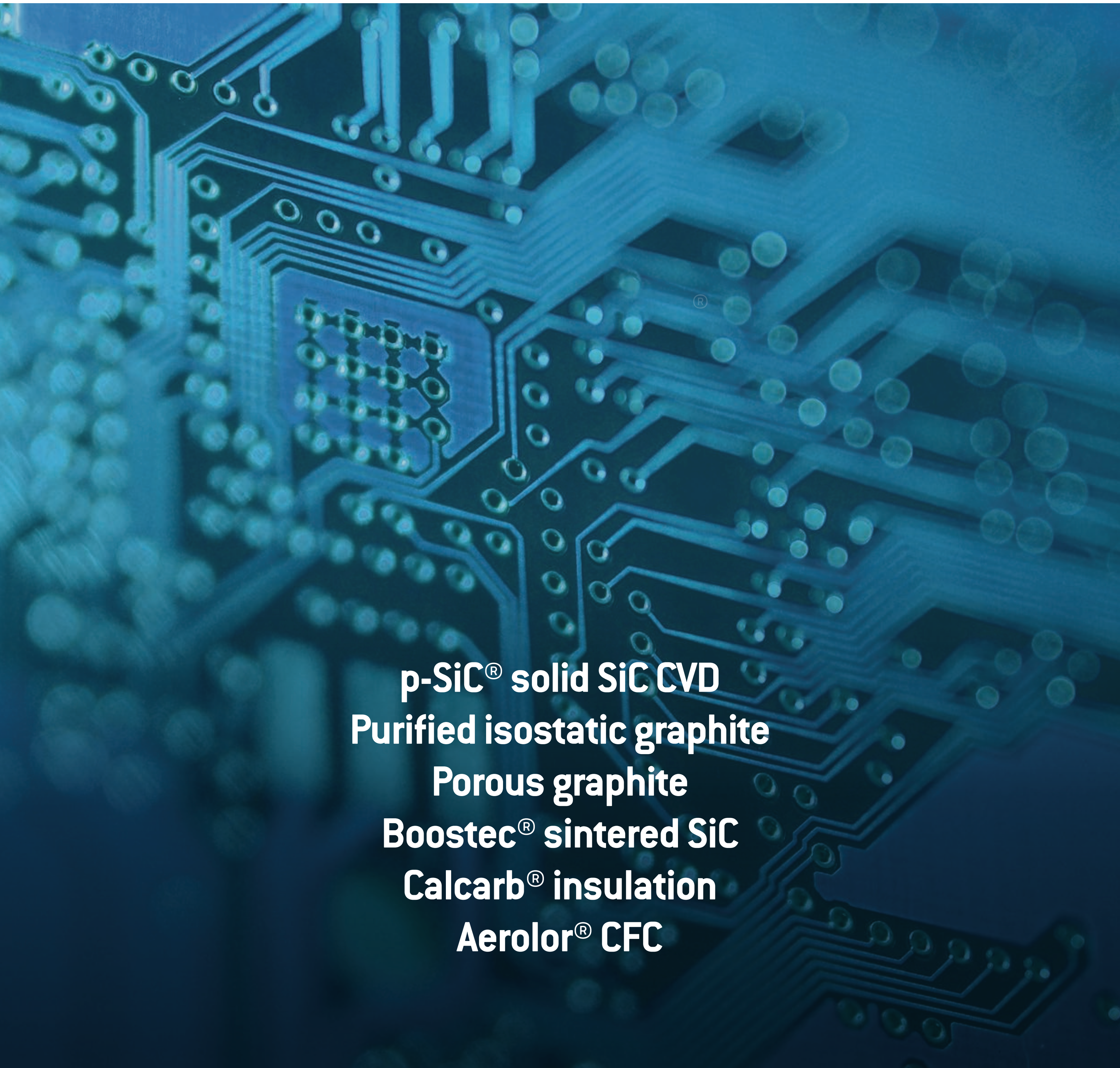
Expertise, our source of energy

ELECTRONICS

ADVANCED MATERIALS FOR THE SEMICON INDUSTRY



p-SiC® solid SiC CVD
Purified isostatic graphite
Porous graphite
Boostec® sintered SiC
Calcarb® insulation
Aerolor® CFC

WE ARE MERSEN.

Mersen offers complementary, reliable, high-performance material solutions to support advanced technology for the future.

Through close collaboration with our customers, we develop solutions to address leading-edge semiconductor production challenges.

8

MERSEN PRODUCES, DESIGNS, AND ENHANCES 8 ADVANCED MATERIAL SOLUTIONS WORLDWIDE.

