HEXOLOY® SILICON CARBIDE

Ceramic Materials For High Performance Applications

SAINT-GOBAIN

CERAMICS

Worldwide Leaders in Ceramic Technology

No other company in the world has more expertise with silicon carbide than Saint-Gobain Ceramics. We make more of this remarkable material for high-performance components than anyone else in the world.

It began in 1891 when a young scientist, Dr. Edward Goodrich Acheson, attempted to make artificial diamonds. Instead he invented silicon carbide (SiC), the first man-made abrasive hard enough to cut glass. Acheson trade-marked his discovery under the name Carborundum, the name also given to the company he founded. The Carborundum Company developed many variations of silicon carbide over the years, including the extemely strong and versatile material known as Hexoloy® sintered silicon carbide. In 1996, The Carborundum Company's advanced ceramic business was acquired by Saint-Gobain along with its century-long heritage of leading ceramic technology.

Today Saint-Gobain has earned a reputation for providing advanced, high-tech ceramic components to worldwide markets. These markets span multiple industries, requiring materials that are resistant to extreme temperature, thermal shock, high impact, abrasion and corrosion.

The Hexoloy® Difference

Design engineers have discovered that traditional views of ceramics don't apply to Hexoloy® silicon carbide products. Hexoloy products open new application and design possibilities that are impractical with ductile metals and lesser ceramic materials.

Hexoloy sintered alpha silicon carbide is produced by the pressureless sintering of ultra-pure submicron powder derived from the original Acheson process. This powder is mixed with non-oxide sintering aids, then formed into complex shapes by a variety of methods and consolidated by sintering at temperatures above 2000°C (3632°F).

The sintering process results in a single-phase, fine-grain silicon carbide product that's very pure and uniform, with virtually no porosity. Whether submerged in corrosive environments, subjected to extreme wear and abrasive conditions, or exposed to temperatures of 1650°C (3000°F), Hexoloy sintered alpha silicon carbide will outperform other commercially available ceramics or metal alloys, including superalloys.

Hexoloy silicon carbide is ideal for applications such as automotive water pumps, chemical and slurry pump seals and bearings, nozzles, pump and valve trim, paper and textile equipment components, ballistic armor and more. Its unique properties can make a significant difference in a wide variety of high performance applications.

It's hard.

Hexoloy silicon carbide is one of the hardest high performance materials available.

Hardness (Knoop): 2800 kg/mm2 at room temperature.

It's strong.

Hexoloy silicon carbide parts exhibit extremely high strength and excellent resistance to creep and stress rupture at temperatures up to 1650°C (3000°F).

Flexural strength: (4 pt.): 55,000 psi (380 MPa).

Fracture toughness: 4.20 x 103 lb/in2/√m

Modulus of elasticity (RT): 59 x 106 lb/in2 (410 GPa).

It's light.

Hexoloy silicon carbide weighs less than half as much as most metal alloys, 40 percent as much as steel and about the same as aluminum.

It's dense.

Densities of fired parts are consistently in excess of 98 percent of the theoretical density of Hexoloy silicon carbide - 3.21 g/cm3.

Density: 3.10 g/cm3 minimum.

It's wear resistant.

The extreme hardness and small grain size of Hexoloy silicon carbide make it ideal for applications where parts are subject to high abrasion and sliding wear.

Specified wear rate (pin on disc): SiC vs. SiC 1 x 10-9 mm2/kg.

Coefficient of friction (pin on disc): SiC vs. SiC 0.2.

It's energy-efficient.

Hexoloy silicon carbide's maximum service temperature of 1650°C allows processes to run hotter and cleaner resulting in energy savings and lower maintenance and downtime costs.

It resists corrosion, oxidation and erosion.

The high density, low porosity and chemical inertness of Hexoloy silicon carbide permit it to function in environments of hot gases and liquids, in oxidizing and corrosive atmospheres, and in strong acids and bases, even at extremely high temperatures.

It resists heat.

The high thermal conductivity of Hexoloy silicon carbide, combined with its low thermal expansion, produces excellent thermal shock resistance far better than tungsten carbide, aluminum oxide and RB silicon nitride. These properties make it a promising candidate for replacing ductile metals in high temperature applications.

It can be formed into complex shapes.

New research allows Saint-Gobain to mass produce complex shapes by extrusion, dry pressing and isostatic pressing at room temperature. Additional features can be achieved through green machining of these components prior to furnacing.

It requires minimum machining.

The as-fired surface finish of Hexoloy silicon carbide parts is excellent. This surface quality, combined with tight dimensional control, yields parts that may require little or no additional machining or finish grinding, depending on application.

