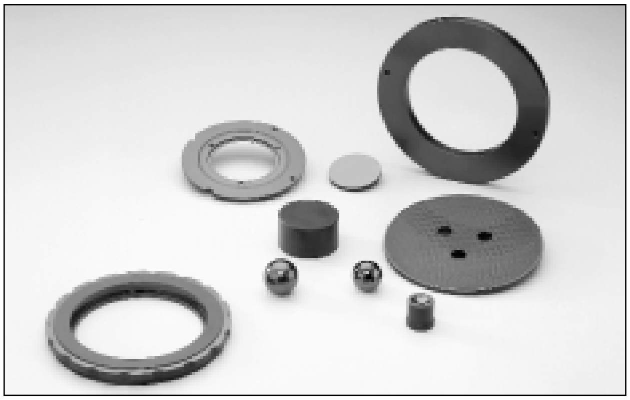
CVD SILICON CARBIDE®



CVD SILICON CARBIDE® is the ideal performance material for design engineers. It outperforms conventional forms of silicon carbide, as well as, other ceramics, quartz, and metals in chemical seals and bearings, equipment components, semiconductor wafer-handling and chamber components, optical components and other demanding applications.

Advanced Materials' bulk chemical vapor deposition (CVD) process produces freestanding monolithic CVD SILICON CARBIDE. This solid material is highly pure (99.9995%), and is theoretically dense with no voids or micro cracks. Due to its cubic ß crystal structure, it offers isotropic characteristics. Hundreds of tests conducted over the past several years confirm the material's homogeneity- not only within a production run- but also from batch to batch. These inherent advantages to our unique CVD process result in reproducible material with superior performance characteristics.

CVD SILICON CARBIDE's attributes include:

- low coefficient of thermal expansion,
- high thermal conductivity,
- high strength and stiffness,
- theoretical density with no porosity,
- lightweight (similar to Al and Be), and
- hardness (second only to diamond).

These attributes lead to performance advantages:

- resistance to wear and abrasion,
- resistance to corrosion, oxidation and erosion,
- performance at high temperatures (up to 1700°C)
- superior flatness, and
- polishable to <3 Å RMS.

As the technology leader, Advanced Materials knows how to maximize CVD SILICON CARBIDE performance for your application. Components made from CVD SILICON CARBIDE can be fabricated in a range of shapes and sizes to your exact specifications. Three grades of CVD SILICON CARBIDE are available:

- low resistivity grade (<10 Ω cm)
- high resistivity grade (>1000 Ω cm)
- standard grade

Properties	Typical Values[1]
Crystal Structure (face-centered cubic ß-phase)	FCC polycrystalline
Sublimation Temperature (C)	~2700
Grain Size (µm)	5
Density (g cm^{-3})	3.21
Hardness (kg mm^{-2})	
Knoop (500 g load)	2540
Vickers (500 g load)	2500
Chemical Purity[2]	≥99.9995% SiC
Flexural Strength, 4-point[3]	
@ RT (MPa/Ksi)	415/60
@ 1400°C (MPa/Ksi)	575/84
Weibull Parameters	
Modulus, m	11
Scale Factor , ß (MPa/Ksi)	424/61
Fracture Toughness, K_{IC} Values	
Micro-indentation (MN $m^{-1.5}$)	3.3
Controlled Flow (MN $m^{-1.5}$)	2.7
Elastic Modulus	
Sonic (GPa/10^6 psi)	466/68
4-point Flexure (GPa/10^6 psi)	461/67
Coefficient of Thermal Expansion (K^{-1})	
@ RT	2.2×10^{-6}
@ RT to 1000˚C	4.0×10^{-6}
Heat Capacity(Jkg^{-1} K^{-1})	640
Thermal Conductivity (Wm^{-1} K^{-1})	300
Poisson's Ratio	0.21
Polishability[4]	<3Å RMS
Electrical Resistivity[5]	
Low Resistivity Grade	<1 Ω cm
High Resistivity Grade	>1000 Ω cm

(1) Average values at room temperature.
(2) Total metallic impurities; detailed data on specific impurities is available upon request.
(3) Flexure beams had a 0.5µm RMS surface finish.
(4) Polishability was measured with optical profilometer.
(5) Measured according to ASTM standard.

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High Temperature Property Retention

CVD SILICON CARBIDE is a high temperature material with a sublimation temperature of about 2700˚C. In an inert environment, this material can be used up to a temperature of 1700˚C. Above 1800°C there is an onset of phase change from cubic phase to hexagonal α-phase. As you can see in the table below, the material can be safely used up to a temperature of 1500˚C with a good retention of thermal and mechanical properties.