XXL

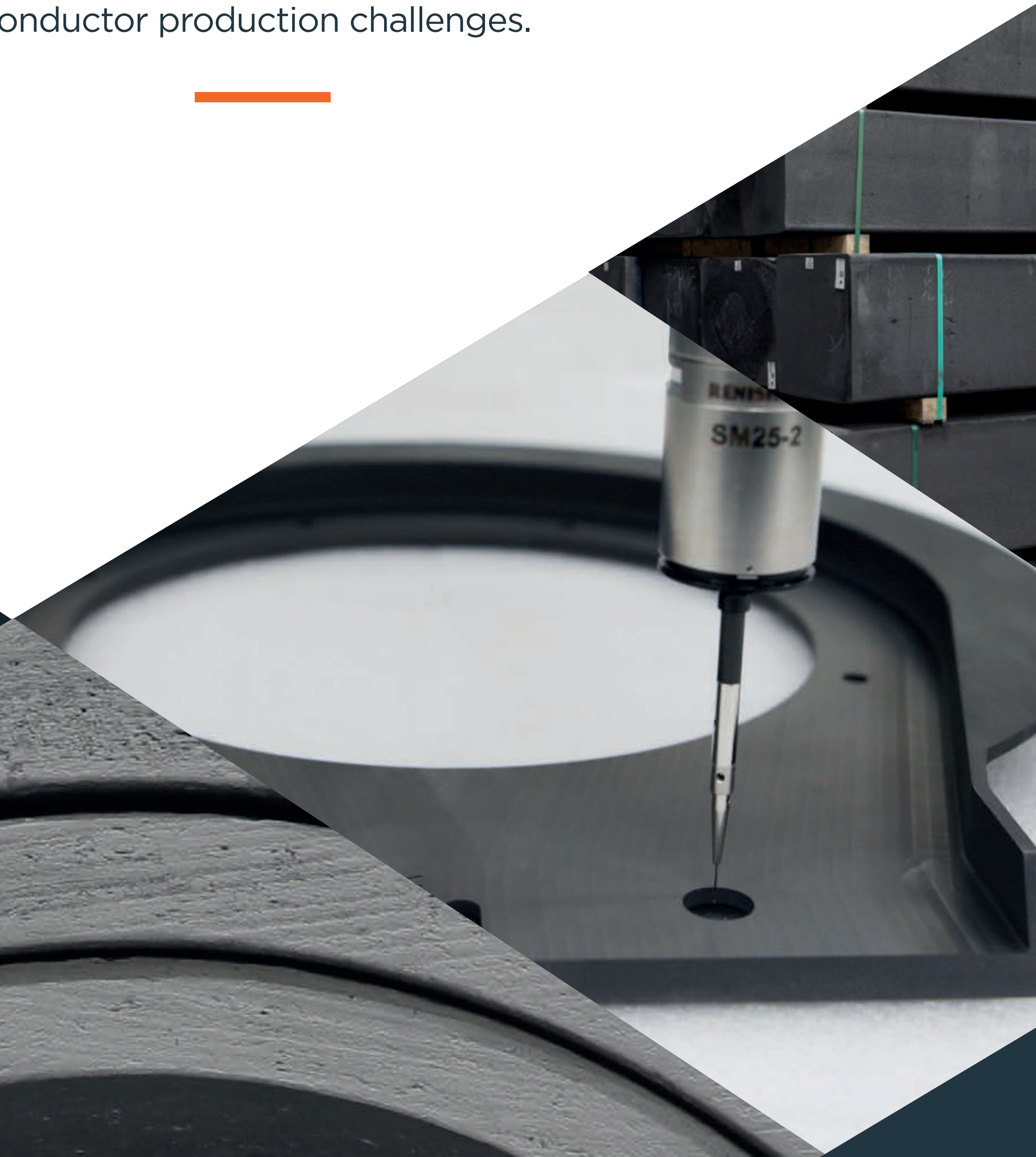
LARGE SIZE PRODUCTION AND MACHINING CAPABILITIES UP TO 1,500 mm / 60”

35

EXTENDED NETWORK OF MACHINING SHOPS AROUND THE WORLD

16

R&D CENTERS



POLYSILICON MANUFACTURING
Electronic grade.

GRAPHITE SOLUTIONS.

ULTRA HIGHLY PURIFIED (UHP).

MERSEN supplies leading polysilicon producers with an extended range of reactor components made from isostatic graphite, extruded graphite and graphite felt.

PROCESS

Raw silicon is transformed into a liquid called trichlorosilane ($SiHCl_3$), which is produced by a reaction with hydrogen chloride gas (HCl). The liquid is then distilled to remove the contaminants. The resultant pure trichlorosilane is used to make rods of polycrystalline silicon (polysilicon). These rods are produced via chemical vapor deposition (CVD).

After passing through the CVD reactor, vapors containing a mix of $SiHCl_3$ and $SiCl_4$ are being sent to the converter. In the converter, $SiCl_4$ is being converted into $SiHCl_3$ by high temperature hydrogenation.

Products: Graphite sleeves, heat exchangers, gas injection parts / diffusion plates

MERSEN SOLUTIONS - REACTOR

- **Purified graphite** electrodes to improve polysilicon quality (no contamination)
- **Low resistivity** graphite grade to limit heat and reduce contact between electrode and polysilicon (potential source of contamination)
- **High strength** graphite grade to resist to vibrations and pressure in the reactor
- **High precision machining** and smooth surface needed for optimized electrical contact (avoid electrical arcing and silicon over heating)

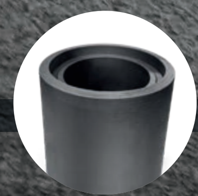
Grades	
Purified Grade **2910 UHP5 (< 5 ppm)**	High thermal shock resistance, high purity
Purified Grade **2191 UHP5 (< 5 ppm)**	High thermal conductivity, high strength, high purity

MERSEN SOLUTIONS - CONVERTER

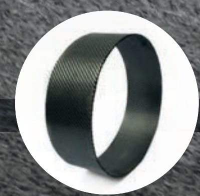
- Graphite parts with an improved resistance to methanization above 900°C (C+2 H_2) thanks to SiC coated graphite.

Grades	
2303 SiC coated	Fine grain grade, long lifetime in an aggressive environment
6501 SiC coated	Cost effective grade with SiC coating, very competitive.

COMPLEMENTARY PRODUCTS



CALCARB® CBCF



AEROLOR® CFC

CZOCHRALSKI PROCESS
Silicon crystals growth

HOT ZONE EXPERTISE.

MERSEN provides complete solutions for CZ crystal growth furnaces, including graphite parts, insulation packages as well as Carbon Fiber Composites (CFC)

PROCESS

The Czochralski (CZ) method is a crystal growth technology that starts with insertion of a small seed crystal into a melt in a crucible, pulling the seed upwards to obtain a single crystal.

