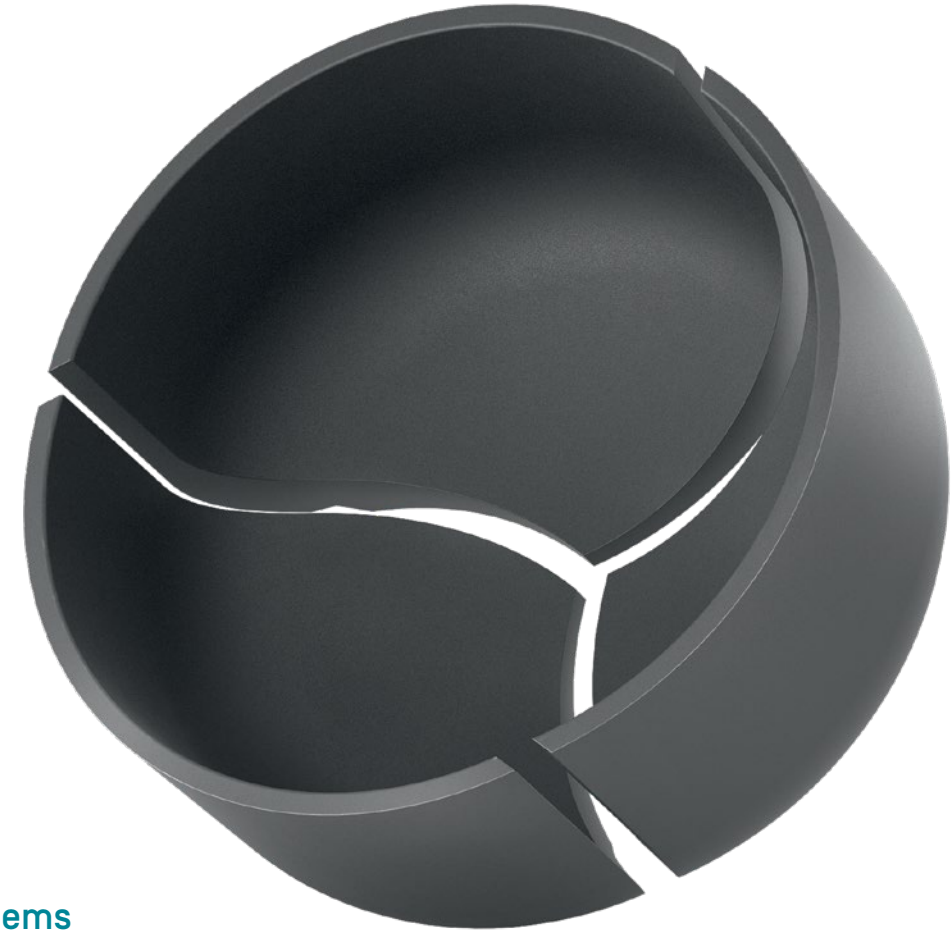
sgl carbon

The Sun Supporters

Our specialty graphites for the photovoltaic industry

SIGRABOND®
SIGRAFIL®
SIGRAFINE®
SIGRAFLEX®
SIGRATHERM®



Graphite Materials & Systems

2000

SIGRAFINE® isostatic graphite
Size matters

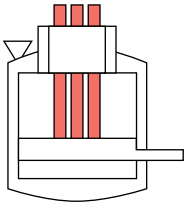
Silicon-based solar cells promise to be a cornerstone for the power supply by sustainable energy sources. To cover the increasing demand, economy of scale counts. Thanks to the world's largest cold isostatic press with a diameter of 1800 mm, height of >2000 mm and a maximum pressure of 2000 bar, we are able to press green carbon bodies in various geometries and grades.

This is just one of our smart solutions along the entire PV value chain from the heat treatment to coating and purification of finished parts and a way to support the world with safe energy.

