			
Toxicity rating		Non-toxic			
A renewable resource?		✖			

Environmental notes

Both resin and hardener are irritants; their vapors are potentially toxic. Ventilation and skin protection are important, but both are achievable. Thermosets cannot be recycled, though it may be possible to use them as fillers. Cutting and machining of glass and carbon-fiber composites requires special forced-air ventilation to remove the fine glass or carbon dust that is damaging if inhaled.

Supporting information

Design guidelines

Epoxy molding compounds are supplied in liquid or granular form. They can be shaped by transfer molding at low pressures (350-700 kPa). When designing with epoxy, as with any thermosetting material, allowance must be made for shrinkage on cooling; perfectly flat molded surfaces are not achievable, and the minimum wall thickness for average-sized epoxy molded parts is 2.0mm. Unmodified epoxies have a high viscosity; they are shaped by transfer molding. Diluted epoxy resins have a lower viscosity and cure slowly, but can be cast or used to impregnate a mat or weave of fibers. The addition of fillers gives epoxies improved machinability, hardness, impact resistance and thermal conductivity; thermal expansion and mold shrinkage are both reduced. Plasticizers and flexibilizers increase flexibility and toughness. Epoxy is also commonly used as a pattern or mold material. Epoxy resin laminates are formed using a wide range of processes, from batch techniques such as hand lay up and bulk molding compound (BMC) molding, producing, for example, mechanical components like gears and distributor caps, to continuous processes such as filament winding, pultrusion and continuous laminating, making rods or girder stock. Epoxy resins are tougher than polyesters and have lower shrinkage, but are more expensive. if brought into contact with the skin, epoxies can cause skin irritations.

Technical notes

Most epoxies are formed by the combination of bisphenol-A and epichlorohydrin in the presence of a catalyst. Catalysts include several amines and acid anhydrides, and the temperature at which the epoxy will cure (ranging from room- to high -temperature) is determined by the type of catalyst, which also affects the properties of the final product.

Typical uses

Pure epoxy molding compounds: the encapsulation of electrical coils and electronics components.
Epoxy resins in laminates: pultruded rods, girder stock, special tooling fixtures, mechanical components such as gears, adhesives, often for high-strength bonding of dissimilar materials, patterns and molds for shaping thermoplastics.

Tradenames

Araldite, Epikote, Epolite, Fiberite, Lytex, Stycast

Links

Reference
ProcessUniverse
Producers