Fluid Handling

Mechanical seal faces and high performance bearings made of Hexoloy silicon carbide are ideal for a wide variety of demanding fluid handling applications such as automotive water pumps, chemical processing, refining, mining, pulp and paper processing, mixers and refrigeration. They offer universal corrosion resistance, low coefficient of friction, excellent wear resistance, high strength, and high thermal conductivity.

Engineered Products For Worldwide Markets

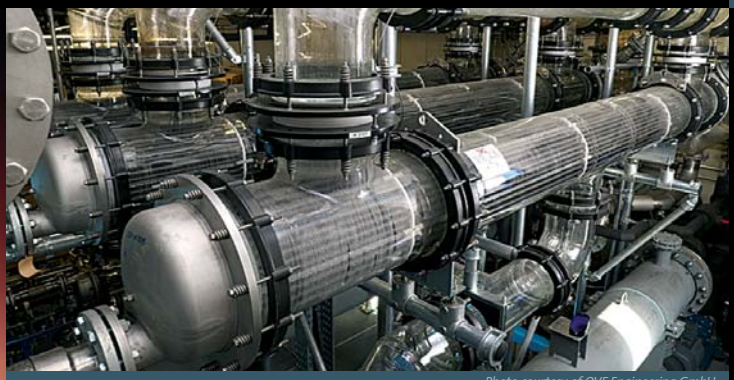


Photo courtesy of QVF Engineering GmbH.

Chemical Processing

Hexoloy silicon carbide has long been the material of choice for mechanical seals and high performance bearings used in a variety of chemical processing industries. It is also ideal for sparger tubes, nozzles, vessel linings and other demanding applications in the chemical, petrochemical, petroleum refining, pharmaceutical and pulp and paper industries. Hexoloy components are custom made to meet specific application requirements. They offer universal corrosion resistance, low coefficient of friction, excellent wear resistance, high strength, and high thermal conductivity.

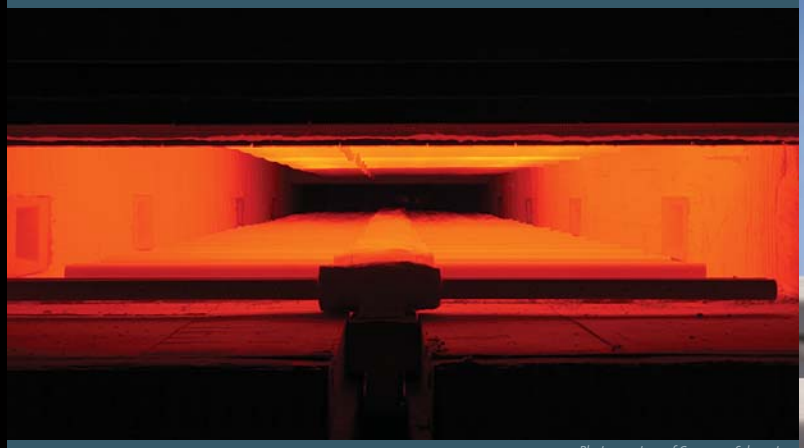
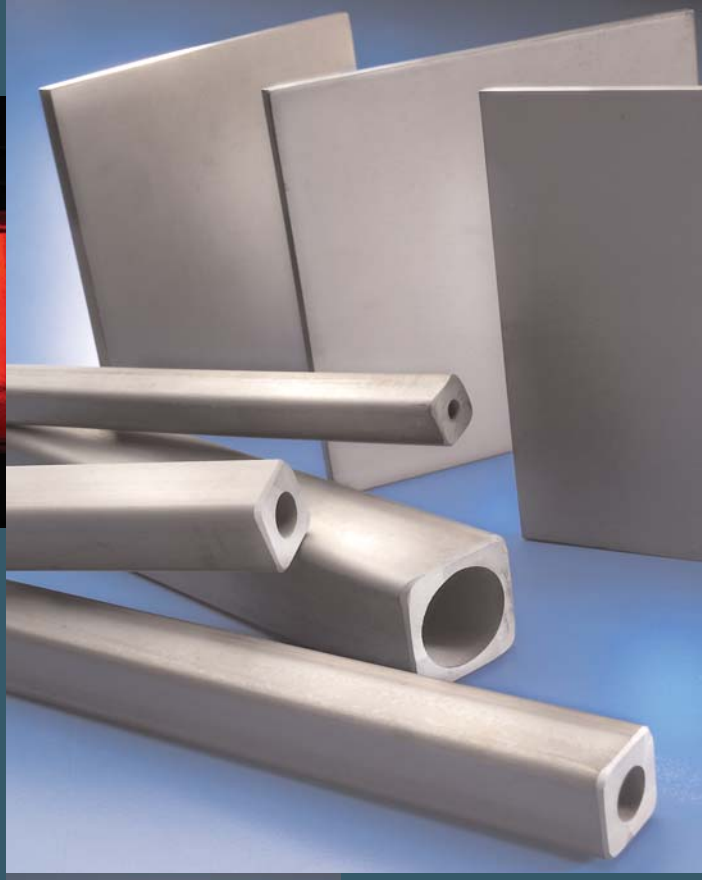


Photo courtesy of Company Schwartz.