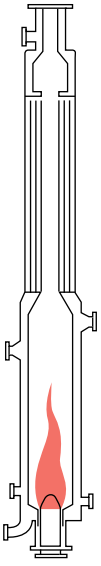

mm

Our specialty graphites for the photovoltaic industry

Most processes in the photovoltaic value chain operate at high temperature and in an extremely corrosive environment. At the same time, high purity and precision are required to produce solar silicon grades. Our specialty graphites are indispensable to fulfill the tight specifications of the photovoltaic industry.



↑ Refining metallurgical grade silicon

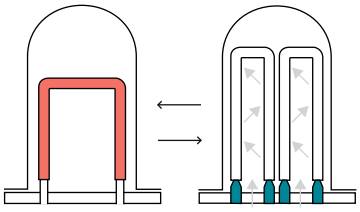


↑ HCl synthesis

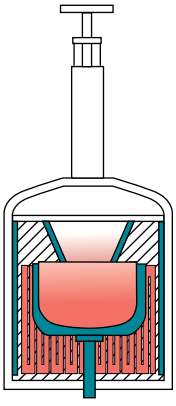
Value chain	Upgrading metallurgical grade silicon (UMG)	Trichlorosilane (TCS) production
Typical applications	• UMG silicon	• Trichlorosilane
Products of SGL Carbon	• Crucibles • Heaters	• HCl synthesis units
Materials used by SGL Carbon	• SIGRAFINE® isostatic, extruded and vibration molded graphite	• SIGRAFINE® extruded and vibration molded graphite

Learn more about our process technology: www.sglcarbon.com

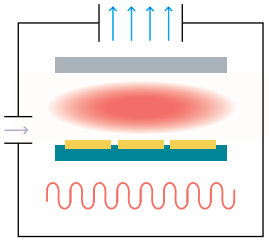
We offer efficient solutions, starting with highly pure graphite electrodes for the deposition of highly pure polysilicon. We also supply finished articles like heaters, crucibles and insulation components for Czochralski pulling of monocrystalline silicon ingots. Our portfolio is completed by wafer carriers for PECVD units made of isostatic graphite or carbon-fiber reinforced composites with state-of-the-art designs.



