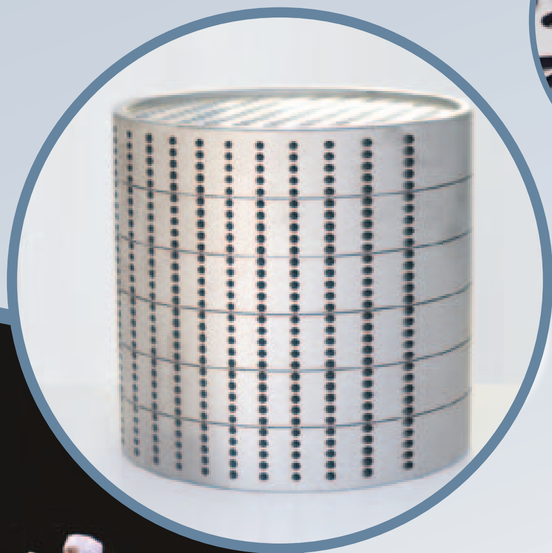
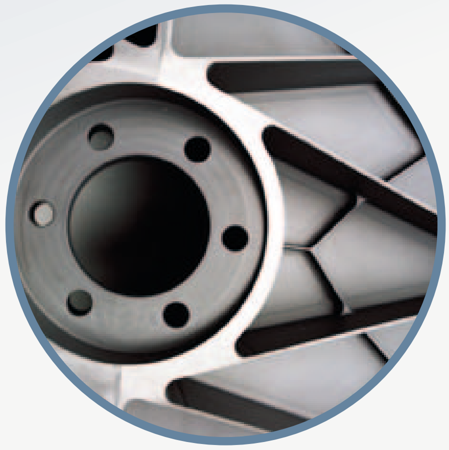
PRODUCT

BOOSTEC® SiC

SINTERED SILICON CARBIDE
AN OUTSTANDING MATERIAL





MERSEN

BOOSTEC® SiC,
AN EXCEPTIONAL MATERIAL

Boostec® SiC is a polycrystalline technical ceramic of alpha SiC type, obtained by pressureless sintering. This process yields a pure silicon carbide with no traces of free silicon.

Its low residual porosity is fine and completely closed, i.e. the material is perfectly water tight.
The very strong covalent Si-C bond gives Boostec® SiC exceptional physical properties that are particularly stable over time: high stiffness and hardness, low thermal expansion, high chemical and thermal stability...

Its fine, homogeneous micro-structure is isotropic and virtually free of secondary phases, leading to perfectly isotropic, homogeneous and reproducible physical properties. In particular, no dispersion or anisotropy of its coefficient of thermal expansion is detectable with an extreme precision of $0.001 \cdot 10^{-6}\ K^{-1}$.

Unlike glasses, glass-ceramics and oxide ceramics, Boostec® SiC does not present a phenomenon of sub-critical cracking.
Unlike toughened ceramics (silicon nitride, stabilised zirconia), Boostec® SiC shows no sensitivity to mechanical fatigue.
The mechanical properties (bending strength, modulus of elasticity, toughness) of Boostec®SiC hardly change with temperature, from cryogenic environments close to absolute zero up to 1450 °C.
Boostec® SiC is a non-magnetic, semi-conductor material.

Sintered Silicon Carbide

Excellent resistance to corrosion and abrasion

Low coefficient of thermal expansion

High mechanical strength

High stiffness

Lightweight material

Exceptional thermo-mechanical stability

High thermal conductivity, similar to that of aluminium

Properties	Typical Values (at 20 °C)
Density	$3.15\ g/cm^3$
Young's Modulus	420 GPa
Bending strength / Weibull modulus (coaxial double ring DIN EN 1288-1 & 5)	400 MPa / 11
Poisson Coefficient	0.16
Toughness (K_{1c})	$3\ MN.m^{-3/2}$
Coefficient of thermal expansion	$2.2 \cdot 10^{-6}\ K^{-1}$.
Thermal Conductivity	$180\ W.m^{-1}.K^{-1}$
Electrical Resistivity	$10^5\ \Omega.m$