Thermal

For the toughest high temperature applications, Hexoloy silicon carbide will outperform most metal, refractory and other ceramic materials. The material's low coefficient of thermal expansion and high thermal conductivity give it excellent thermal shock resistance, allowing it to survive rapid thermal cycling. At elevated temperatures, Hexoloy silicon carbide actually increases in strength where other ceramics and metals quickly drop off. Thermal components are available custom made to meet customer requirements. These include burner nozzles, thermocouple protection tubes, immersion heater tubes, recuperation tubes, oxygen sensors, test fixtures and furnace belt links. Hexoloy silicon carbide is also ideal for kiln system components such as beams, tiles, batts, posts and rollers.

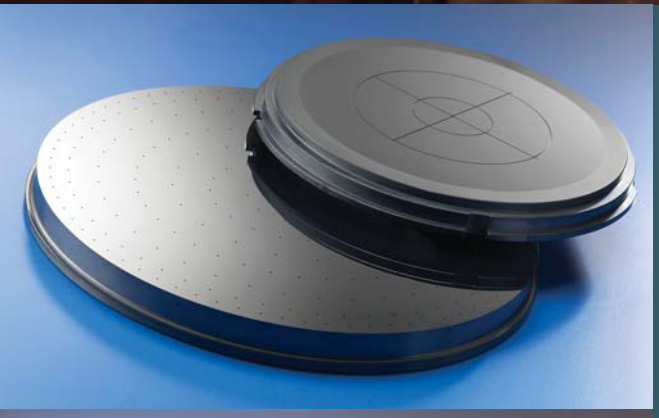


Armor

Saint-Gobain Ceramics offers a broad range of ceramic materials for composite armor protection systems including Hexoloy silicon carbide, Norbide® boron carbide, reaction bonded silicon carbide, alumina, sapphire and others. The various properties of these materials, such as high hardness, compressive strength and elastic modulus provide superior ballistic capability to defeat high-velocity projectiles for transport aircraft, helicopters, land vehicles, AC-130U gunships and body armor. Materials can be supplied as finished components, unfinished, machined blanks, pressed near net shape blanks, high volume pressed net shape components, and complex, highly machined parts.

Automotive

Hexoloy silicon carbide seal faces for water pump and other transportation applications are proven superior in meeting the requirements of vehicles around the world. Saint-Gobain Ceramics currently supplies over 50 million seal faces for use by global automakers, replacing seal faces made of materials such as aluminum oxide, carbon graphite and bronze. Many leading automakers and truck engine manufacturers have converted 100% of their production to seal assemblies using sintered silicon carbide as one or both of the seal faces. Benefits include extreme hardness and high strength, high abrasion and wear resistance, excellent corrosion resistance and superior thermal shock resistance.



Specialty Markets

Semiconductor

Applications for Hexoloy in high technology industries include components for semiconductor wafer processing such as vacuum chucks, chemical mechanical polishing (CMP) blocks and susceptors. These applications take advantage of Hexoloy silicon carbide's thermal expansion match to silicon, high elastic modulus, chemical inertness, and high thermal conductivity. Hexoloy silicon carbide is well suited as a structural material for low mass wafer carrier components, and rigid, dimensionally stable platforms with exceptional flatness for wafer lapping and polishing.

