Description

Image


Caption

1. Silicon nitride bearing balls ranging from 1 to 20mm. © Lucasbosch at en.wikipedia - (CC BY-SA 3.0) 2. Detail of a ball bearing made of silicon nitride bearing balls. © Solaris2006 at en.wikipedia - (CC BY-SA 3.0)

The material

Silicon nitride, Si_3N_4, is a man made compound, synthesized as a powder through several different chemical reactions. Parts made from these powders are sintered by standard methods to produce a ceramic with a unique set of properties. High performance silicon nitrides were developed for automotive engine wear parts such as valves, cam followers and turbocharger vanes, and have proved effective although the cost has not yet dropped enough to allow widespread use. The very high quality bodies developed for these applications are now used for parts for other high temperature applications in chemically aggressive environments in which wear is a problem.

Composition (summary)

Si3N4

General properties

Density	194	-	212	lb/ft^3
Price	* 16	-	24.5	USD/lb
Date first used	1958			

Mechanical properties

Young's modulus	42.1	-	46.1	10^6 psi
Shear modulus	* 14.5	-	18.6	10^6 psi
Bulk modulus	* 30.5	-	33.6	10^6 psi
Poisson's ratio	0.26	-	0.28	
Yield strength (elastic limit)	* 87	-	104	ksi
Tensile strength	87	-	104	ksi
Compressive strength	76	-	798	ksi
Elongation	0			% strain
Hardness - Vickers	1.4e3	-	1.6e3	HV
Fatigue strength at 10^7 cycles	* 43.5	-	72.5	ksi
Fracture toughness	3.64	-	6.1	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 2e-5	-	5e-5	

Thermal properties

Melting point	4.33e3	-	4.52e3	°F
Maximum service temperature	1.83e3	-	2.19e3	°F
Minimum service temperature	-458	-	-456	°F
Thermal conductor or insulator?	Good conductor			

Thermal conductivity	12.7	-	17.3	BTU.ft/h.ft^2.F
Specific heat capacity	0.16	-	0.191	BTU/lb.°F
Thermal expansion coefficient	1.78	-	2	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e20	-	1e21	µohm.cm
Dielectric constant (relative permittivity)	7.9	-	8.1	
Dissipation factor (dielectric loss tangent)	* 5e-4	-	7e-4	
Dielectric strength (dielectric breakdown)	* 279	-	330	V/mil

Optical properties

Transparency	Translucent		
Refractive index	1.95	-	2

Processability

Moldability	2	-	3
Weldability	1	-	2

Eco properties

Embodied energy, primary production	1.26e4	-	1.39e4	kcal/lb
CO_2 footprint, primary production	4.63	-	5.12	lb/lb
Recycle	✗			

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 and to survive thermal shock well. The main drawbacks are their low toughness, requiring careful design and flaw-free fabrication, and their high cost, which has slowed their take up. Silicon nitride is dark gray or black in color. It can be polished to a very smooth, reflective surface, giving parts with a striking appearance. 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.

Technical notes

Silicon nitride can be synthesized by powder methods, and by CVD (Chemical vapor deposition), giving a degree of design flexibility. Its key features, shared with silicon carbide, are very high hardness outstanding wear resistance, outstanding corrosion resistance, a tolerance of thermal shock, and the ability to carry loads at temperature as high as 1700 C.

Typical uses

Rotating bearing balls and rollers; cutting tools; engine parts - valves, turbocharger rotors; cam followers, tappet shims; gas turbine blades, vanes, buckets; metal forming rolls and dies; precision shafts and axles in high wear environments; heaters and igniters; molten metal processing, particularly in the aluminum foundry industry.

Links

Reference

ProcessUniverse

Producers