SUSCEPTOR

- **High corrosion resistance** with low porosity / high density graphite to reduce reactive area on SiC conversion
- **SiC coated graphite** possible to reduce the porosity of the material for an improved resistance to corrosion (SiO attacks)
- **Good resistance to stress** of SiC conversion through high flexural strength and appropriate CTE
- **Purity levels** below 5 ppm to avoid contamination

Grade	2124

HEATER

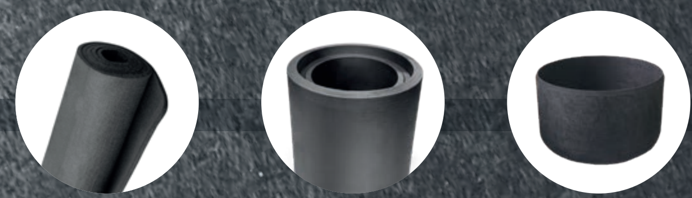
- **Appropriate and uniform electrical resistivity** for an improved quality of the Si ingot
- **High temperature resistance** of the graphite at Si melting point - 1,400°C (2,550°F)
- Homogenous heat distribution with a **heater in a single part** / no hot spots
- **High purity** to meet application requirements
- **Low porosity** graphite for an extended lifetime and an improved resistance to corrosion
- **Medium flexural strength** for flexibility of assembly and good resistance to potential breakages

Grades	2020	1940

TREMENDOUS STRESS

During cooling cycles, the susceptor material starts shrinking when the temperature goes down.
The coefficient of thermal expansion of the silica crucible is extremely small, only about one-tenth of that of the susceptor material, generating tremendous stress.

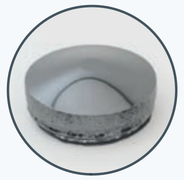
COMPLEMENTARY PRODUCTS



CALCARB® SOFT FELT

CALCARB® CBCF AND LF7

AEROLOR® CFC

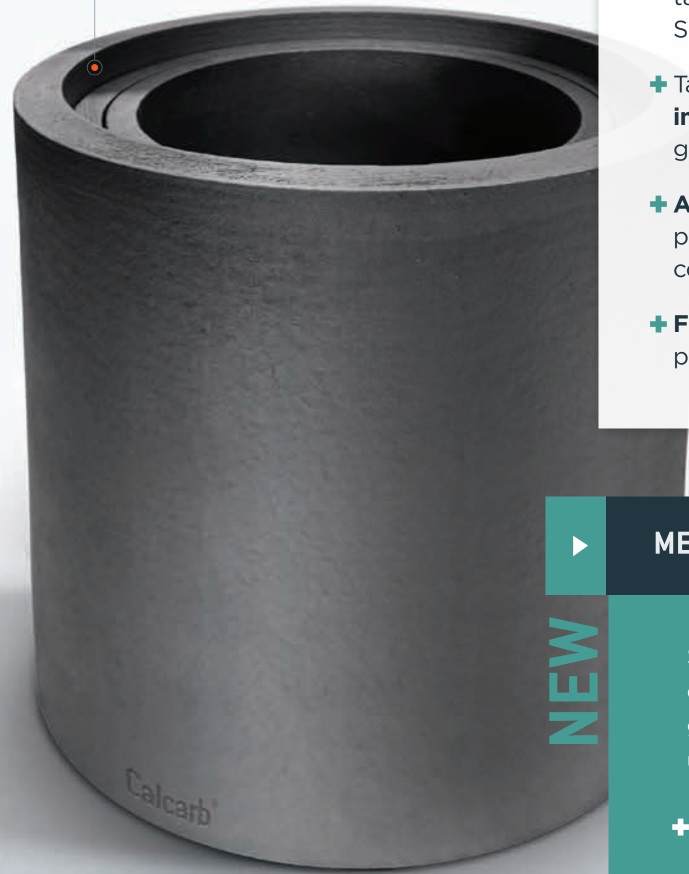


SUBLIMATION GROWTH
Physical Vapor Transport (PVT)

READY FOR THE NEXT GENERATION OF POWER DEVICES.

MERSEN provides a complete solution for sublimation growth process, from isostatic and porous graphite to high performance graphite insulation.

FINE GRAIN GRAPHITE GRADE



HIGH PERFORMANCE INSULATION CYLINDER WITHIN CYLINDER WITHIN CYLINDER CALCARB®EDGE

PROCESS

In physical vapor transport (PVT) often called as sublimation growth, a source material held at a given temperature sublimates, and its vapor is transported by diffusion and convection to the seed crystal held at a lower temperature where it can crystallize. Silicon carbide (SiC), gallium nitride (GaN), aluminum nitride (AlN), zinc oxide (ZnO), and other materials have attracted attention as next-generation power devices. These monocrystalline manufacturing processes involve high temperatures and harsh environments using corrosive gases such as ammonia and hydrogen chloride.

MERSEN SOLUTIONS

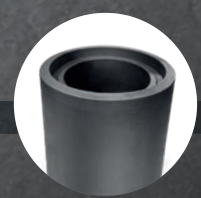
- **High temperature resistance** as process undergoes sublimation at the source at a high temperature (1,800-2,600°C/3,270-4,710°F) and low pressure.
- **TaC coated graphite** for an outstanding resistance to heterogeneous chemical reactions of Si- and C- containing gas species.
- Tac coating to **prevent incorporation of carbon inclusions** into the grown crystals for an improved growth rate and size of the crystals
- **Appropriate CTE** of the graphite to prevent pealing phenomena of coated parts generating potential contamination
- **Fine grain graphite grades** for intricate and precise design

NEW MERSEN POROUS GRAPHITE

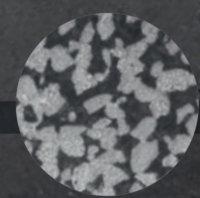
SiC crystal quality is related to the purity of the powder source, but the use of porous graphite tends to provide wafers with better uniformity in resistivity value.

- **Blocks impurities** with a lower intensity of Al, B and Ti impurity concentration
- **Improves uniformity** of radial temperature gradient and the temperature distribution inside the crucible
- **Stabilizes gas flows** for a homogeneous flow of reactive species and lower boule defects
- **SiC vapors are enriched of carbon** for a better control of the stoichiometry in the vicinity of the boule

COMPLEMENTARY PRODUCTS



CALCARB®EDGE 15% ENERGY SAVINGS



POROUS GRAPHITE

CALCARB® SOFT FELT

WAFER PREPARATION - EPITAXY

Create a perfect crystalline foundation layer.

HIGH PURITY SiC COATED GRAPHITE.

Ultra-pure, superior heat resistance, even thermal uniformity and outstanding durability against in-situ cleaning.