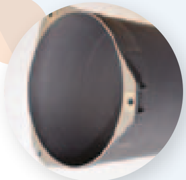
Typical Chemical Composition

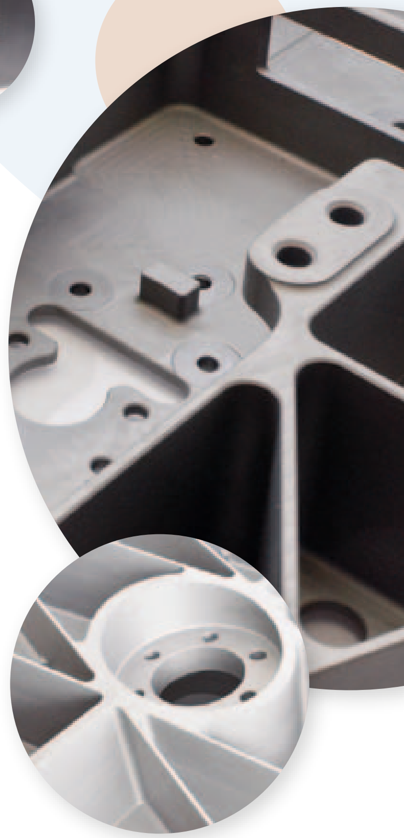
SiC	> 98.5 %
B	< 1 %
free C	< 0.2 %
SiO_2	< 500 ppm
free Si	< 500 ppm
Fe	< 500 ppm
Al	< 400 ppm
Ca	< 30 ppm
K	< 1 ppm
Mg	< 1 ppm
Na	< 1 ppm

BOOSTEC® SiC, TECHNOLOGY

The technology developed by Boostec enables it to serve its markets...

- from prototype to small production runs,with monolithic parts in SiC (coated with CVD SiC if required), SiC/SiC or SiC/metal assemblies that can take very complex shapes and reach very large dimensions.





Fabrication of monolithic ceramics

- Isostatic pressing of large, rough shapes
- green machining of pressed blocks
- Sintering (T > 2000 °C) under protective atmosphere
- Grinding
- Lapping
- Final inspection
- Cleaning

Maximum overall dimensions
Cylinders Ø 1.25 m x height 0.60 m
Blocks 1.70 m x 1.20 m x 0.60 m

Brazed SiC/SiC assemblies

Capacity:
up to Ø 3.50 m x 0.8 m

Other assemblies SiC/SiC or SiC/metal

- Epoxy gluing
- Bolting
- Shrink-fitting

CVD SiC coating

Capacity: up to Ø 1.50 m

GAIA Torus (image courtesy of Astrium)

MIRRORS AND STABLE STRUCTURES
for telescopes (space, ground), scientific instrumentation and high speed lasers

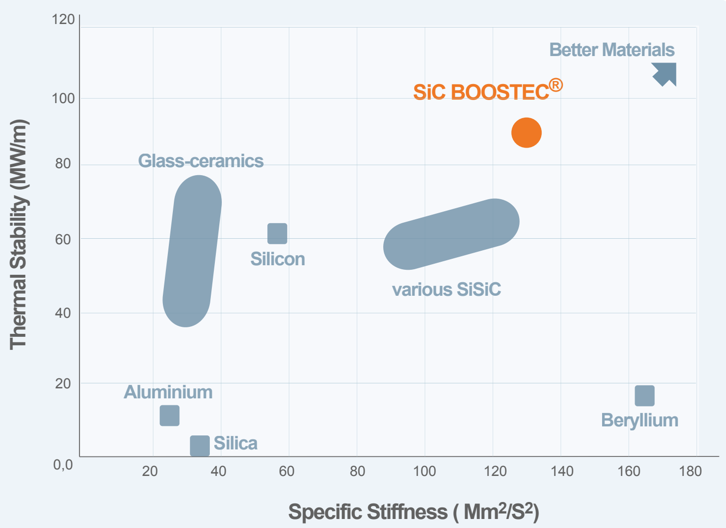
GAIA BAM Optical Bench
(image courtesy of TNO / Astrium)

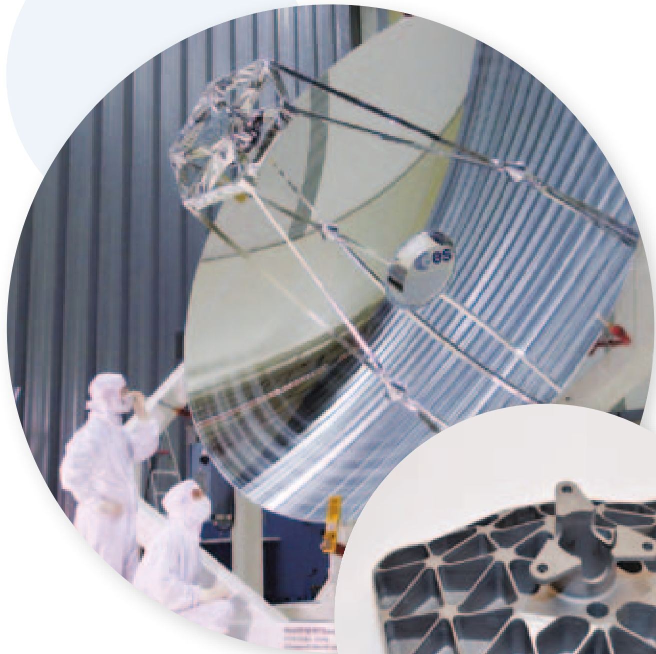
Of the industrial materials that might be considered, Boostec® SiC achieves the best compromise between the key parameters that are common to all these applications :