Summary of Temperature Dependence of Important Mechanical, Electrical, and Thermal Properties of CVD SILICON CARBIDE[1]

	-140°C	*-100°C*	*0°C*	*200°C*	*500°C*	*700°C*	*1000°C*	*1200°C*	*1500°C*
Specific Heat ($Jkg^{-1}K^{-1}$)	175	301	574	952	1134	1189	1251	1295	1355
Thermal Conductivity ($Wm^{-1}K^{-1}$)	396	485	333	221	137	110	78	63	48
Thermal Expansion Coefficient ($K^{-1}x10^{-6}$)	0.4	0.8	1.9	3.7	4.6	4.9	5.0	5.1	-
Elastic Modulus (GPa)	-	-	460	457	450	440	435	422	415
Flexural Strength (MPa)	460	465	470	480	500	515	540	555	575

[1]The data presented in the chart above were obtained from measurements at Advanced Materials, University of Dayton Research Institute, Thermophysical Properties Research Laboratory at Purdue University and a number of other commercial and university laboratories.

CVD SILICON CARBIDE for Reflective Optics Applications

CVD SILICON CARBIDE is an excellent reflective optics material exhibiting superior polishability with low scatter, exceptional thermal and cryogenic stability and high resistance to atomic oxygen and electron beam degradation. CVD SILICON CARBIDE is used as substrates for fabricating mirrors for surveillance, high energy lasers, laser radar systems, synchrotron x-ray and VUV telescopes, large astronomical telescopes and weather satellites. CVD SILICON CARBIDE lightweight mirrors can be produced either by conventional fabrication, near-net shape fabrication, or precision machining.

Ultraviolet Reflectivity of CVD SILICON CARBIDE[1]

Wavelength	*% Reflected*
58.4 nm	26
72.5 nm	33
103.2 nm	38
104.8 nm	39
112.5 nm	41
120-190.0 nm	>41

[1]All test samples were polished and uncoated. The normal angle of incidence was used.

Infrared Reflectivity of CVD SILICON CARBIDE[1]

Wavelength	*% Reflected*
2.5-6.0 µm	>16
8.0 µm	12
10.0 µm	3
10.5 µm	70
11.0 µm	92
12.0 µm	99
13.0 µm	63
16.0 µm	34
16.0-50.0 µm	>26

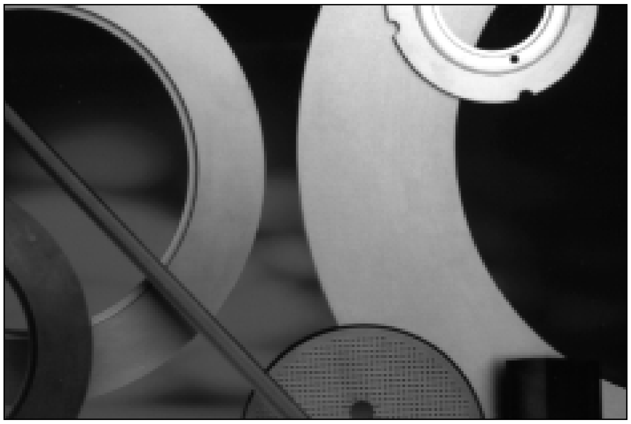
[1]All test samples were polished and uncoated. The normal angle of incidence was used.

CVD SILICON CARBIDE Components for Semiconductor Processing Equipment

Recognized as the premiere choice for RTP/epi rings and susceptors and plasma etch chamber components, solid CVD SILICON CARBIDE excels where high temperatures (>1500°C), ultra-high purity (>99.9995%) and chemical resistance are system requirements. CVD SILICON CARBIDE contains no secondary phase at grain boundaries resulting in components with lower particle generation. In addition, these components can be cleaned in hot HF/HCl cleaning cycles with minor degradation resulting in very low particle generation and longer life.

Advanced Materials' controlled resistivity grades of CVD SILICON CARBIDE ideally satisfy the semiconductor process engineer's need for high and low resistivity wafer-handling and chamber components in equipment requiring RF coupling such as in plasma etch, CVD and MOCVD. Controlled resistivity grade CVD SILICON CARBIDE is available as follows:

- low resistivity grade (<1 Ω cm)
- high resistivity grade (>1000 Ω cm)



The advantages of CVD SILICON CARBIDE for 200 and 300mm semiconductor processing applications are clear: controlled resistivity, higher purity, longer life cycle, lower particle generation and better temperature uniformity. For plasma etch chamber equipment, the superior erosion resistance of CVD SILICON CARBIDE to F, Cl, and Br chemistry plasma results in longer component life. For thermal process applications, CVD SILICON CARBIDE components provide low mass and very thin cross sections while maintaining thermal stability resulting in excellent temperature uniformity across the wafer during processing.