MERSEN SOLUTIONS

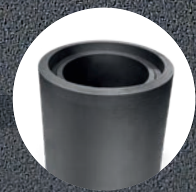
- **Superior high temperature resistance** as process undergoes 1,500+ °C (2,730°F)
- **High purity** SiC coated graphite to avoid pollution of the process
- **Fine** SiC coated graphite for a smooth surface
- **Superior lifetime** with ultra-pure SiC or TaC coated graphite against aggressive gases being used
- **Even thermal uniformity** of the graphite for an improved quality of the process
- **High durability** against in-situ chemical cleaning

Grades	2380	2320

PROCESS

Applications with the toughest requirements call for silicon wafers with an especially high surface quality. In these cases, a thin, defect-free crystal layer is additionally deposited onto the polished surface from the gas phase. To apply the epitaxial layer, the silicon wafer is fastened to a susceptor and heated to a high temperature with the help of infrared lamps (for Si). The process gas flow and temperature are carefully controlled in order to create an epitaxial layer with a very homogeneous resistance and thickness profile.

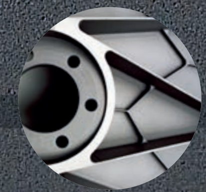
COMPLEMENTARY PRODUCTS



CALCARB® CBCF

TaC COATED GRAPHITE

SiC COATED GRAPHITE



BOOSTEC® SiC + SiC CVD

ATOMIC LAYER DEPOSITION (ALD)

Ultimate precision and layer uniformity at even the finest nodes.

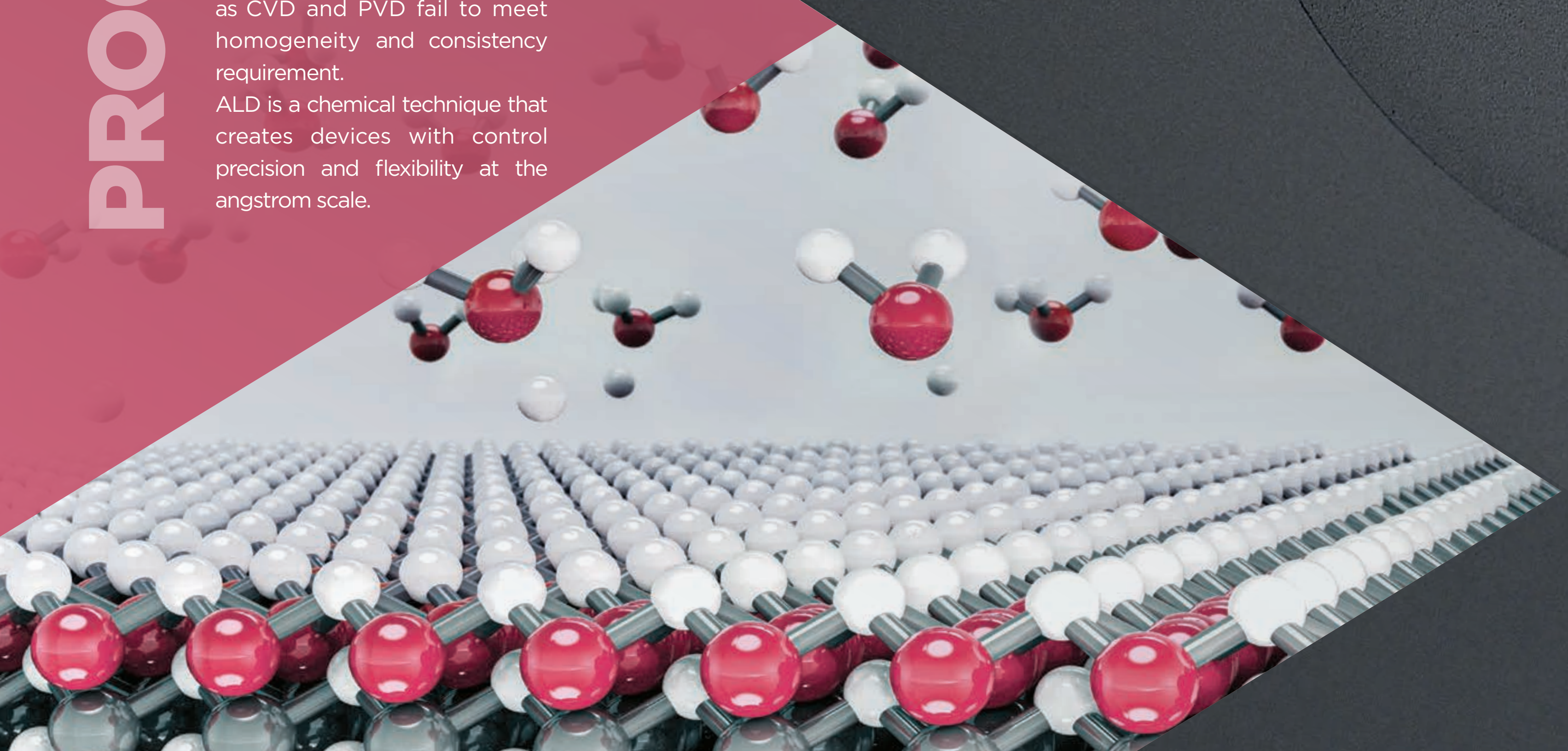
SUSCEPTORS FOR YIELD IMPROVEMENT AND LIFETIME ENHANCEMENT.

FROM ONE POCKET TO XXL SUSCEPTOR DIAMETER.

MERSEN has a unique capability in the production of premium isostatic graphite grades for the semicon industry. Thanks to its expertise, MERSEN produces graphite susceptors with outstanding flatness and exceptional precision required by the industry.

PROCESS

When the required film thickness starts to approach the nanometer scale, conventional thin film deposition techniques such as CVD and PVD fail to meet homogeneity and consistency requirement.
ALD is a chemical technique that creates devices with control precision and flexibility at the angstrom scale.



