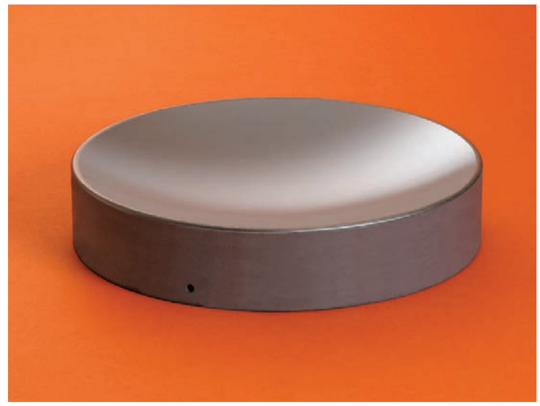
OPTICS MATERIALS AND APPLICATIONS

Flats, spheres and aspheres

Overview

Entegris' SUPERSiC® silicon carbide is the material of choice for performance benefits beyond what beryllium, aluminum, glass and other types of silicon carbide can offer. SUPERSiC attributes include high stiffness and strength, excellent thermal properties and stability in cryogenic environments, without the health concerns of beryllium. These superior characteristics make the SUPERSiC material an ideal selection for industrial, space-based, and airborne/ground electro-optical applications.

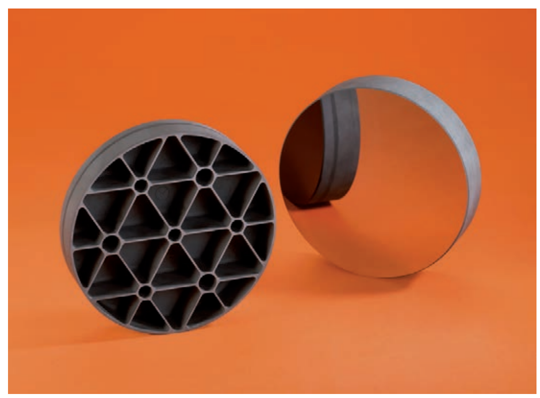
Reflective optics manufactured from Entegris' silicon carbide material are uniquely suited to offer high optical quality mirrors for demanding applications. Substrates made from SUPERSiC are the preform foundation onto which chemical vapor deposited silicon carbide, or optical-grade silicon coatings are applied. Application of either coating provides a ready-made substrate for subsequent polishing and reflectance coat finishing.



Silicon cladded spherical mirror

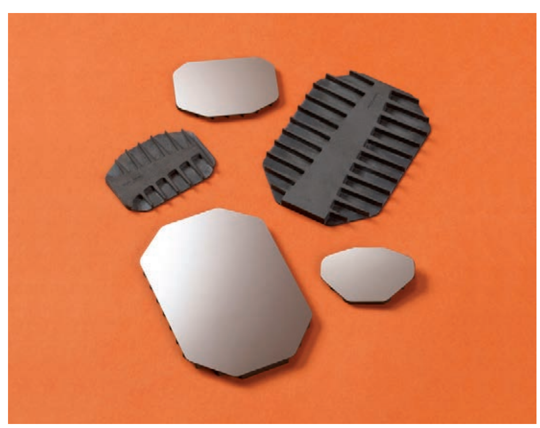
Shapes

Entegris' unique Chemical Vapor Conversion (CVC) process provides innovators the ability to design complex shapes and contours that would be expensive and difficult to manufacture by other methods. Conventional lathe and mill machining equipment and tools are used to produce a graphite preform to near-net shape. Entegris' process allows the freedom to create complex shapes with no more difficulty than would be experienced using aluminum. The CVC process completes the transformation from graphite to 100% silicon carbide.



Lightweight flat silicon carbide mirrors

Flats, spheres, aspheres or off-axis aspheric contours are easily manufactured with the SUPERSiC silicon carbide process. Shape-making ability is further complemented through conversion bonding or Reaction-Bonded Silicon Carbide (RBSC) technologies. Structural and optical designs may incorporate closed-cell and back plate features for added stiffness and weight reduction, while maintaining the structural integrity of a monolith.