CVD SILICON CARBIDE
Typical Trace Element Impurities in Parts Per Billion By Weight (ppbw)

Element	GDMS1	NAA2	Element	GDMS1	NAA2	Element	GDMS1	NAA2
Li	<3.2	–	Ge	<28	–	Ba	<5.7	< 2.2
Be	<5.9	–	As	<9.4	5.70	La	<1.2	<0.0062
B	290	–	Se	<100	0.11	Ce	<9.8	<0.038
Na	30	0.63	Br	–	<0.02	Eu	–	0.021
Mg	<34	–	Rb	<11	<0.36	Tb	–	<0.0004
Al	9.1	–	Sr	<1.1	<3.9	Yb	–	<0.021
P	28	–	Y	<0.87	–	Nd	<7.3	–
S	88	–	Zr	<3.2	<4.5	Hf	<6.1	<0.0058
K	<9.4	<21	Nb	<3.5	–	Ta	–	<0.0057
Ca	<5.8	<840	Mo	<17	0.28	W	<12	0.688
Sc	<0.64	<0.0006	Ru	<7.5	–	Re	<5.3	–
Ti	<4.2	<1400	Rh	<3.6	–	Os	<6.3	–
Cr	–	0.16	Pd	<25	–	Ir	<8.5	<0.0001
V	<1.4	–	Ag	<20	<0.047	Pt	<9.6	< 19
Mn	<3.9	–	Cd	<150	<0.57	Au	–	0.028
Fe	<40	<5	In	<22	<0.097	Hg	<43	<0.02
Co	<4.0	<0.67	Sn	<29	<4.1	Tl	<21	–
Ni	<13	205	Sb	<27	0.072	Pb	<7.1	–
Cu	<16	1.55	I	<63	–	Bi	<6.1	–
Zn	<36	1.28	Te	<26	–	Th	<0.61	<0.007
Ga	<29	<0.16	Cs	<13	<0.0083	U	<0.42	<0.039

[1]Gas Discharge Mass Spectroscopy; Measurements performed at Charles Evans & Associates
[2]Neutron Activation Analysis; Measurements performed at AT&T Analytical laboratory

CVD SILICON CARBIDE Comparison

Until recently most silicon carbide was made by the sintering and/or hot pressing of powders. Sintered hot pressed forms of silicon carbide are second phase materials which contain additives and are not theoretically dense. Due to their porous nature they cannot be optically polished and they do not possess the high temperature oxidation resistance or strength of silicon carbide made by the CVD process. In the chart below, CVD SILICON CARBIDE is compared to other competing optical materials like beryllium and ULE, and to other competing semiconductor materials like quartz and polysilicon; and it is also compared to silicon carbide made by other processes.

	Typical Material Properties[1]					
To Other Materials ▼	***Density (gcm^{-3})***	***Thermal Conductivity ($Wm^{-1}K^{-1}$)***	***Specific Heat ($Jkg^{-1}K^{-1}$)***	***Elastic Modulus (GPa)***	***CTE RT to 1000°C ($K^{-1}x10^{-6}$)***	***Polishability***
Be (0-50)	1.85	216	1880	303	11.4[(3)]	≤10 Å RMS
ULE[(2)](7971)	2.20	1.3	708	67	0.03[(3)]	≤3 Å RMS
Polysilicon	2.3	150	920	110	3.8	≤5 Å RMS
Quartz	2.2	1.4	1210	70	0.5	≤3 Å RMS
CVD SILICON CARBIDE	**3.21**	**300**	**640**	**466**	**4.0 2.2[(3)]**	**≤3 Å RMS**
Reaction Bonded SiC	3.1	120-170	-	391	4.3	≥20 Å RMS
Hot Pressed SiC	3.2	50-120	-	451	4.6	≥50 Å RMS
Sintered SiC	3.1	50-120	-	408	4.5	≥100 Å RMS
To Other SiC Processes ▲						

[(1)]Room temperature values unless noted otherwise
[(2)]Corning Inc., Corning NY
[(3)]Room temperature values

For more information, visit our website at www.cvdmaterials.com

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