- **specific stiffness:**
  Young's modulus / density
- **thermal stability:**
  thermal conductivity / Coefficient of thermal expansion

Other key advantages of Boostec® SiC:

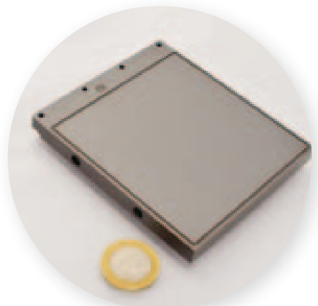
- Monophase material, highly homogeneous
- Micro-structure and thus physical properties perfectly isotropic, in particular the thermal expansion
- Perfect reproducibility of the thermal expansion from one item to another, from one batch to another
- High mechanical strength and absence of mechanical fatigue
- Total absence of outgassing and moisture absorption
- Perfect stability over time
- Insensitivity to radiation in the space environment
- Physical properties retained or even improved at cryogenic temperatures; qualification for space applications down to 30 K
- The optical face of the mirrors can be CVD coated with SiC to mask the fine residual porosities of the sintered SiC



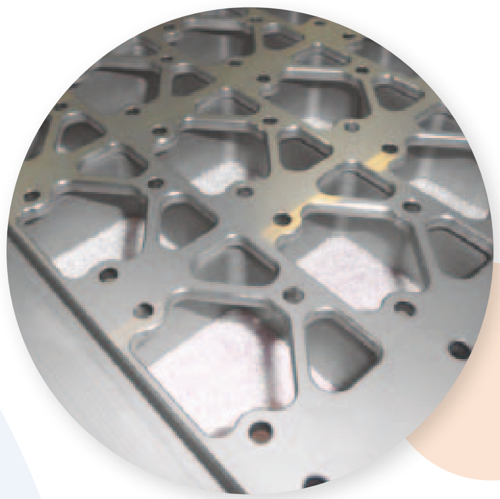


Herschel Telescope
(image courtesy of ESA / Astrium)

Light-weight mirror with central fixation
(image courtesy of Astrium)



CCD package
(image courtesy of E2V)



GAIA focal plane structure
(image courtesy of Astrium)

Space, Science and Laser Industry

Scientists look for ever larger, lighter, more stable and even colder telescopes to observe the earth or the far universe with extreme precision. Boostec® SiC has shown itself indispensable to meet the mass and thermo-mechanical stability requirements of certain on-board instruments. The excellent mechanical properties of Boostec® SiC permit the production of all SiC optical benches and telescopes: the mirrors, the structure and the focal plane elements (detector support, structure, folding mirrors) are made of SiC. These instruments are insensitive to temperature variations without any temperature control.

Mid 2013, ten "all Boostec® SiC" telescopes were operational in space, including Herschel, the largest space telescope. Boostec is the only company in the world capable of producing SiC parts of 3 meters in diameter.

Ground-based observatories profit from the same remarkable properties of Boostec® SiC, especially for their mirrors or their adaptive optics.

Boostec® SiC technology also offers exceptional opportunities for the extremely stable structures or optical benches used on the ground; it permits the realisation of large dimension optical benches (up to 3.5 m in length) with complex shapes in a single piece, thus reducing the assemblies.

Optosic® high speed mirrors

Laser scanner mirror
(image courtesy of Optosic)

Our SiC technology permits the realisation of lighter mirrors, with high dynamic flatness, low inertia and therefore very agile, for sighting systems, high speed laser scanners and LIDARS. SiC is becoming essential for terrestrial or airborne topographic mapping as well as industrial laser applications such as material processing, marking, metrology or rapid prototyping, where ever greater speed, precision and larger dimensions are sought.