Galvo silicon carbide scanning mirrors

Coatings

Polishing

SUPERSiC silicon carbide contains about 18% residual porosity, providing a substrate core that is inherently lightweight. Applying an encapsulating or selectively placed coating completes the substrate's preparation. Entegris offers three coatings as a polishing surface: Chemical Vapor Deposition (CVD) SiC, non-crystalline silicon and crystalline silicon. These coatings may be conventionally polished or, in the case of silicon, single-point diamond turned. All three options offer distinct advantages in performance, cost and lead time.

Applications

Scan Mirrors

Precise dynamic response from an optic within a scanning system is paramount to its successful operation. Entegris scan mirrors made from SUPERSiC grade materials are lightweight but exceptionally stiff to provide the characteristics desired under rapid motion conditions. Designs may utilize open or closed-back structures for improved rigidity and stability. Laser-based applications where energy dissipation is a concern also benefit from SUPERSiC's excellent thermal properties.

Lithography

Precision dynamic response is not limited to optic alone. Lithography applications benefit from the mechanical performance of SUPERSiC as well. SUPERSiC silicon carbide provides considerable mechanical stiffness through a wide range of temperatures. Applying a CVD SiC coating on SUPERSiC components ensures protection against particulate contamination, effectively sealing the parts and making them lightweight, stiff and clean – all factors highly desired for lithography processing.

Telescope – Structures and Mirrors

Assembling a telescope with metering structures and optics made of the same material is the "Holy Grail" of material configurations. Using SUPERSiC materials for both structures and mirrors is a major advance towards optimal performance by eliminating errors induced from mismatched properties. Space-based applications, in particular, benefit considerably from low coefficient of thermal expansion and high stiffness of SUPERSiC materials. The suite of options available – increased elastic modulus from SUPERSiC-Si grade, CVD SiC coatings, Si claddings, reflectance coatings and others – provide multiple selections for any design project.

SUPERSiC Materials

Entegris' unique conversion process produces the highest quality silicon carbide products available on the market today. This process starts with graphite material specially designed and manufactured for use as the precursor in the conversion process.

Near-net shaped parts are machined in graphite, purified, and subjected to a proprietary conversion process which substitutes pure silicon atoms for carbon atoms. During conversion, Entegris has the ability to fuse parts so that they enter the furnace as an assembly of individual pieces and exit as a monolithic unit, with properties indistinguishable from those of a part originally made from one piece. This is done without the use of adhesives or other bonding agents. This conversion bonding process enables the creation of extremely complex, lightweight structures for aerospace optics such as spaceflight worthy, closed-back, off-axis or aspherical mirrors for satellite systems. These material and process advantages have placed Entegris at the forefront of silicon carbide component development.

SUPERSiC

SUPERSiC is the base SiC of Entegris, converted graphite.

SUPERSiC-3C

SUPERSiC-3C is SUPERSiC that has been coated with a 75 µm CVD SiC coating, which encapsulates the substrate and seals the surface. This material is ideal for low-cost optics and structures.

SUPERSiC-Si

SUPERSiC-Si is SUPERSiC that has been infiltrated with high-purity silicon. SUPERSiC-Si has improved mechanical properties over SUPERSiC. This material is ideal for CVD SiC coating or silicon cladding.

SUPERSiC-Si-3C

SUPERSiC-Si-3C is SUPERSiC that has been infiltrated with silicon and then coated with a 75 µm CVD SiC coating, sealing the porosity. This material is ideal for space-based optics and structures.

SUPERSiC-Si-8C

SUPERSiC-Si-8C is SUPERSiC that has been infiltrated with silicon and then coated with a 200 µm CVD SiC coating. This material is ideal for large optics and lithography components.

SUPERSiC-Si-4S

SUPERSiC-Si-4S is SUPERSiC that has been infiltrated with silicon and then selectively cladded with a 100 µm silicon cladding. This material is ideal for Single-Point Diamond Turning (SPDT), for reduced lead time and total cost.