UNIQUE LARGE DIAMETER CAPABILITIES WITH OUTSTANDING FLATNESS

MICROMETER MACHINING ACCURACY

MERSEN SOLUTIONS

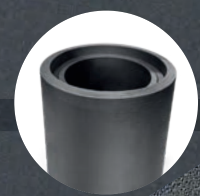
- Unique production capabilities of **large diameter** graphite parts (up to 1,500 mm / 60")
- **Machining expertise** to produce intricate large dimension susceptors
  - **2.5-4.0 µm** range for top surface roughness
  - **0.4-2.0 µm** for pocket sealing edge roughness
- **Outstanding flatness** of the susceptor
- **Fine grain grades** for intricate design

SiC COATING ENHANCEMENT

- **Prevent delamination** / SiC wafer contamination
- **Extended lifetime** - prevent precursors to attack the susceptor
- **Provides additional protection** during cleaning processes

Grades	2303	2320	2380

COMPLEMENTARY PRODUCTS



CALCARB® CBCF

SiC COATED GRAPHITE

ION IMPLANTATION
Turning the wafer into a semiconductor

EXTEND LIFETIME.
PREVENT CONTAMINATION.

Mersen produces beam liners, electrodes, apertures, and beam stops with wear resistant, ultra-pure graphite for stable and repeatable processes.

MERSEN SOLUTIONS

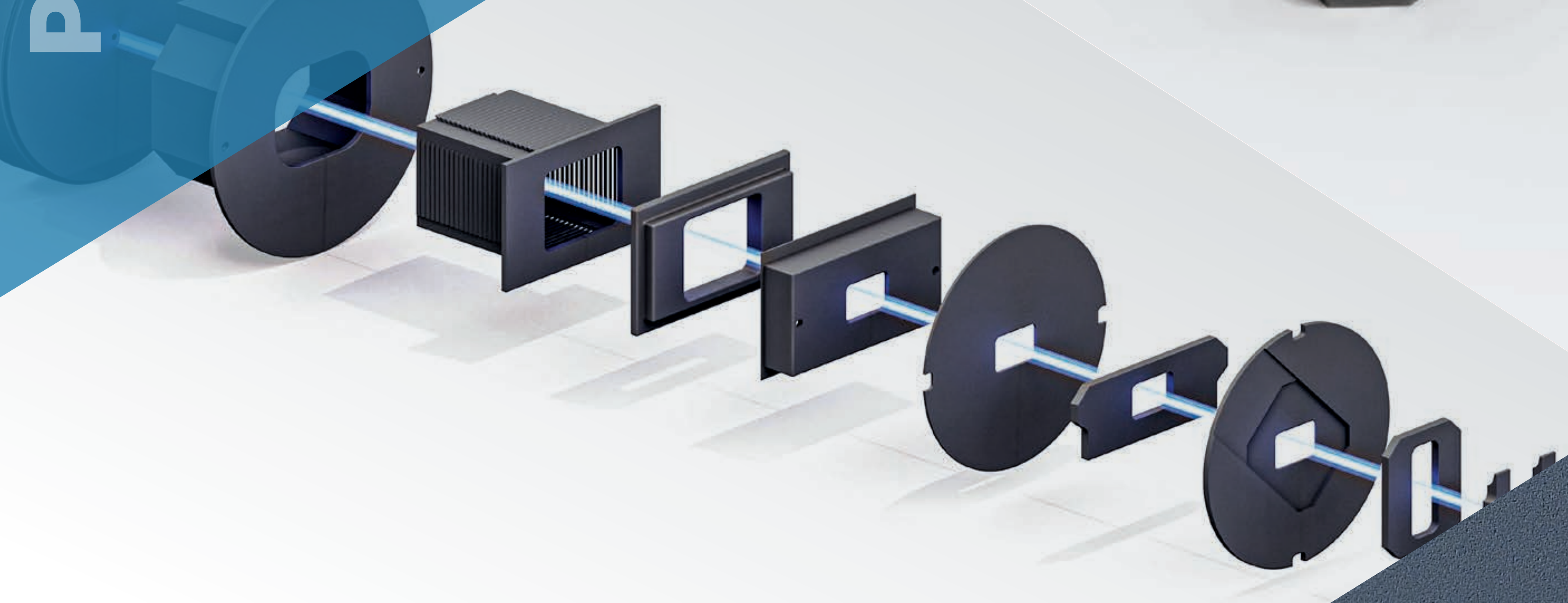
- **Wear resistant graphite** to avoid contamination of the wafer due to particle erosion
- **High strength / high hardness** graphite for repeatable and stable process performance
- **Avoid outgassing of contaminants** in selecting fine-grain graphite with limited porosity
- **Ultra-pure** graphite to avoid metal contamination
- **Reduce particle** generation by sealing the surface with PyC coated graphite
- **Encapsulate particles** with VCI impregnation

Grades

2160	Standard grade for ion implant.
2340	Fine grain, high hardness, small pore size, reduced porosity.
2120	Cost effective grade for less sensitive parts - away from the beam.

PROCESS

Implanter systems dope wafers with ions to modify material properties such as conductivity or crystal structure. The beam path is the center of an implanter system. Here the ions are generated, concentrated, greatly accelerated, and focused on the wafer at very high speeds.



COMPLEMENTARY PRODUCT

P-SIC® SOLID
SiC CVD

HIGH PERFORMANCE GRAPHITE.

ENHANCED.

SiC COATED GRAPHITE

HIGHER YIELD.

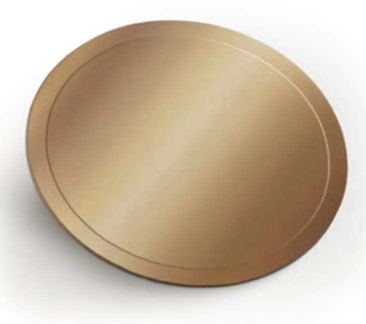
High purified graphite coated with a fine layer Silicon Carbide using a Chemical Vapor Deposition (CVD) process that provides exceptional protection against corrosion, oxidation, and chemical attack.

- Extended lifetime of the graphite parts
- Reaction stoichiometry is maintained
- Avoid impurity migration for improved quality
- Excellent oxidation resistance, corrosion resistance and chemical resistance
- Stable at high temperature
- Outstanding thermal conductivity and excellent heat distribution of both graphite and Silicon Carbide layer for improved yield
- Extreme hardness of the Silicon Carbide layer
- Excellent CTE match between graphite and coating material for a great stability and longer lifetime

TaC COATED GRAPHITE

EXTREME TEMPERATURE.

