Silicone elastomers (SI, Q)

Description

Image

Caption

The silicone elastomer seal and strap of these swimming goggles resist chemical attack by bleaches and other chemicals. © Justus Blümer at Flickr - (CC BY 2.0)

The material

Silicones are high-performance, high cost materials. Silicone and fluoro-silicone elastomers have long chains of linked O-Si-O-Si- groups (replacing the -C-C-C-C- chains in carbon-based elastomers), with methyl (CH3) or fluorine (F) side chains. They have poor strength, but can be used over an exceptional range of temperature (-100 C to + 300 C), have great chemical stability, and an unusual combination of properties (Silly Putty is a silicone elastomer - it bounces when dropped but flows if simple left on the desk).

Composition (summary)

Most common version: (O-Si(CH3)2)n

General properties

Density		81.2	-	112	lb/ft^3
Price	*	4.77	-	5.67	USD/lb
Date first used		1943			

Mechanical properties

Young's modulus		7.25e-4	-	0.0029	10^6 psi
Shear modulus		2.9e-4	-	9.57e-4	10^6 psi
Bulk modulus	*	0.181	-	0.196	10^6 psi
Poisson's ratio		0.47	-	0.49	
Yield strength (elastic limit)		0.348	-	0.798	ksi
Tensile strength		0.348	-	0.798	ksi
Compressive strength		1.45	-	4.35	ksi
Elongation		80	-	300	% strain
Fatigue strength at 10^7 cycles		0.331	-	0.58	ksi
Fracture toughness		0.0273	-	0.455	ksi.in^0.5
Mechanical loss coefficient (tan delta)		0.06	-	0.15	

Thermal properties

Glass temperature		-190	-	-99.7	°F
Maximum service temperature		440	-	548	°F
Minimum service temperature		-99.7	-	-54.7	°F
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.173	-	0.578	BTU.ft/h.ft^2.F
Specific heat capacity		0.251	-	0.31	BTU/lb.°F

Thermal expansion coefficient	139	-	167	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.16e19	-	1e22	µohm.cm
Dielectric constant (relative permittivity)	2.9	-	4	
Dissipation factor (dielectric loss tangent)	0.002	-	0.008	
Dielectric strength (dielectric breakdown)	381	-	635	V/mil

Optical properties

Transparency	Translucent			
Refractive index	1.4	-	1.44	

Processability

Castability	4	-	5	
Moldability	4	-	5	
Machinability	2	-	3	
Weldability	1			

Eco properties

Embodied energy, primary production	*	1.28e4	-	1.42e4	kcal/lb
CO2 footprint, primary production	*	7.55	-	8.34	lb/lb
Recycle	✗				

Supporting information

Design guidelines

Silicone resins are the most expensive thermosetting resin to use in composite materials and they are difficult to process. They feel like natural rubber, but have a completely different structure. Glass fibers and other fillers are commonly used as reinforcement. The resulting parts are relatively low in strength but have high heat resistance. For glass fiber composites, the mechanical properties are better with a phenolic or melamine resin, but the electrical properties are better with silicone. Electrical and high temperature applications dominate their use. They are chemically inert, do not absorb water and can be used in surgical or food processing equipment and seals. Silicones can be produced as fluids, adhesives, coatings, elastomers, molding resins and release agents. But each suffers from a short shelf life (3-6 months). Silicone fluids were the earliest commercial silicones, used as lubricants over a wide range of temperature (-75 C to 450 C). Silicone adhesives can be made as liquids or pastes, they can be non-curing, self-curing or heat-curing. RTV silicone was first developed for its rapid mold filling - a few seconds at high temperatures. Silicone elastomers can be air-curing, cold-curing by the addition of a catalyst or heat-curing; they may be pure or loaded with carbon black to give conductivity. Silicone molding resins are compounded with inert fillers to allow the production of flexible parts with high heat resistance. Silicones are the most chemically stable of all elastomers, with useful properties from -110 C to +310 C, good electrical properties, but relatively low strength (8MPa).

Technical notes

Silicone and fluoro-silicone elastomers have long chains of linked O-Si-O-Si- groups (replacing the -C-C-C-C- chains in carbon-based elastomers), with methyl (CH3) or fluorine (F) side chains. Silicones are based on the repetition of silicon and oxygen in the polymer chain; it can be used as an elastomer or a thermoset.

Typical uses

Wire and cable insulation, mold release agents and flexible molds, lens cleaning tissue coatings, seals, gaskets, adhesives, o-rings, insulation, encapsulation and potting of electronic circuitry, surgical and food processing equipment, baby bottle tips, breast implants.

Links

Reference

ProcessUniverse

Producers