↑ Converter / Siemens reactor



↑ Monocrystalline Si growth

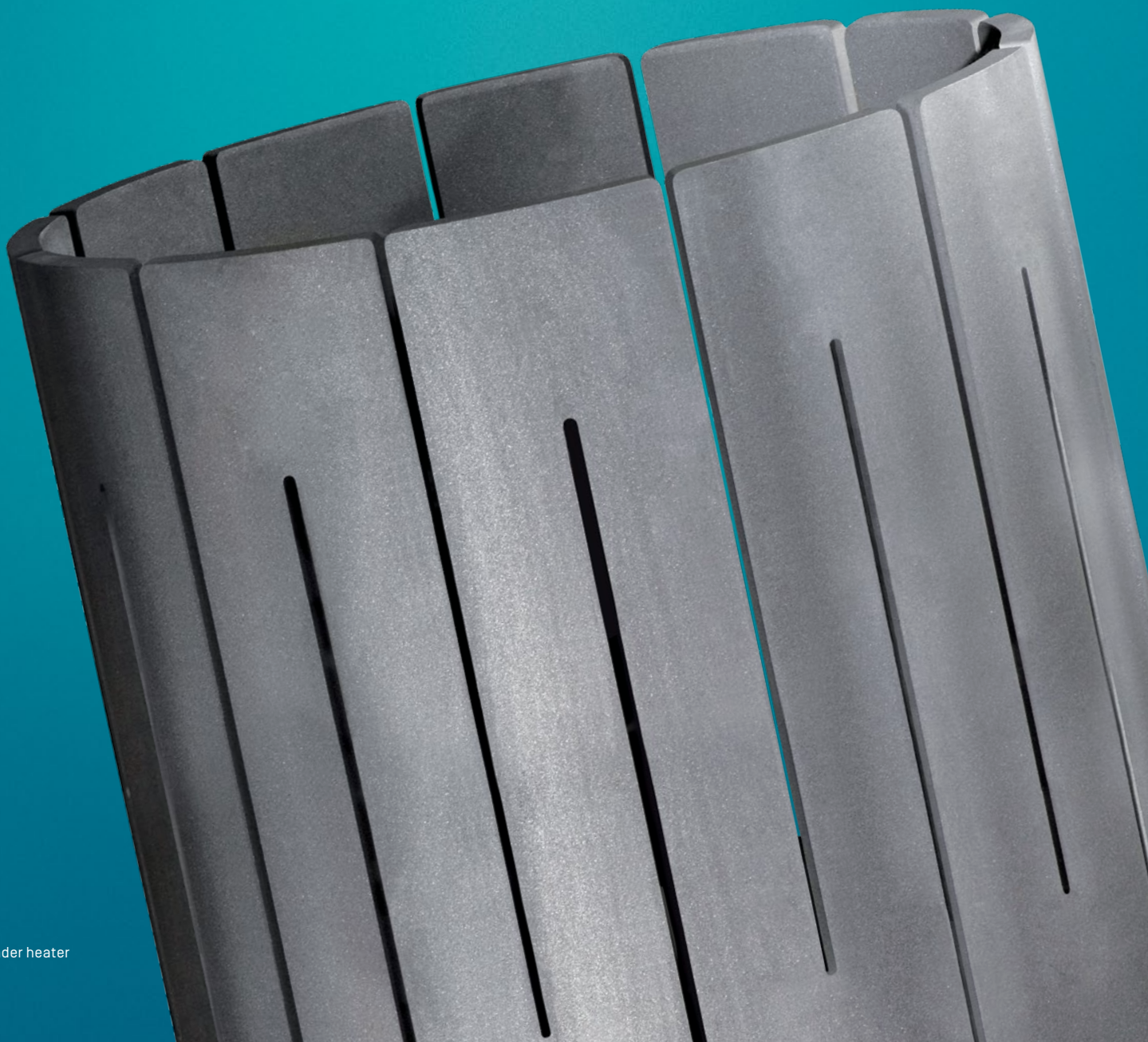


↑ Plasma-enhanced chemical vapor deposition (PECVD)

Polysilicon production	Growing monocrystalline silicon	Antireflection and passivation layer deposition
• Polysilicon	• Monocrystalline silicon	• Silicon nitride/oxide • Aluminum oxide
• Heating elements • Heat shields • Insulation • Graphite chucks	• Heaters • Crucibles • Insulation • Heat shields	• Carrier boats • Single wafer trays
• SIGRAFINE® isostatic and extruded graphite • SIGRAFINE® SiC coating • SIGRATHERM® carbon and graphite felts • SIGRABOND® carbon fiber-reinforced carbons and graphites • SIGRAFLEX® expanded flexible graphite foil	• SIGRAFINE® isostatic and extruded graphite • SIGRAFINE® SiC coating • SIGRATHERM® carbon and graphite felts • SIGRABOND® carbon fiber-reinforced carbons and graphites • SIGRAFLEX® expanded flexible graphite foil	• SIGRAFINE® isostatic graphite • SIGRABOND® carbon fiber-reinforced carbons and graphites

Products for the photovoltaic industry

We supply tailor-made graphite products along the entire value chain of silicon-based solar cells: electrodes, heating elements, heat-shields and insulation parts for the polysilicon production and monocrystalline silicon ingot growth.
We also provide individualized finishing steps like purification, mechanical processing or coating.



