Silicon

Description

Image

Caption

1. Photovoltaic solar panels. © NASA - Public domain 2. Polycristalline silicon wafer in photovoltaic panel. © Georg Slickers at en.wikipedia - (CC BY-SA 2.5) 3. Solar array of the MAVEN spacecraft inspected by a technician. © NASA - Public domain

The material

Silicon is the second most abundant element, exceeded only by oxygen and making up 26% of the earth's crust by weight. It is found largely as silicon oxides such as sand (silica), quartz, rock crystal, amethyst, agate, flint, jasper and opal, and as silicates asbestos, feldspar, clay and mica. It is a reactive element, important as an alloying element in steels, cast irons, and certain copper and aluminum alloys where it gives both corrosion resistance and strength. Silicon is transparent to infrared and is used a windows and lenses for IR lasers. Its most important application, of course, is as a semiconductor, the mainstay of the electronics industry. Silicon is present in the sun and stars and is a principal component of a class of meteorites known as aerolites. Silicon is important in plant and animal life. Diatoms in both fresh and salt water extract silica from the water to use as a component of their cell walls. Silicon is an important ingredient in steel. Silicon carbide is one of the most important abrasives. Workers in environments where silica-containing dust is breathed may develop a serious lung disease known as silicosis. Hydrolysis and condensation of substituted chlorosilanes can be used to produce a very great number of polymeric products, or silicones. These range from liquids to hard, glasslike solids with many useful properties. Elemental silicon transmits more than 95% of all wavelengths of infrared and has been used in lasers to produce coherent light at 456 nm.

Composition (summary)

100% Si

General properties

Density	144	-	147	lb/ft^3
Price	* 4.14	-	6.87	USD/lb
Date first used	1823			

Mechanical properties

Young's modulus	20.3	-	22.5	10^6 psi
Shear modulus	8.99	-	9.43	10^6 psi
Bulk modulus	13.8	-	15.2	10^6 psi
Poisson's ratio	0.21	-	0.22	
Yield strength (elastic limit)	23.2	-	26.1	ksi
Tensile strength	23.2	-	26.1	ksi
Compressive strength	464	-	502	ksi
Elongation	0.1	-	0.15	% strain
Hardness - Vickers	900	-	1.12e3	HV
Fatigue strength at 10^7 cycles	* 18.9	-	21.8	ksi
Fracture toughness	0.755	-	0.855	ksi.in^0.5

Mechanical loss coefficient (tan delta)	*	7e-5	-	1e-4	

Thermal properties

Melting point		2.58e3	-	2.61e3	°F
Maximum service temperature	*	980	-	1.07e3	°F
Minimum service temperature		-458	-	-456	°F
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		80.9	-	86.7	BTU.ft/h.ft^2.F
Specific heat capacity		0.16	-	0.171	BTU/lb.°F
Thermal expansion coefficient		1.11	-	1.78	µstrain/°F

Electrical properties

Electrical conductor or insulator?		Semiconductor			
Electrical resistivity		1e6	-	1e12	µohm.cm
Dielectric constant (relative permittivity)		11	-	12	
Dissipation factor (dielectric loss tangent)	*	0.001	-	0.005	
Dielectric strength (dielectric breakdown)	*	127	-	305	V/mil

Optical properties

Transparency		Opaque			
Refractive index		3.6	-	3.8	

Processability

Castability		1	-	2	
Machinability		1	-	2	

Eco properties

Embodied energy, primary production		6.15e3	-	6.8e3	kcal/lb
CO2 footprint, primary production		3.78	-	4.18	lb/lb
Recycle	✗				

Supporting information

Design guidelines

Silicon has a high strength, a high thermal conductivity and a low thermal expansion coefficient. This recommends it for the mechanical components of small precision instruments. A highly developed technology exists for machining silicon chemically and with particle beams - an outgrowth of the semiconductor industry - that is now being deployed to make MEMS (micro electro-mechanical systems) that perform mechanical and other functions at the micron scale.

Technical notes

To function well as a semiconductor silicon must be prepared in a super-pure, single-crystal form. A sophisticated technology has grown up to provide this: single crystals 200 mm in diameter and 1 meter long can be grown, and techniques for precision cutting and machining have been developed. Its availability opens up possibilities for using silicon for other devices, particularly those exploiting its thermal and mechanical properties as well as its electrical attributes.

Typical uses

Microcircuits; precision instruments; IR lenses and windows; MEMS devices

Links

Reference

ProcessUniverse

Producers