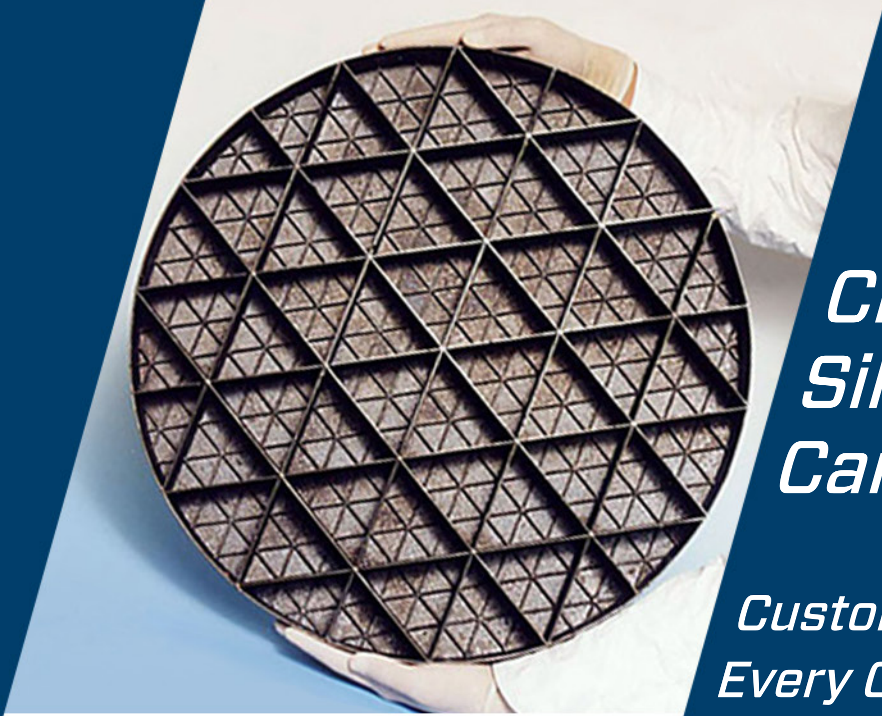


CERAFORM
Silicon
Carbide

Customizable for
Every Optical Mission

NORTHROP GRUMMAN

CERAFORM Silicon Carbide

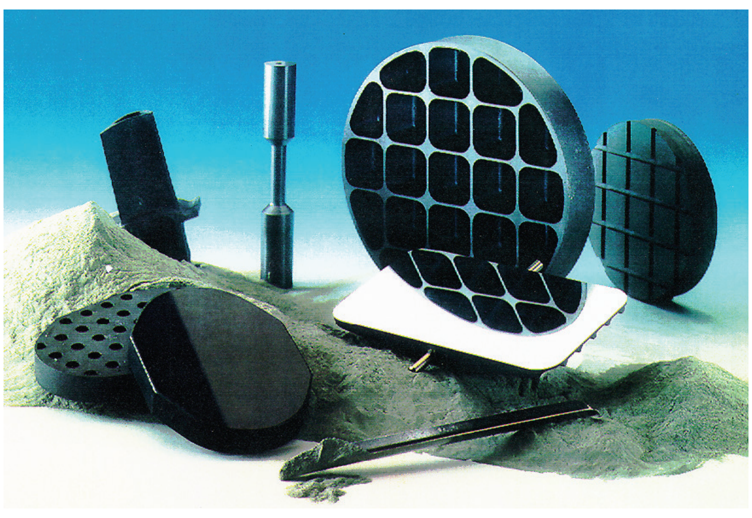
Customizable for Every Optical Mission

CERAFORM Silicon Carbide (SiC) sets a new standard for optical applications, such as high energy laser mirrors, space-borne mirrors and structures, cryogenic mirrors, fast response scan mirrors, and high heat flux applications, thanks to its unique combination of key enabling properties.

CERAFORM SiC is an optical grade reaction bonded silicon carbide, consisting of a ceramic matrix of free silicon containing a bimodal distribution of SiC grains. CERAFORM SiC is slip cast and thermally processed to form a fully dense ceramic component using a proprietary process developed over a 20-year period.

Available only through Northrop Grumman's AOA Xinetics, CERAFORM SiC offers high performance optical quality, stiffness and dimensional stability, with low thermal distortion and at lower weights than other products. In addition, it is made using a cost-effective ceramic casting process, which enables the creation of complex shapes and lightweight substrates. CERAFORM SiC embodies the best combination of material properties to make it ideal for those applications that require stable optical quality in extreme environments. It is competitive with beryllium as a structural material, with glass as an optical material, and with Invar or graphite epoxy as a metering material. Most significantly, with AOA Xinetics unique manufacturing processes, CERAFORM SiC can be tailored to provide engineers the freedom to incorporate unique optical and structural features into their designs; e.g. the ability to produce a complete optical telescope assembly from SiC.

These combined capabilities make CERAFORM SiC the new standard in optical materials.