Meander heater

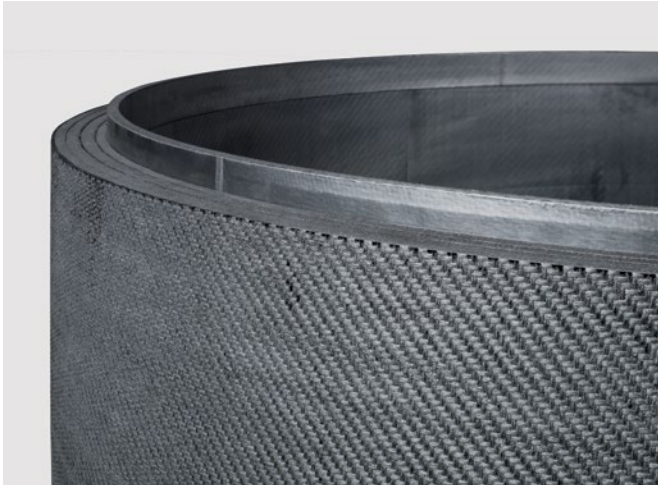
Solutions for polysilicon production

Surviving the process
Material components in fluidized bed/Siemens reactors and STC-TCS converters are subjected to temperatures up to 1000 °C (1800 °F) and highly corrosive environments. Our graphite specialties are extremely resistant to heat and corrosion and increase the yield of the processes.

Solution pool
We have been supplying polysilicon producers with a wide range of engineered solutions for many years including purified electrodes for polysilicon deposition, heaters, gas ducts for STC-TCS converters, heat shields and thermal insulation components. The applied materials are SIGRAFINE isostatic, extruded and vibration molded graphite, SIGRATHERM graphite rigid felts, SIGRABOND carbon fiber reinforced carbon and SIGRAFINE SiC coating.

Customizing shape, size and surface
Our experts select the best materials for our comprehensive portfolio and manufacture custom-tailored products. With our shaping and connecting solutions, for example, we supply converter insulation in virtually any length and diameter. To increase the service life of highly stressed components – like those in converters – we offer special silicon carbide (SiC) coatings.

↑ Electrodes (polychucks) for Siemens reactors



↑ Graphite rigid felt cylinder for insulation of converters

You will find technical data sheets for our products in our website: www.sglcarbon.com

Solutions for silicon crystal pulling

↑ Support crucible made from SIGRAFINE isostatic graphite

The hot zone challenge
All processes used to grow monocrystalline silicon ingots operate at high temperatures in aggressive environments – like CZ-growth of PV-grade silicon ingots with silicon vapor as corrosive gas. This is why the hot zones of industrial crystal growth furnaces are generally equipped with heat and corrosion resistant graphite components.

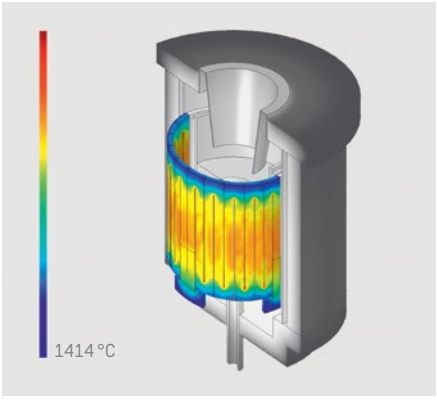
Broad range of materials for monocrystalline silicon ingot pulling
We produce materials for a wide range of typical parts, including heaters, crucibles, reflectors and heat shields made from high-strength, homogeneous fine-grain graphite (SIGRAFINE) or carbon-reinforced carbon (SIGRABOND), as well as insulation components in either rigid or soft felt (SIGRATHERM) and SIGRAFLEX foil. Our experts rely on decades of experience to select the best materials at the highest purity to fit into every type of crystal-growing furnace.

Optimizing the furnace design
Together with our Modelling and Simulation Group we offer thermomechanical and gas-flow dynamics optimization of crystal growth furnaces. The overall consideration of the CZ hot zones allows us to select the right material and to design customized solutions. In this way we support our customers with innovative products and minimize their total cost of ownership.