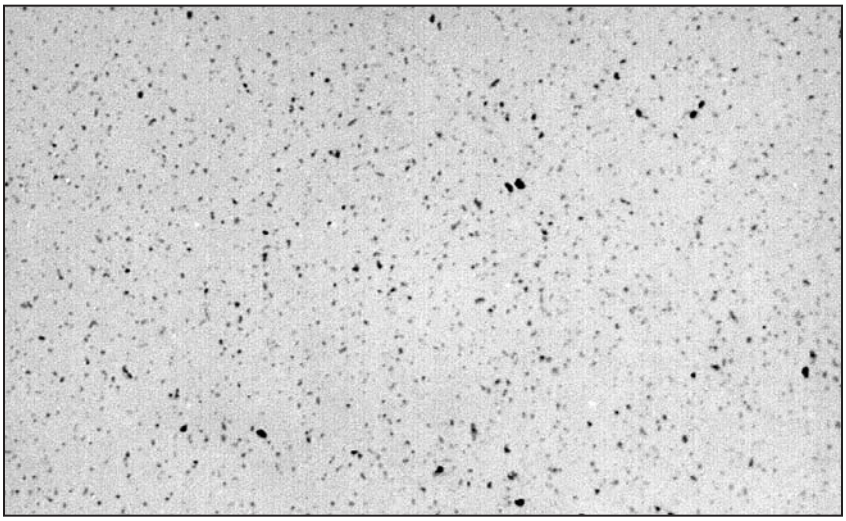
Mining

Hexoloy SA silicon carbide, a fully dense, monolithic ceramic with high thermal conductivity and excellent corrosion and erosion resistance offers distinct advantages for mining applications. Hexoloy SA valve trim has set performance standards for use in nickel and gold ore processing and has provided reliable performance in extreme temperature, pressure and corrosive environments.

Saint-Gobain Structural Ceramic Materials

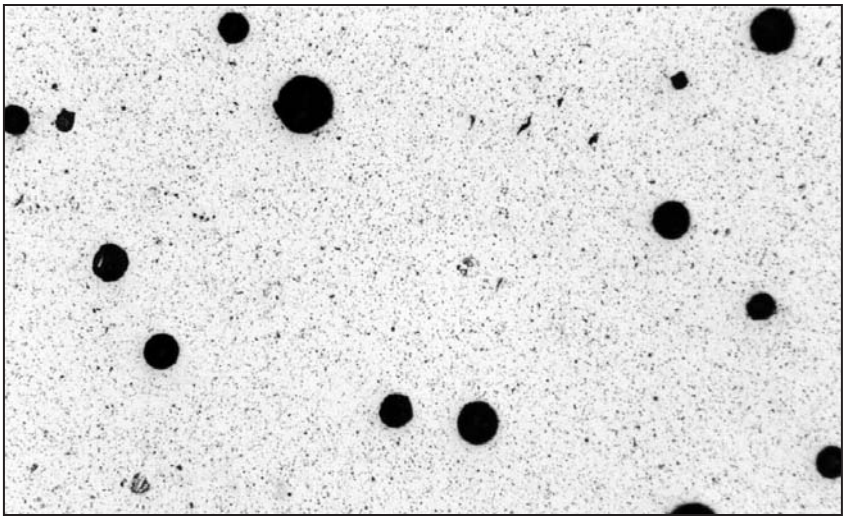
Hexoloy® SA

Hexoloy® SA SiC is a pressureless, sintered form of alpha silicon carbide, with a density greater than 98 percent theoretical. It has a very fine grain structure (4 - 10 microns) for excellent wear resistance and contains no free silicon, which makes it highly chemically resistant in both oxidizing and reducing environments.



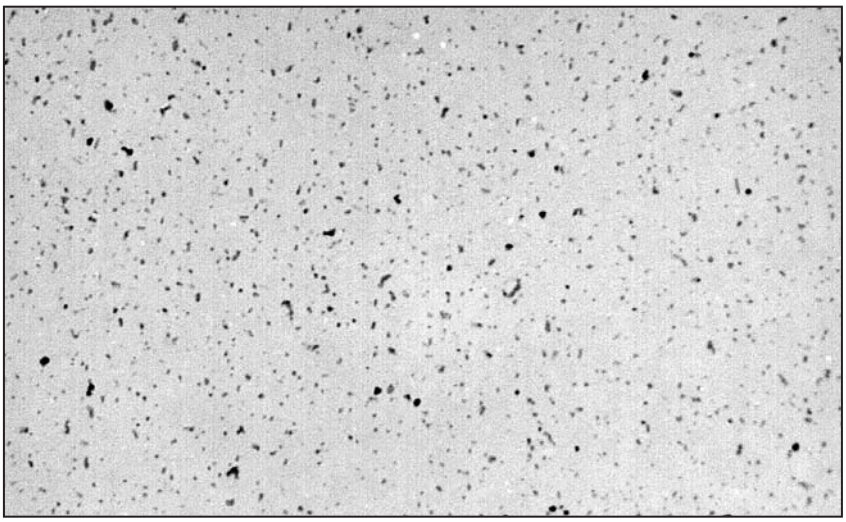
Hexoloy® SP

Hexoloy® SP SiC is a sintered alpha silicon carbide material designed specifically for optimum performance in sliding contact applications such as pump seal faces and product lubricated bearings. This material improves upon the exceptional friction properties of Hexoloy SA SiC (sintered alpha SiC) through the addition of size-controlled spherical pores.