High purified graphite coated with a fine layer of TaC (tantalum carbide) using a Chemical Vapor Deposition (CVD) process that provides a non-porous surface. TaC coating protects graphite parts in harsh envionments at extreme high temperatures.



- Stable at extreme temperatures (alternative to SiC coatings when temperature exceeds CVD Silicon Carbide coating capabilities)
- Protection in harsh chemical environments and in-situ cleaning - Resistance to H_2, NH_3, SIH_4 and Si
- Ultra-high purity to prevent contamination of the process
- High resistance to thermal shocks for faster operation cycles
- Improved lifetime usage without coating delamination
- Extremely hard coating with excellent resistance to wear and abrasion

PYRO COATED GRAPHITE (PyC)

IMPERMEABLE.

High purified graphite coated with a fine ayer of pyrolytic carbon using a Chemical Vapor Deposition (CVD) process that provides a non-porous surface.

- Chemically inert with a good protection against chemical corrosion and in-situ cleaning
- High purity to minimize contamination risks
- Surface is sealed / low surface permeability for use in high-vacuum applications
- Prevent dust particles to avoid contamination of the process
- Harder surface than the graphite substrate for an improved resistance to abrasion
- Stable at extreme temperatures
- Acid resistant parts

VITREOUS CARBON IMPREGNATION (VCI)

PARTICLE RESTRICTER.

High purified graphite is impregnated with glass-like carbon.

- Prevent dust particles to avoid contamination of the process
- High purity to minimize risks of contamination
- Stable at high temperature
- Extended lifetime of the graphite parts

GREAT STIFFNESS & GEOMETRICAL STABILITY

FOR OUTSTANDING ACCURACY.

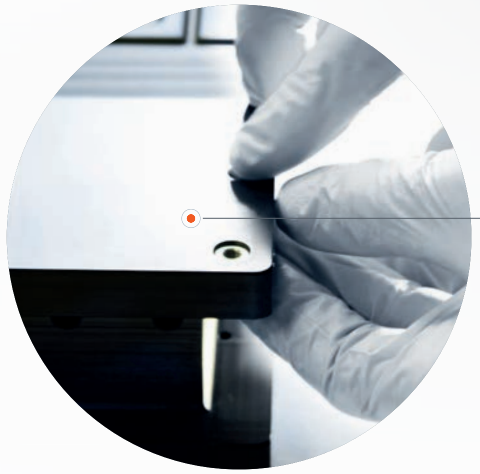
Boostec®SiC is a polycrystalline technical ceramic of α SiC type, obtained by pressureless sintering. This process leads to a silicon carbide that is completely free of non-combined silicon.

This material has a great stiffness, which provides advantageous vibrational behaviour, very good thermal conductivity and low thermal expansion, which produces great geometrical stability under load and over time.

WAFER CHUCKS AND FRAME PARTS / STRUCTURAL COMPONENTS FOR METROLOGY, MEASURING SYSTEMS, INDEXING AND POSITIONING

Application: Holding and support plates for Si wafers for various processes during chip production in the semiconductor industry. Brackets, fixtures and structural components for metrology, measuring systems, lenses, mirrors and/or sensors.

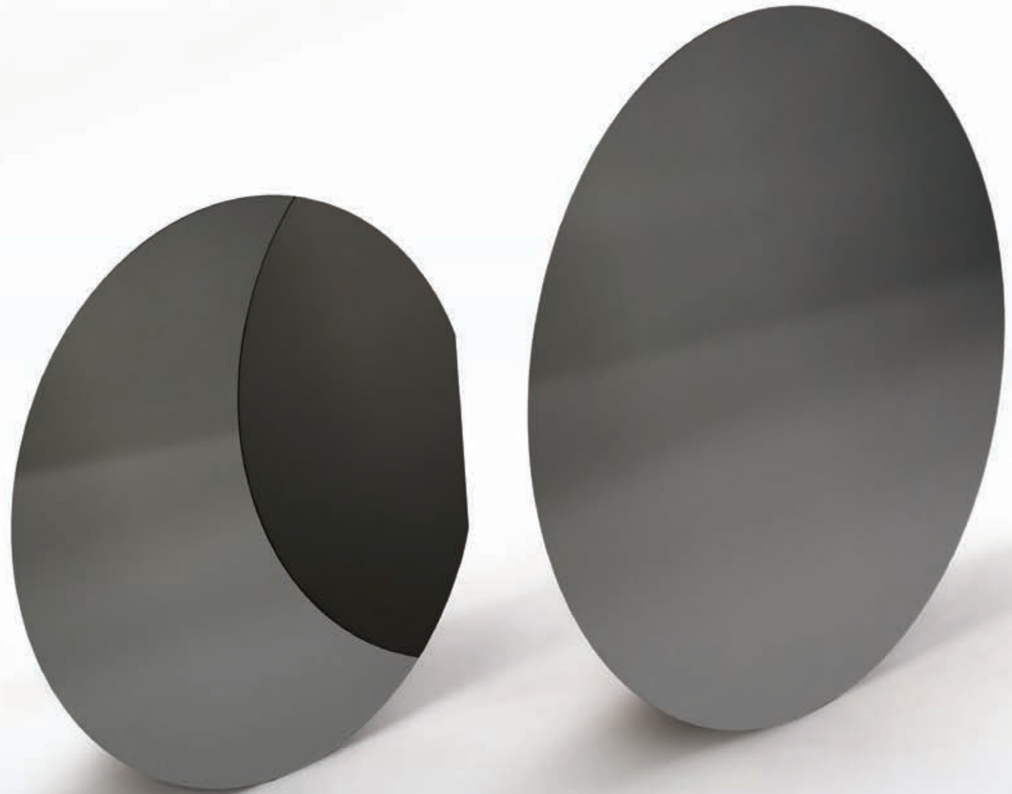
- **Rigidity**
- **Low thermal expansion**
- **Low weight**
- **Geometrical stability**
- **Non magnetic**
- **Polishable**



HIGH STABLE STRUCTURES FOR METROLOGY FROM 10mm TO SEVERAL METERS TO AVOID HOT SPOTS

TAILORED RESISTIVITY ULTRA-PURE SOLID SiC BY CVD

ENGINEERED FOR SEMICON APPLICATIONS.