SUPERSiC-SP

SUPERSiC-SP is the newest grade in Entegris' family of silicon carbide materials. The product improves on the mechanical properties of SUPERSiC-Si by changing the densification material from silicon to silicon carbide.* The result is a material that is stronger in flex and tensile load. Further, the monolithic material ensures an even more uniform response to thermal loading.

**Some trace amounts of free silicon will remain.*

Typical Material Properties

PROPERTY	SUPERSiC	SUPERSiC -3C (-3CX)	SUPERSiC -Si (-4S)	SUPERSiC-Si -3C (-8C)	SUPERSiC-SP
Apparent density:	3.13 g/cm^3 (0.113 lb/in^3)	3.15 g/cm^3 (0.114 lb/in^3)	3.01 g/cm^3 (0.109 lb/in^3)	3.03 g/cm^3 (0.110 lb/in^3)	3.04 g/cm^3 (0.110 lb/in^3)
Bulk density:	2.53 g/cm^3 (0.092 lb/in^3)	2.55 g/cm^3 (0.092 lb/in^3)	2.93 g/cm^3 (0.106 lb/in^3)	2.95 g/cm^3 (0.107 lb/in^3)	3.00 g/cm^3 (0.109 lb/in^3)
Total porosity: % of volume	20%	20%†	4%	4%†	5%
Open porosity: % of total	19%	0%††	1%	0%††	1%
Total impurity level:	<10 ppm	<10 ppm	<10 ppm	<10 ppm	<10 ppm
Flexural strength:	155 MPa (22,400 psi)	155 MPa (22,400 psi)	192 MPa (27,900 psi)	192 MPa (27,900 psi)	220 MPa (31,900 psi)
Tensile strength:	129 MPa (18,700 psi)	129 MPa (18,700 psi)	124 MPa (17,940 psi)	124 MPa (17,940 psi)	162 MPa (23,510 psi)
Elastic modulus:	217 GPa (31 10^6 psi)	217 GPa (31 10^6 psi)	331 GPa (48 10^6 psi)	331 GPa (48 10^6 psi)	373 GPa (54 10^6 psi)
Specific stiffness:	86 kN.m/g	85 kN.m/g	113 kN.m/g	112 kN.m/g	124 kN.m/g
Poisson's ratio:	0.17	0.17	0.17	0.17	0.17
Dynamic shear modulus:	97 GPa (14 10^6 psi)	97 GPa (14 10^6 psi)	138 GPa (20 10^6 psi)	138 GPa (20 10^6 psi)	159 GPa (23 10^6 psi)
Fracture toughness:	2.44 MPa.m$^{0.5}$	2.44 MPa.m$^{0.5}$	3.78 MPa.m$^{0.5}$	3.78 MPa.m$^{0.5}$	N/A
Hardness knoop:	1992 kg/mm^2	N/A	1643 kg/mm^2	N/A	N/A
Thermal diffusivity:	100 mm^2/s	100 mm^2/s	115 mm^2/s	115 mm^2/s	111 mm^2/s
Thermal conductivity: W/m.K (Btu/hr/ft°F)	170 (98)	170 (98)	220 (127)	220 (127)	224 (129)
Electrical resistivity:	0.009 Ω-cm (3700 µΩ-in)	N/A	0.010 Ω-cm (4000 µΩ-in)	N/A	0.008 Ω-cm (3280 µΩ-in)
Instantaneous coefficient of thermal expansion at RT:	2.4 10^{-6}/K (1.3 10^{-6}/°F)	2.4 10^{-6}/K (1.3 10^{-6}/°F)	2.4 10^{-6}/K (1.3 10^{-6}/°F)	2.4 10^{-6}/K (1.3 10^{-6}/°F)	2.4 10^{-6}/K (1.3 10^{-6}/°F)

†Porosity is sealed under the dense coating; porosity is not exposed to the process.

††Porosity sealed off by CVD SiC coating.

For More Information

Please call your Regional Customer Service Center today to learn what Entegris can do for you. Visit *www.entegris.com* and select the Customer Service link for the center nearest you.

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