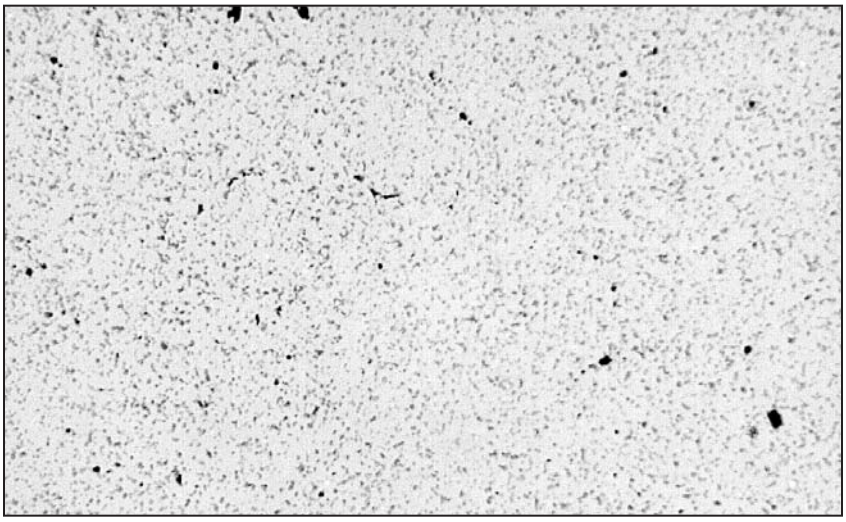


Hexoloy® SE

Hexoloy® SE SiC offers an excellent alternative material to metals, superalloys and other ceramics for applications such as chemical processing, high temperature furnaces, and other demanding, severe environment applications. Hexoloy SE SiC provides exceptional properties including extreme hardness; high strength; virtually universal corrosion resistance; high temperature stability; high thermal conductivity.

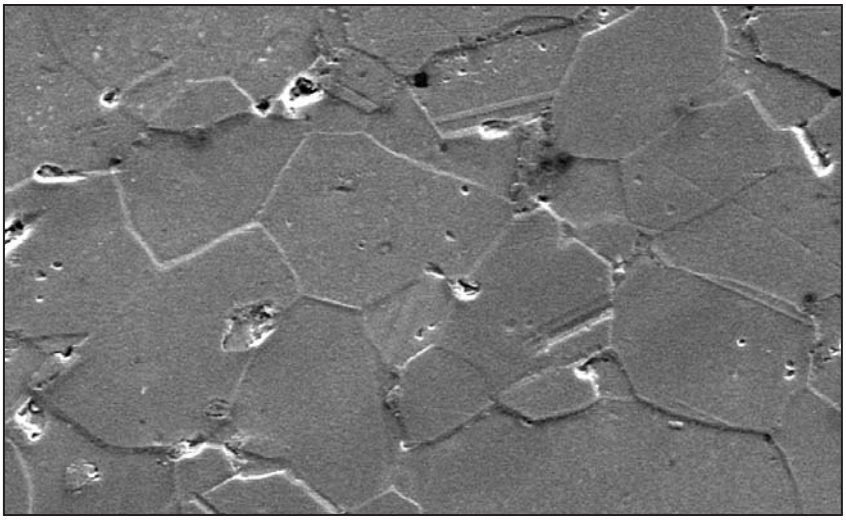


www.hexoloy.com



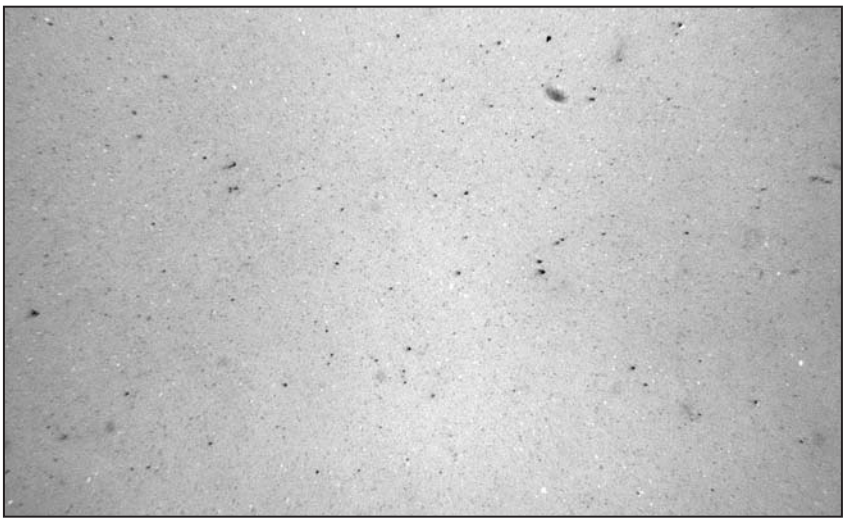
Hexoloy® SG

Hexoloy® SG SiC is a unique, patented analogue of Hexoloy SA SiC. It is a sintered silicon carbide and has no free silicon metal. It is electrically conductive, permitting DC-magnetron sputtering rates approximately half that of aluminum. It also has excellent thermal conductivity.