Size Versatility

In development for over 20 years, AOA Xinetics' CERAFORM SiC can be used to custom manufacture products of nearly any size. CERAFORM SiC has been scaled up to 1.5 with surface finishes of 10 Å, and with areal densities less tham 10 kg/m².

Dimensional Stability

CERAFORM SiC offers customers a high dimensional stability, due to a low thermal expansion coefficient which minimizes distortion, and a high thermal conductivity to minimize thermal gradients, and a high elastic modulus to resist thermal bowing. The material also boasts homogeneity of the thermal expansion through cryogenic extremes, providing a three-fold improvement in coefficient thermal expansion and uniformity over beryllium and negligible thermal hysteresis.

Additionally, CERAFORM SiC has proven stable from both a macroscopic (figure distortion), a microscopic (surface finish) perspective, with no measurable change detected for repeated thermal cycles.

CERAFORM SiC also demonstrates impressive stability at cryogenic temperatures. In a test of cooldown to 80 Kelvin, flat samples demonstrated a figure stability of better than $\lambda/30$ rms (visible) without noticeable global figure change. The equivalent peak-to-valley distortion was on the order of 0.1 μm or less.

Stiffness

CERAFORM SiC structural stiffness with minimal weight, crucial to missions in space-borne or highly dynamic environments. Since CERAFORM SiC shrinks less than 0.1%, it can be cast directly to near net shape. In contrast, hot pressed or sintered alpha SiC has a linear shrinkage of 20%, which compromises dimensional control during firing. Additionally, through optimized sectional stiffness, a CERAFORM SiC mirror can be as much as 30% lighter than one made using beryllium, while maintaining a higher specific sectional stiffness.

Thermal Performance

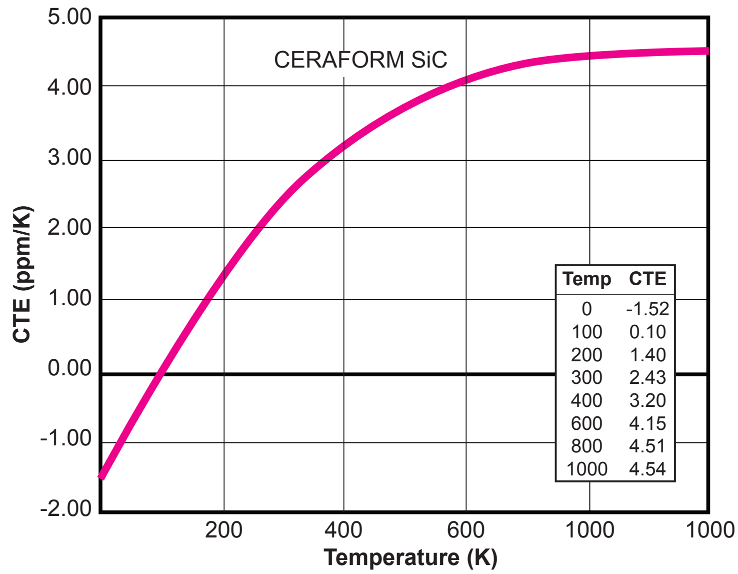
CERAFORM SiC offers the best ratio of high conductivity and low CTE, in contrast to metals, which exhibit high conductivity but high CTE, and glasses, which exhibit low CTE but low conductivity. As a result, CERAFORM SiC outperforms even the near-zero expansion glasses in applications where heat flux and temperature range are important. Additionally, CERAFORM SiC resists thermal bowing because it has the best of all materials and is the most dimensionally stable.

Optical Quality

Bare CERAFORM has been shown to produce a surface roughness to 10Å. The limitation is due to the Si and SiC bi-modal nature of CERAFORM. The Si phase polishes at a different rate than the SiC. In order to achieve surface roughness's of 2Å or better, the surface will require a silicon or CVD SiC cladding; both single phase claddings.

Conclusion

CERAFORM SiC is the most attractive mirror material overall when size versatility, dimensional stability, stiffness, thermal performance, and optical quality are considered.



CERAFORM CTE

Property	Unit	Aluminum 6061-T6	Beryllium 1-70	Ceraform SiC	Silicon	ULE	Desired Value
ρ, Density	g/cm³	2.71	1.85	2.92	2.33	2.21	Low
E, Young's Modulus	GPa	68.3	303	310	130	67.6	High
ν, Poisson's Ratio	----	0.33	0.07	0.19	0.26	0.17	Low
α^2, Thermal Expansion	ppm/°C	22.7	11.4	2.44	2.62	±0.03	Low
$\Delta\alpha$, CTE	ppb/°C	100	100	30	10	10	Low
κ, Thermal Conductivity	W/°C	156	216	157	135	1.31	High
C_ρ, Specific Heat	J/Kg°C	879	1820	670	713	766	Low
σ, Design Stress	MPa	124	17	70	62	7	High

Typical Materials Comparison Table

For more information, or consultation regarding your dimensioning needs, please contact:

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