MATERIAL OUTSTANDING KEY PROPERTIES

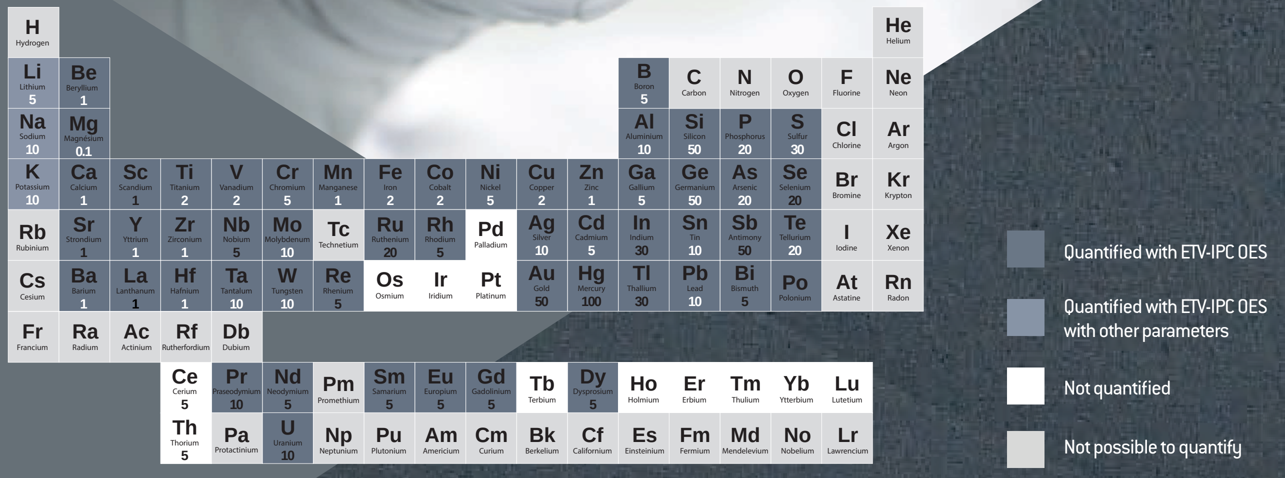
- **High thermal shock resistance –** for improved ramp rates and component life
- **n-doped polycrystalline SiC** (p-SiC)
- **Tailored resistivity down to** < 5 µohm.cm (0.0000019 ohm-in)
- **High CVD purity**
- **High density** / no porosity
- **High thermal conductivity:** >230 W/m.K (>133 BTU h·ft·°F) at room temperature)
- **Withstands cleaning processes –** Highlyresistant to concentrated hydrofluoric HF and nitric acid (HNO_3) wet cleans and high temperature in-situ etching with gaseous HCl
- **High to low transmissivity** grades available for applications where optical or infrared transmissivity is critical
- **Low thermal mass –** high-strength and stiffness allows the use of thin, light-weight components

PURIFICATION EXPERTISE

MASTERING PURITY

WE TAYLOR-MADE PURIFICATION PROCESS TO ANSWER TO YOUR REQUIREMENT.

By adjusting the temperature and the time of the process, our experts in purification answer to the most stringent requirement of the semiconductor industry.



ETV-ICP

ELECTROTHERMAL VAPORIZATION - INDUCTIVELY COUPLED PLASMA

HOW?

Atomization principles

+ Samples in high purity graphite are heated rapidly to high temperatures (2,800°C / 5,070°F).
+ Analytes are vaporized in the presence of halogenated modifier gas and transported directly into inductively coupled plasma region of ICP instruments.

Inductively Coupled Plasma

+ The gas carrying analytes (fluorides with impurities) is introduced into a plasma chamber. Molecules are excited under plasma and emit light with different wavelengths characteristic of each element of impurity.

Optical Emission Spectrometry

+ Light is then decomposed by wavelength through a polychromator (prism-like) and quantified by detector. Light intensity at a given wavelength is directly proportional to the concentration of an element in the plasma. Thus the exact concentration of each element can be calculated.

WHAT?

Parts Per Billion (ppb)

+ Low limits of detection for most elements of the periodic classification.

YOUR BENEFITS

+ In-house capabilities of measurement
+ Accurate
+ Easy calibration
+ Rapid results