Norbide® Hot Pressed Boron Carbide

Norbide® Hot Pressed Boron Carbide (B4C) is one of the hardest materials known and offers excellent chemical and wear resistance for demanding applications such as blast nozzles, monument nozzles and lightweight armor components. Components made with Norbide B4C offer longer service life which can translate into lower costs, reduced maintenance and less downtime for many applications.



Noralide® NBD-200 Hot Pressed Silicon Nitride

Noralide® NBD-200 Hot Pressed Silicon Nitride (Si3N4) offers a combination of characteristics that make it an ideal material for seal face components in nuclear applications, as well as other applications where maximum fracture toughness and flexural strength are required. Hot-pressed for maximum strength and density, Noralide Si3N4 provides better fracture resistance than other ceramic materials.

Saint-Gobain Structural Ceramic Materials: Typical Physical Properties

Physical		Units	Hexoloy SA	Hexoloy SP	Hexoloy SE	Enhanced Hexoloy SA
Composition*			SSiC	SSIC	SSiC	SSiC
Grain Size		µm	4-10	4-10	4-10	4-10
Density		g/cm^3	3.1	3.04	3.07	3.1
Hardness (Knoop 0.1 kg load)		kg/mm^2	2800	2800	2800	2800
Hardness (Vickers 10 kg load)		GPa	–	–	–	–
Flexural Strength 4 pt @ RT**		MPa $x\ 10^3$ lb/in^2	380 55	240 35	380 55	428 62
Compressive Strength @ RT		MPa $x\ 10^3$ lb/in^2	3900 560	– –	– –	3900 560
Modulus of Elasticity @RT		GPa $x\ 10^6$ lb/in^2	410 59	400 58	350 N/A	410 59
Weibull Modulus (2 parameters)		–	8	19	8	12
Poisson Ratio		N/A	0.14	0.14	0.14	0.14
Fracture Toughness @ RT Double Torsion & SENB		MPa x m$^{1/2}$ $x\ 10^3$ lb /in^2/in$^{1/2}$	4.60 4.20	4.3 3.9	4.60 4.20	4.60 4.20
Fracture Toughness @RT Indentation		MPa x m$^{1/2}$	–	–	–	–
Coefficient of Thermal Expansion RT to 700°C		$x\ 10^{-6}$ mm/mmK $x\ 10^{-6}$ in/in°F	4.02 2.20	4.2 2.3	4.02 2.20	4.02 2.20
Max. Service Temp (air)		°C °F	1900 3450	1900 3450	1900 3450	1900 3450
Mean Specific Heat @ RT		J/gmK	0.67	0.59	0.67	0.67
Thermal Conductivity	@RT	W/m°K Btu/ft h˚F	125.6 72.6	110 64	125.6 72.6	125.6 72.6
	@100°C	W/m°K Btu/ft h˚F	– –	– –	– –	– –
	@200°C	W/m°K Btu/ft h˚F	102.6 59.3	– –	102.6 59.3	102.6 59.3
	@400˚C	W/m°K Btu/ft h˚F	77.5 44.8	– –	77.5 44.8	77.5 44.8
Permeability @RT to 1000 °C			Impervious to gases over 31 MPa			
Apparent Porosity		%	–	–	0.6	–
Electrical Resistivity	@RT**** @1000˚C	ohm-cm ohm-cm	10^2-10^8 0.01-0.2	N/A N/A	10^2-10^8 0.01-0.2	10^2-10^8 0.01-0.2
Emissivity		–	0.9	0.9	0.9	0.9
Dielectric Constant (RT, 1 MHz)		–	–	–	–	–
Loss Tangent (RT, 1 MHz)		–	–	–	–	–
Pore Volume Fraction		%	–	4.0-6.0	–	–
Pore Size (Typical)		µm	–	50	–	–

* Composition code: SSiC = Sintered Silicon Carbide; AlN = Aluminum Nitride; B_4C = Boron Carbide; Si_3N_4 = Silicon Nitride
** Test Bar Size: 3 x 4 x 45 mm (0.118" x 0.157" x 1.772")
*** RT to 1000°C
**** Dependent upon dopants in Hexoloy SA SiC which will decrease electrical resistivity
N/A = Not Applicable or Not Available