Learn more about fine-grain graphite on www.sglcarbon.com

Learn more about modeling and simulation on www.sglcarbon.com

↑ Graphite components for CZ units



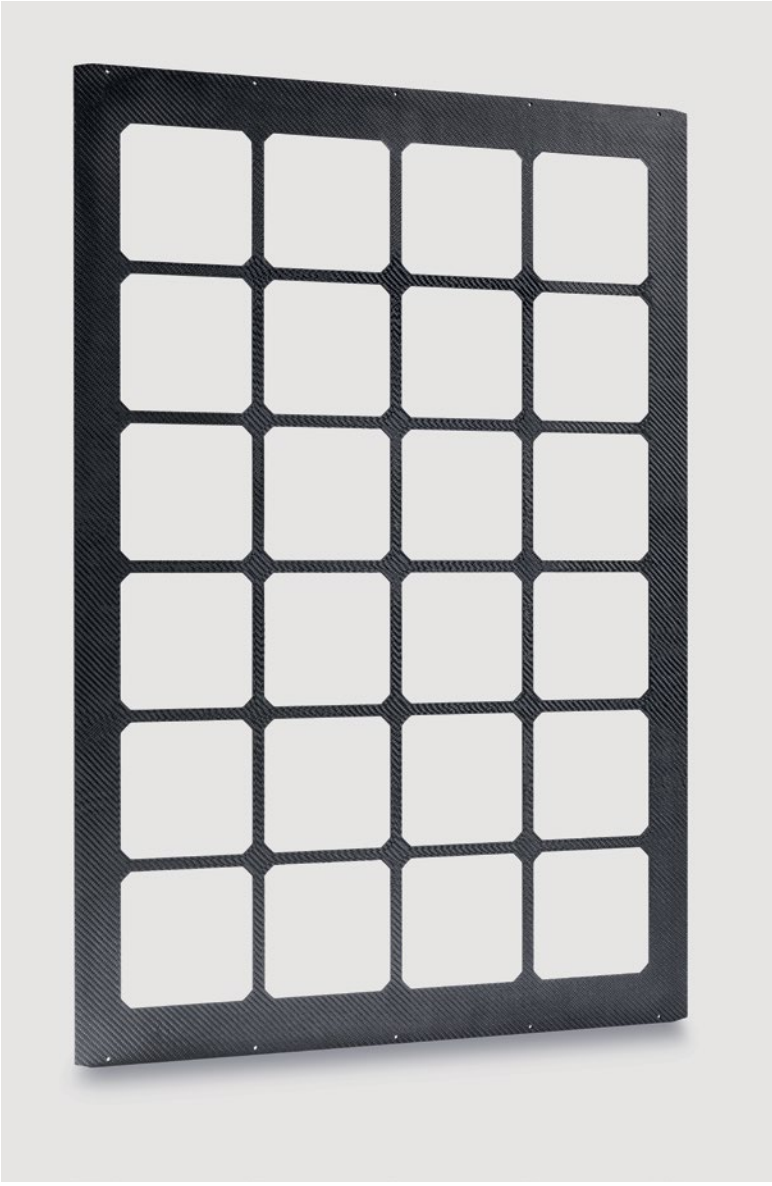
↑ Heater simulation in CZ unit

Solutions for wafer trays in PECVD reactors

Precise positioning
The homogeneity of functional thin-films grown by PECVD is critical for the efficiency of the solar cell and can be affected if the position of the silicon wafer in the PECVD reactor is not exact. To avoid this, we developed precision-made carrier systems from dimensionally stable specialty graphite for carrier boats and carbon fiber-reinforced carbon for wafer trays.

Batch furnaces
To increase the number of plates per carrier boat and to ensure low pump-down times, the flexural strength of the graphite material has to be high and the open porosity should be low. Moreover, isotropic material properties are important for a homogeneous heat distribution at the plates. Our material grades SIGRAFINE R6510 and R6520 perfectly fulfill these material requirements. Boats with graphite plates made of these materials are used to deposit high-end antireflection and PERC layer stacks.