MERSEN MATERIAL GRADES

CALCARB® RIGID HIGH TEMPERATURE INSULATION

GRADES	CBCF 14	CBCF 15	CBCF 18	CBCF 25	EDGE
DESIGN AVAILABILITY	BOARD / CYLINDER / DISK / COMPONENTS	CYLINDER	BOARD / CYLINDER / DISK / COMPONENTS	BOARD / DISK / COMPONENTS	BOARD / CYLINDER
BULK DENSITY g/cm^3	0,14 +/- 0,03	0,15 +/- 0,03	0,18 +/- 0,03	0,25 +/- 0,03	0,16 +/- 0,02
COMPRESSIVE STRENGTH MPa	1,09	0,80	1,10	2,10	1,10 +/- 0,5
FLEXURAL STRENGTH MPa	1,65	1,50	1,03	2,70	1,30 +/- 0,5
COEFFICIENT OF THERMAL EXPANSION (CTE) - 25° TO 1,000°C	3,0 +/- 0,2 x 10^{-6}	3,0 +/- 0,2 x 10^{-6}	3,0 +/- 0,2 x 10^{-6}	3,0 +/- 0,2 x 10^{-6}	3,10+/- 0,2 x 10^{-6}
1,000° TO 2,000°C	2,6 +/- 0,2 x 10^{-6}	2,6 +/- 0,2 x 10^{-6}	2,6 +/- 0,2 x 10^{-6}	2,6 +/- 0,2 x 10^{-6}	2,6 +/- 0,2 x 10^{-6}
SPECIFIC SURFACE AREAS - m^2.g^{-1}	22	20	18	11	22
THERMAL CONDUCTIVITY* W/m.K	VACUUM / NITROGEN	VACUUM / NITROGEN	VACUUM / NITROGEN	VACUUM / NITROGEN	VACUUM
400°C	0,05 / 0,09	0,11 / 0,159	0,17 / 0,224	0,30 / 0,325	0,16
800°C	0,12 / 0,19	0,16 / 0,237	0,22 / 0,317	0,38 / 0,415	0,22
1,200°C	0,25 / 0,378	0,29 / 0,409	0,32 / 0,485	0,48 / 0,531	0,32
1,600°C	0,45 / 0,579	0,52 / 0,689	0,55 / 0,724	0,64 / 0,723	0,46
2,000°C	0,61 / 0,879	0,85 / 1,041	0,84 / 1,170	0,92 / 1,080	0,60
BOARD SIZE (MAX)	1,500 x 1,500 mm	1,500 x 1,500 mm	1,500 x 1,500 mm	1,500 x 1,500 mm	1,500 x 1,500 mm
BOARD THICKNESS (MAX)	250 mm	250 mm	250 mm	250 mm	250 mm
DISK DIAMETER	from 635 mm to 1,854 mm	N/A	from 635 mm to 1,854 mm	from 635 mm to 1,854 mm	from 635 to 1,854 mm
DISK THICKNESS (MAX)	406 mm	N/A	406 mm	406 mm	407 mm
CYLINDER OD (MAX)	1,651 mm	1,100 mm	1,651 mm	N/A	1,651 mm
CYLINDER HEIGHT(MAX)	350 mm	500 mm	880 mm		350 mm
MAX WALL THICKNESS	40 mm	55 mm	55 mm		40 mm

Rigid insulation product enhancement available : Silicon Carbide (SiC) ; CVI Pyrocarbon ; CVD coating ; Graphite paint coating ; graphite foiled, wear protect

Declared purity levels reached with Halogen Purification (HP) process.	
GUARANTEED**	< 20 ppm
TYPICAL*	< 5 ppm

*Reflects the measurement of 5 metals. Al,Cu,Fe,Cr,Ni **Reflects measurement of 34 elements

ISOSTATIC GRAPHITE

		1940	2020	2120	2124	2160	2191	2303	2320	2340	2380	2910
BULK DENSITY	g/cm^3	1,79	1,78	1,87	1,84	1,84	1,75	1,76	1,80	1,90	1,82	1,74
	lbs/ft^3	112	111	117	114	114	109	110	113	118	114	109
ELECTRICAL RESISTIVITY	μΩ.cm	1,397	1,550	1,220	1,140	1,370	1168	1,372	1,120	1,320	991	1,600
	Ω-inch	0.00055	0.00061	0.00048	0.00045	0.0005	0.00046	0.00054	0.00044	0.00052	0.00039	0.00069
FLEXURAL STRENGTH	MPa	43	45	76	66	78	44	40	50	103	52	30
	psi	6,300	6,500	11,000	9,500	11,400	6,400	5,800	7,300	15,000	7,500	4,400
HARDNESS	shore	63	52	70	68	72	55	59	60	75	60	55
THERMAL CONDUCTIVITY	W/m°C	93	85	105	112	102	110	95	122	105	131	77
	Btu-Ft/Ft^{2}Hr°F	54	49	60	65	59	64	55	71	60	76	45
COEFFICIENT OF THERMAL EXPANSION (CTE) ASTM E228	x10^{-6}/C°	5.2	4.0	6.0	5.5	5.5	4.2	4.8	4.8	7.5	4.8	4.1
	x10^{-6}/F°	2.9	2.2	3.3	3.1	3.1	2.3	2.7	2.7	4.2	2.7	2.3

BOOSTEC® SiC

		Temperature	Typical value	Unit
THEORITICAL DENSITY		20°C	3.21	10^3 kg/m^3
TOTAL POROSITY (FULLY CLOSED)		20°C	1.5	%
COEFFCIENT OF THERMAL EXPANSION		20°C	2.2	10^{-6} /°C
THERMAL CONDUCTIVITY		20°C	180	W/m.K
BENDING STRENGTH (DIN EN 2188-1 & 5)	MECHANICAL STRENGTH	20°C	400	MPa
	WEIBULL MODULUS	20°C	11	MPa
YOUNG'S MODULUS		-200°C to 1,000°C	420	GPa
OUTGASSING (ESA EC SS-Q-70-02A)	TML (TOTAL MASS LOAD)	20°C / 200°C	0. 01	%
	CVCM (COLLECTED VOLATILE CONDENSABLE MATERIALS)		0.0	%

CFC AEROLOR®

		AEROLOR® A015	AEROLOR® GALAXY
BULK DENSITY	g/cm^3	1,65	1,45
	lbs/ft^3	103	90
FLEXURAL STRENGTH	MPa	160	120
	psi	23,200	17,400
TENSILE STRENGTH	MPa	140	100
	psi	20,300	14,500
ASH CONTENT	ppm	< 200	< 200
PROCESSING TEMPERATURE	°F	>3,630	>3,630
	°C	>2,000	>2,000

SOFT FELT

	SOFT FELT
BULK DENSITY g.cm^3	0,075 +/- 0,01
FLEXURAL STRENGTH MPa	0,051
MODULUS OF ELASTICITY GPa	0,558
IMPURITY ppm	< 400
ASH CONTENT	< 0,06 %
TEMPERATURE PROCESS (MIN)	2,000°C
CARBON CONTENT (ESTIMATED)	> 99,94 % 1,93 AT 1,000°C
THERMAL CONDUCTIVITY* W/m.K	VACUUM
800°C	0,207
1,000°C	0,257
1,200°C	0,329
1,400°C	0,413
1,600°C	0,524
1,800°C	0,657
2,000°C	0,812
THICKNESSES	6/8/10/12 mm

*Thermal conductivity measured with laser fl ash ; results would be signifi cantly lower with hot plate.

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