Saint-Gobain Structural Ceramic Materials: Typical Physical Properties

Physical		Units	Hexoloy SG	AlNimax™ HP	Norbide Hot Pressed	Noralide NBD-200
Composition*			SSiC	>99.9 AlN	B_4C	Si_3N_4
Grain Size		µm	4-10	3	8	<2
Density		g/cm^3	3.0	3.26	2.50	3.18
Hardness (Knoop 0.1 kg load)		kg/mm^2	2800	N/A	2800	N/A
Hardness (Vickers 10 kg load)		GPa	–	–	–	16
Flexural Strength 4 pt @ RT**		MPa $x\ 10^3$ lb/in^2	311 N/A	340 N/A	425 N/A	806 N/A
Compressive Strength @ RT		MPa $x\ 10^3$ lb/in^2	– –	– –	2900 420	3500 –
Modulus of Elasticity @RT		GPa $x\ 10^6$ lb/in^2	N/A N/A	N/A N/A	440 N/A	320 N/A
Weibull Modulus (2 parameters)		–	18	N/A	N/A	N/A
Poisson Ratio		N/A	0.17	N/A	0.18	N/A
Fracture Toughness @ RT Double Torsion & SENB		MPa x m$^{1/2}$ $x\ 10^3$ lb /in^2/in$^{1/2}$	3.9 N/A	2.6 N/A	3.1 N/A	N/A N/A
Fracture Toughness @RT Indentation		MPa x m$^{1/2}$	–	–	–	4.1
Coefficient of Thermal Expansion RT to 700°C		$x\ 10^{-6}$ mm/mmK $x\ 10^{-6}$ in/in°F	4.6 N/A	5 N/A	5 N/A	2.9*** N/A
Max. Service Temp (air)		°C °F	1900 3450	N/A N/A	600 1112	N/A N/A
Mean Specific Heat @ RT		J/gmK	0.65	N/A	N/A	N/A
Thermal Conductivity	@RT	W/m°K Btu/ft h˚F	118 –	80 N/A	90 N/A	N/A N/A
	@100°C	W/m°K Btu/ft h˚F	– –	– –	– –	29 –
	@200°C	W/m°K Btu/ft h˚F	92 –	– –	– –	– –
	@400˚C	W/m°K Btu/ft h˚F	70 –	– –	– –	– –
Permeability @RT to 1000 °C			Not impervious	Impervious to gases over 31 MPa		
Apparent Porosity		%	–	–	–	–
Electrical Resistivity	@RT**** @1000˚C	ohm-cm ohm-cm	1.0 N/A	$>10^{13}$ N/A	0.3 N/A	$>10^{12}$ N/A
Emissivity		–	0.9	0.9	N/A	N/A
Dielectric Constant (RT, 1 MHz)		–	–	9	–	–
Loss Tangent (RT, 1 MHz)		–	–	$<10^{-3}$	–	–
Pore Volume Fraction		%	–	–	–	–
Pore Size (Typical)		µm	–	–	–	–

* Composition code: SSiC = Sintered Silicon Carbide; AlN = Aluminum Nitride; B_4C = Boron Carbide; Si_3N_4 = Silicon Nitride
** Test Bar Size: 3 x 4 x 45 mm (0.118" x 0.157" x 1.772")
*** RT to 1000°C
**** Dependent upon dopants in Hexoloy SA SiC which will decrease electrical resistivity
N/A = Not Applicable or Not Available

Forming

Economical forming is determined by volume and tolerances of the final part. Dry pressing to size is the most economical forming method for volumes of 300 pieces or more. This method helps to justify the initial expense of tooling designed specifically for each part. Isostatic pressing is suited to low volumes and prototype items.

Extrusion

Extrusion is used for high-volume, constant cross-section long-length tubing and rod where a constant cross section over long length is desired. Saint-Gobain Ceramic's extruded products offer our customers a part with optimized balance of length combined with minimal weight and wall thickness. Our capability ranges from 1/2" OD (12mm) up to a cross section of 2" x 2" (50.8mm x 50.8mm) in lengths of up to 15 ft (4.5M) and 10 ft (3.0M) respectively.

Pre-Sinter (Green) Machining

Machining in the pre-sintered or green state is often desirable because it allows manufacturing of finished shapes without expensive grinding of sintered material. Green machining is accomplished using conventional CNC lathes and mills. Stock removal can be accomplished 15 times faster in the green state than in the sintered state. Green machining provides parts to tolerances of 0.5 percent to 1.0 percent of their final dimensions. Typical green machined surface finishes range from 32 to 64 micro inches.