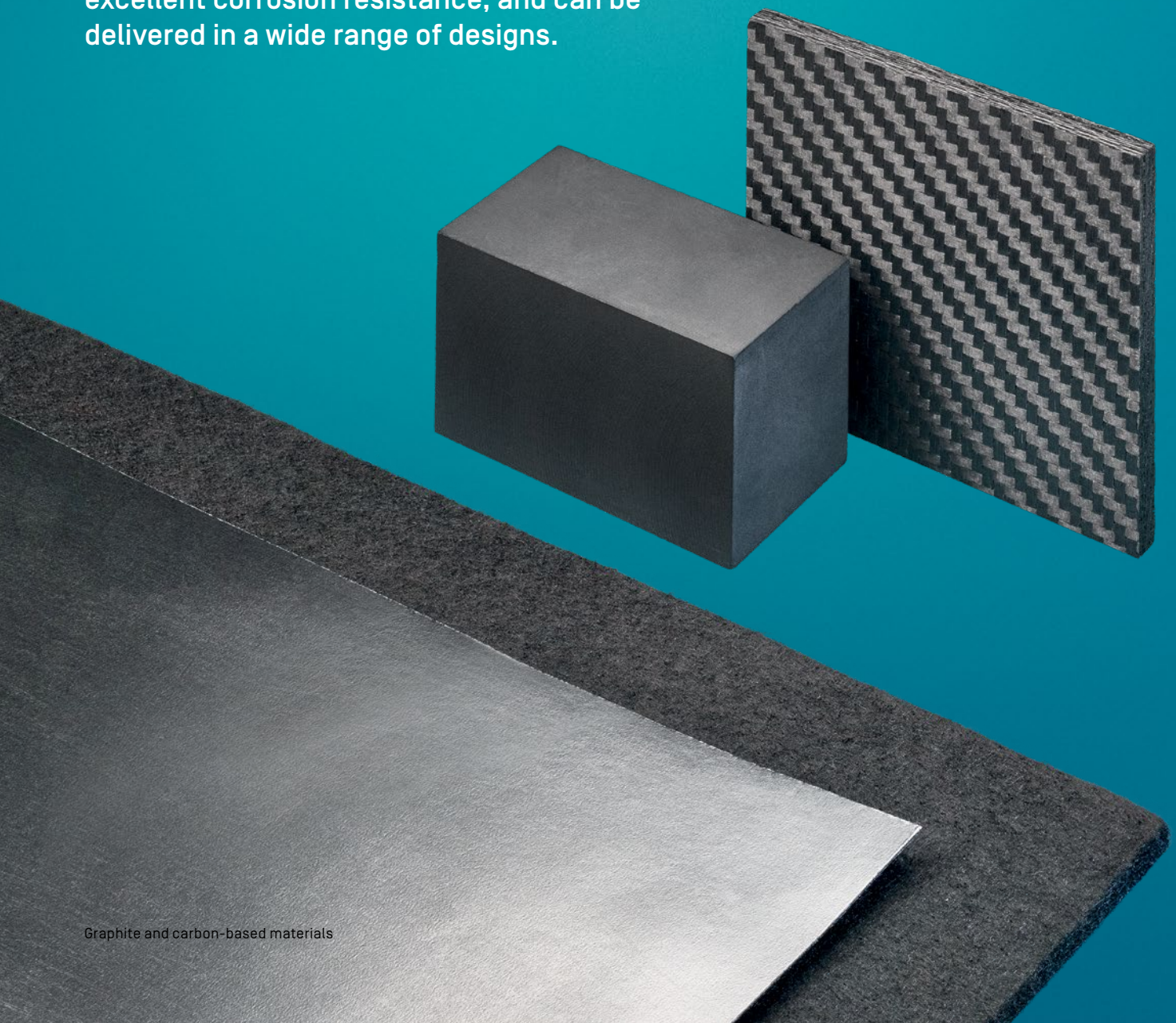
Continuous furnaces
Rigidity and light weight are crucial material parameters to guarantee a stable electrode distance within the plasma reactor. The high Young's modulus and low weight of our carbon fiber reinforced carbon grade SIGRABOND Standard reduces the bending of the carrier. At the same time, the woven structure of this grade enables an easy machinability of the carriers and supports the adhesion of the deposited layers on the CFRC surface. The combination of these properties makes it possible to produce slender wafer trays with a complex geometry for the double-sided deposition of functional PERC and heterojunction layers.



