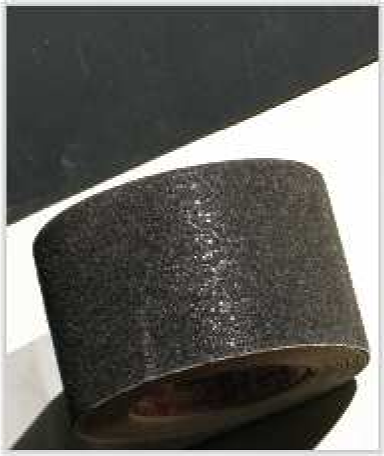
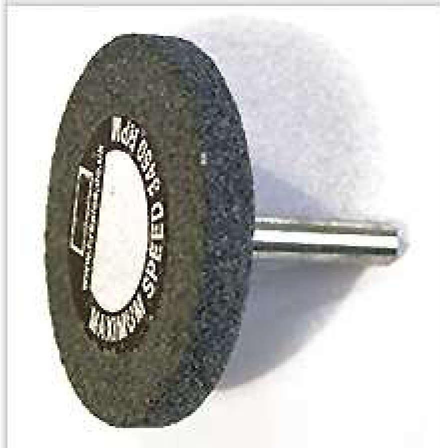
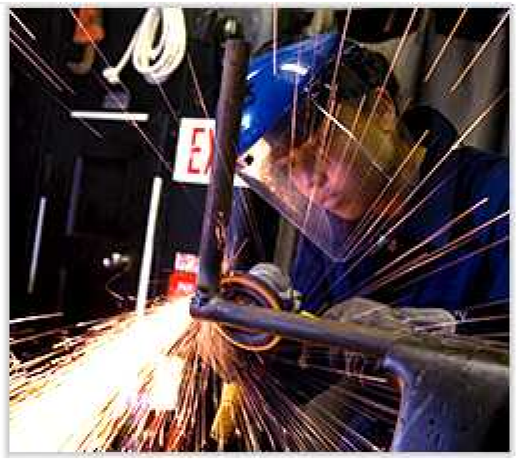
Silicon carbide

Description

Image

Caption

1. Samples of silicon carbide sandpaper. © Tiesse at en.wikipedia - Public domain 2. Silicon carbide grinding wheel. 3. U.S. Navy technician uses a silicon carbide sander. © U.S. Navy - Public domain

The material

Silicon carbide (SiC, carborundum), made by fusing sand and coke at 2200 C, is the grit on high quality sandpaper. It is very hard and maintains its strength to 1400C high temperature, has good thermal shock resistance, excellent abrasion resistance, but, like all ceramics, it is brittle. It has the highest corrosion resistance of all advanced ceramics.

Composition (summary)

SiC

General properties

Density		194	-	200	lb/ft^3
Price	*	6.59	-	9.41	USD/lb
Date first used		1893			

Mechanical properties

Young's modulus		58	-	66.7	10^6 psi
Shear modulus	*	26.1	-	28.6	10^6 psi
Bulk modulus	*	26.8	-	29	10^6 psi
Poisson's ratio		0.16	-	0.18	
Yield strength (elastic limit)		58	-	88.5	ksi
Tensile strength		58	-	88.5	ksi
Compressive strength		145	-	761	ksi
Elongation		0			% strain
Hardness - Vickers		2.3e3	-	2.6e3	HV
Fatigue strength at 10^7 cycles	*	17.4	-	54.8	ksi
Fracture toughness		2.73	-	5.1	ksi.in^0.5

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

Thermal properties

Melting point		3.91e3	-	4.53e3	°F
Maximum service temperature		2.55e3	-	3.09e3	°F
Minimum service temperature		-458	-	-456	°F
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		46.2	-	75.1	BTU.ft/h.ft^2.F
Specific heat capacity		0.158	-	0.191	BTU/lb.°F
Thermal expansion coefficient		2.22	-	2.67	µstrain/°F

Electrical properties

Electrical conductor or insulator?		Poor insulator			
Electrical resistivity		1e9	-	1e12	µohm.cm
Dielectric constant (relative permittivity)		6.3	-	9	
Dissipation factor (dielectric loss tangent)	*	0.001	-	0.005	
Dielectric strength (dielectric breakdown)	*	127	-	254	V/mil

Optical properties

Transparency		Translucent			
Refractive index		2.66	-	2.7	

Critical Materials Risk

High critical material risk?	No

Processability

Moldability	2	-	3
Machinability	1	-	2

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%)	Excellent
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)	Acceptable
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)	Excellent	

Geo-economic data for principal component

Annual world production, principal component	9.94e5 - 1e6	ton/yr

Primary material production: energy, CO2 and water

Embodied energy, primary production	7.61e3 - 8.41e3	kcal/lb
CO2 footprint, primary production	6.24 - 6.9	lb/lb
Water usage	* 4.01 - 12.1	gal(US)/lb
Eco-indicator 99	451	millipoints/kg

Material processing: energy

Grinding energy (per unit wt removed)	* 1.35e4 - 1.5e4	kcal/lb

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	* 9.37 - 10.4	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

Technical ceramics that are used in the pure state, as SiC usually is, are very energy intensive. The ingredients, silicon and carbon, are plentiful, but processing costs make the product expensive.

Supporting information

Design guidelines

Silicon carbide and silicon nitride are two of the emerging breed of high performance technical ceramics. Their extreme corrosion resistance and high hardness makes them a good choice for mechanical components that must withstand corrosive fluids - bearings, including ball bearings, and valve and pump parts in sewage systems, for example. Their other unique feature is their ability to carry significant loads at temperatures as high as 1800 C. The main drawbacks are their low toughness, requiring careful design and flaw-free fabrication, and their high cost, which has slowed their take up. Technical ceramics are formed by the following steps.(a) Pressing, isostatic pressing, powder extrusion (for bars and tubes) or powder injection molding (for intricate, high-volume parts).(b) Green-machining in the unfired state, using standard tools.(c) Firing or "sintering" typically at 1550 - 1700 C for 12 to 20 hours; the part shrinks by about 20%.(d) Diamond grinding to achieve tighter tolerance and surface finish: +/- 10 microns is achievable. The cost of a ceramic part is greatly increased if it has to be diamond-ground. Thus design for net-shape sintering, eliminating step (d) is highly desirable. The standard tolerance for as-fired dimensions is +/- 1% or 125 microns, whichever is greater. Silicon carbide is a blue-black in color; silicon nitride is dark gray or black. Both can be polished to a very smooth, reflective surface, giving parts with a striking appearance.

Technical notes

Silicon carbide starts as a powder, is pressed (with a polymer binder) to the desired shape, then fired at a high temperature, burning off the binder and causing the powder to sinter. It is exceptionally wear and corrosion resistant. Its electrical properties can be adjusted by doping. High strength SiC fibers such as Nicalon, made by CVD processes, are used as reinforcement in ceramic and metal matrix composites.

Typical uses

Mechanical seal faces, bearings, turbocharger bearings, gas turbine rotors, wear and corrosion-resistant parts, high temperature devices, laboratory test equipment, hydraulic plungers, pistons, cylinder liners, guides and feeds, heating elements, body and aircraft armor.

Links

Reference

ProcessUniverse

Producers