Fabrication Processes

Grinding/Finishing

Final grinding is done with diamond wheels and costs increase substantially as blueprint tolerances tighten. Part geometry and concentricity/parallelism also affect costs. For example, improving outside diameter tolerances from +.020 inch to +.010 inch can increase the price by 2X. Improvement from +.020 inch to +.002 inch can increase the price by 4X. Saint-Gobain has the capability of grinding to close tolerances on most shapes (.0005 inch). Typical ground parts exhibit finishes of 16 micro inches or better. When surface finishes are critical for improved friction and wear performance, finishing operations such as lapping and honing can improve surfaces up to 4 micro inches. Lapping and polishing can provide surface flatnesses to one helium light band.

Quality Assurance

Our company mission is to maintain the highest level of quality for our customers. Saint-Gobain has state-of-the-art nondestructive evaluation equipment for final quality inspections of internal structures. These include bulk and surface wave ultrasonics, fluorescent dye penetrant, radiography, acoustic emission and photomicrography.

Customer Service & Support

You can count on Saint-Gobain Ceramic's expertise to help you specify the correct structural ceramic materials to meet exacting component design criteria. Our applications engineering support team has the experience and talent to provide solutions for product design problems. Our proven manufacturing capabilities ensure world class supply and quality assurance and our structural ceramic specialists provide cost effective part procurement. Our dedicated customer service personnel provide the responsiveness and follow-up necessary to meet your requirements. Saint-Gobain Ceramic's ISO 9001 2000 certification means a higher level of quality service and support to match all of your company's needs.

Our parent company, Saint-Gobain Corporation, is one of the largest engineered materials suppliers in the world with more than 1000 companies and more than 230,000 employees in 45 countries. Saint-Gobain is a world leader in its three main sales sectors: housing products, glass and high performance materials. Our global team focus is to create shareholder value, provide exceptional product availability and offer product performance that serves applications needs and supports customers.

For more information, contact one of the offices in our worldwide network or visit www.saint-gobain.com.

Your Worldwide Source For High Performance Ceramic Materials

Saint-Gobain Ceramics offers vast resources to meet your needs for structural ceramic/silicon carbide products. With global representation and manufacturing locations in North America, Europe and Asia we can deliver your solution when you need it, where you need it, in virtually every corner of the world.

North America (USA)

Our Hexoloy silicon carbide premix facility, manufacturing plant and R & D facilities are located in Niagara Falls, NY, USA. Our team of experienced and talented sales and applications engineers provide customer engineered products to help solve your product design problems. You can count on the proven expertise from this team to help you specify the correct structural ceramic materials to meet your exacting component criteria.

Europe (Germany)

Located in Moenchengladbach, Germany, our high volume Hexoloy silicon carbide manufacturing plant is dedicated to the manufacture of water pump seal faces for the automotive industry. Our experienced manufacturing team produces a high volume of water pump seal faces in both Hexoloy SA & SP SiC for worldwide consumption.

Asia (China & Japan)

Saint-Gobain sales offices in Shanghai, China and Seto, Japan offer global representation for all custom engineered Hexoloy SiC components produced through the Hexoloy silicon carbide manufacturing plant in Niagara Falls, NY, USA. Our dedicated sales team will help assist you by offering solutions to all of your design needs.

Contact information for our worldwide locations can be found on the opposite page.

SAINT-GOBAIN
CERAMICS

North America

Saint-Gobain Ceramics
Structural Ceramics
Hexoloy® Products
23 Acheson Drive
Niagara Falls, NY 14303
Telephone: 716-278-6233
Fax: 716-278-2373
E-mail: scd.sales@saint-gobain.com
www.hexoloy.com

Europe

Saint-Gobain Advanced Ceramics
Moenchengladbach GmbH
Postfach 401254
Nobelstrasse 6
41189 Moenchengladbach, Germany
Telephone: 0049 2166 5509-0
Fax: 0049 2166 5509-10

Asia

Saint-Gobain Advanced Ceramics
(Shanghai) Co., Ltd.
Bldg. 7, No. 88 Lane 2888, Hua Ning Rd.
Xin Zhuang Industrial Zone
Shanghai 201108, P.R. China
Tel: +86 21 6489 9993
Fax: +86 21 6442 2667
e-mail: hexoloy.china@saint-gobain.com
www.hexoloy.com.cn

Saint-Gobain KK (Seto Site)
26 Shimo-Jinya-Cho
Seto, Aichi, Japan 489-0051
Tel: +81-561-97-0808
Fax: +81-561-82-2384

Form No. A-12049
02/09

Cover valve photo courtesy of Caldera Engineering.


SAINT-GOBAIN
CERAMICS