↑ C/C carrier frame for solar wafers

Graphites and carbon-based materials for the photovoltaic industry

We supply fine-grain graphite, SiC coating, graphite soft felts and graphite foil for a great diversity of photovoltaic applications. All of our materials are synonymous with high purity, out-standing mechanical strength and excellent corrosion resistance, and can be delivered in a wide range of designs.



Graphite and carbon-based materials

SIGRAFINE® fine-grain graphites

We produce several isostatic graphite grades, each with distinct properties that make them ideally suited for specific application environments.

R6300/CZ3 is our grade for graphite heaters. The electrical resistivity is constant at high temperatures above ~1000 °C, which is beneficial for use in electrical circuits.

R6340 and R6500 are proven work horses when it comes to multiple uses of isostatic graphite. Both grades are used around the world for various parts, including crucibles, fixtures, electrodes or others. The main difference between both grades is the density and grain size, which results in a different thermal expansion and conductivity.

R6510/CZ5 has become an industry standard when parts are subjected to Si-O gaseous environments. Crystal heat shields and funnels made of R6510 have proven to show long service life and low dusting behavior in CZ hot zones and enable high crystal quality.

Our newly developed grade R6520/CZ5.2 exhibits material properties in the range between R6500 and R6510. It has proven to deliver an outstanding and reproducible performance since the market launch.

R6650 is a high-density grade for even more demanding applications in aggressive media, such as molten silicon or gaseous silicon-oxide.

Please contact one of our experts for information on any materials or technology-related device.

Material data of our isostatic SIGRAFINE® fine-grain graphite

		Isostatic graphite					
Typical properties*	Units	R6300/CZ3	R6340	R6500	R6510/CZ5	R6520/CZ5.2	R6650
Average grain size	µm	20	15	10	10	10	7
Bulk density	g/cm³	1.73	1.72	1.77	1.83	1.81	1.84
Resistivity	µΩm	16	12	14	13	13	14
Flexural strength	MPa	40	45	50	60	55	65
Compressive strength	MPa	85	90	110	130	120	150
Thermal expansion 20–200 °C (68–392 °F)	10^{-6} K^{-1}	2.7	3.2	4.2	4.2	4.2	4.1
Ash content	ppm	≤ 200	≤ 200	≤ 200	≤ 200	≤ 200	≤ 200

* Typical average values of different rectangular and round block sizes. The actual individual block values might vary depending on dimension and format. For any Engineering / Design purpose please always contact our technical sales team.

Material data of our extruded and vibration molded SIGRAFINE® fine-grain graphite

		Extruded graphite	Vibration molded graphite		
Typical properties*	Units	HLM	MKUX	MKUN	MKUS
Average grain size	mm (in)	0.8 (0.03)	0.8 (0.03)	0.8 (0.03)	0.8 (0.03)
Bulk density	g/cm³	1.72	1.74	1.67	1.79
Resistivity	µΩm	7.8/9.5	8.2	10/12	8/9
Flexural strength	MPa	19/19	17	10/10	18/17
Compressive strength	MPa	40/39	38	25/25	41/39
Thermal expansion 20–200 °C (68–392 °F)	10^{-6} K^{-1}	3.0/3.5	3.1	2.3/3.2	2.7/3.3
Ash content	ppm	≤ 800	≤ 2000	≤ 700	≤ 700

* Typical average values of different rectangular and round block sizes. The actual individual block values might vary depending on dimension and format. For any Engineering / Design purpose please always contact our technical sales team.