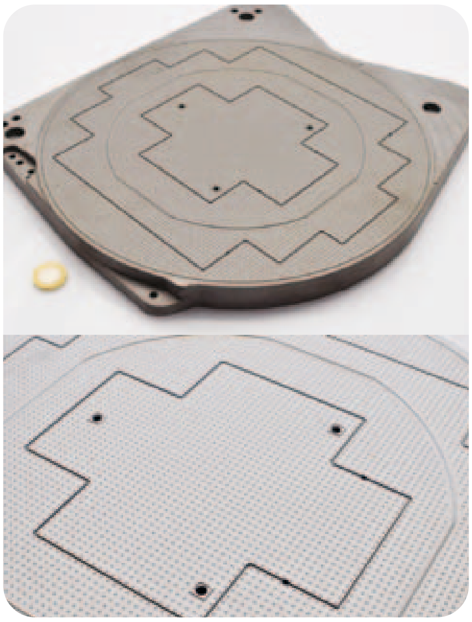
EQUIPMENT FOR THE SEMI-CONDUCTOR INDUSTRY

The semi-conductor industry processes larger and larger silicon wafers that must be moved with increasing speed while ensuring ever more precise positioning. SiC is used to manufacture the chucks and the moving structures of the equipment dedicated to optical inspection, lithography or various other processes.

Key advantages of Boostec® SiC:

- High stiffness
- Low density
- Low coefficient of thermal expansion, close to that of silicon
- High thermal conductivity
- Excellent chemical inertia

If necessary, the sintered SiC can be given a sealed coating of CVD SiC of very high purity.



Chuck (image courtesy of Micro-Controle)

MECHANICAL APPLICATIONS

In mechanical seals, silicon carbide is currently used as a counter-face to carbon. SiC/SiC solutions are used for corrosive fluids (strong acids or alkalis) and, above all, for abrasive suspensions.

Boostec® SiC technology enables the use of silicon carbide to be extended to large parts (up to Ø 1 metre) for particularly demanding applications in sectors such as nuclear or marine engineering and certain chemical installations.
Pump bearings and thrust bearings use SiC/SiC sliding which is lubricated by the liquid flow.

Rings for mechanical seals

Shrink-fitted Bearings

Key advantages of Boostec® SiC:

- Outstanding corrosion resistance
- Excellent resistance to abrasion
- Low density
- High mechanical strength
- Low coefficient of friction (in liquid medium)
- High Thermal conductivity
- Good resistance to thermal shock.

CONTINUOUS FLOW CHEMICAL
Reactors and Heat Exchangers

Unlike batch chemical reactors, the intensification of chemical processes enables this industry to be turned towards a decidedly greener chemistry.
In the context of an agreement with Corning SAS, Boostec is developing and manufacturing high-technology chemical reactors for continuous flow systems. These new reactors represent a real technological breakthrough and reduce the production steps with improved chemical reactions in more compact and safer factories. This equipment, arising from the Corning SAS / Boostec alliance, permits the production on an industrial scale of specific chemical or pharmaceutical products with competitive costs.

The industrial version marketed by Corning SAS is based on the plate heat exchanger concept, designed as a modular structure in blocks, in which the reaction plates made of Boostec® SiC, are interleaved with metal plates in which the heat-bearing liquid circulates.

Boostec® SiC technology is particularly well-suited for this application; it offers:

- production runs of plates with optimised channel patterns at competitive costs,
- assembly techniques permitting the sealed assembly of the modules.

Block heat exchanger

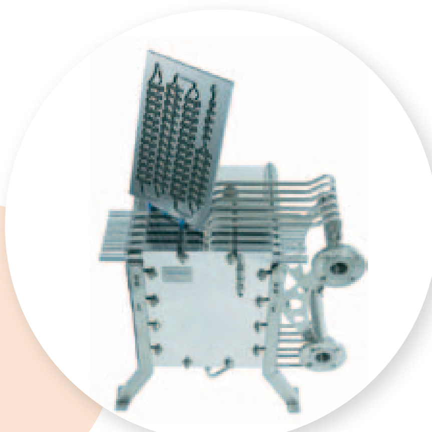
Continuous flow reactor (image Courtesy of Corning SAS)

The "all Boostec® SiC" heat exchangers permit the widening of Mersen's product range. They offer the following key advantages:

- Absence of leakage
- Can be used at high temperature (>500 °C)
- Resistance to high pressures
- Excellent abrasion resistance, permitting the absence of contamination and greater velocity of the fluids, whence reduced fouling
- Possibility of making more compact equipment
- Possibility of cleaning on site (chemical or thermal process)

Key advantages of Boostec® SiC:

- High thermal conductivity
- Perfect sealing
- Excellent resistance to corrosion, even by hot fluids
- Excellent abrasion resistance
- High mechanical strength



Continuous flow reactor (image Courtesy of Corning SAS)

MERSEN
Expertise, our source of energy

A WORLD EXPERT
in materials and solutions
for high temperature processes

A GLOBAL PLAYER

Global expert in materials and solutions for extreme environments as well as in the safety and reliability of electrical equipment, Mersen designs innovative solutions to address its clients' specific needs to enable them to optimize their manufacturing process in sectors such as energy, transportation, electronics, chemical, pharmaceutical and process industries.

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