SIGRAFINE® SiC Coating

High resistance – excellent conductivity
SIGRAFINE SiC coating is a dense, wear-resistant silicon carbide coating. It exhibits high corrosion and heat resistant properties as well as an excellent thermal conductivity. We apply SiC in thin films onto graphite using chemical vapor deposition (CVD) techniques.

Extended service life of graphite and C/C components
The coating improves the surface quality and increases the process efficiency, thus reducing overall operating costs for our customers. Our coating extends the service life of graphite components, increases the resistance against oxidation and achieves the high purity required in processing PV-grade silicon crystals.

Wide range of applications
We supply SiC-coated products made from high-strength isostatic graphite and carbon fiber-reinforced carbon. These include components for fluidized-bed reactors and STC-CTS converters, as well as reflectors for CZ units.

Purity data of SIGRAFINE® SiC coating (glow discharge mass spectroscopy)

Element	ppm	Element	ppm
Sodium	< 0.05	Copper	< 0.01
Magnesium	< 0.01	Zinc	< 0.05
Aluminum	< 0.04	Gallium	< 0.05
Phosphorus	< 0.01	Germanium	< 0.05
Sulfur	< 0.04	Arsenic	< 0.005
Potassium	< 0.05	Indium	< 0.01
Calcium	< 0.05	Tin	< 0.01
Titanium	< 0.005	Antimony	< 0.01
Vanadium	< 0.001	Tungsten	< 0.01
Chromium	< 0.05	Tellurium	< 0.01
Manganese	< 0.005	Lead	< 0.01
Iron	< 0.01	Bismuth	< 0.01
Nickel	< 0.005		

↑ Micrograph of SiC surface

Material data of our SIGRAFINE® SiC coating

Typical properties*	Units	Values	Analysis technique
Structure		beta (cubic) 3C polytype	XRD
Orientation	Fraction [%]	111 preferred	XRD
Bulk density	g/cm³	3.2	XRD
Stoichiometry		1:1 Si/C	XPS
Hardness	GPa	40	Nanoindentation
Fracture toughness	MPa $m^{1/2}$	3.0	Vickers identer
Thermal expansion 100 – 600 °C (212 – 1112 °F)	$10^{-6} K^{-1}$	4.3	Dilatometer
E-modulus	GPa	435	Nanoindentation
Typical film thickness	µm	100	Beta backscatter
Surface roughness	µm	2.5	Profilometer

* For any Engineering / Design purpose please always contact our technical sales team.

SIGRAFLEX® flexible graphite foil

Hot zone solution
SIGRAFLEX products, manufactured from expanded natural graphite, improve the performance of systems and processes in photovoltaic applications, minimize energy consumption and guarantee reliability.

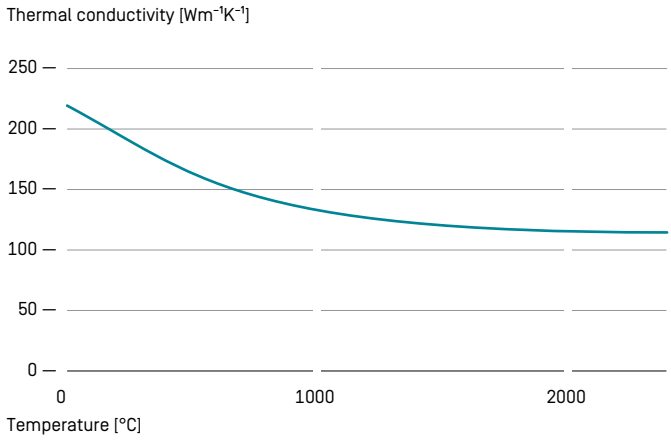
SIGRAFLEX high-purity flexible graphite foils are free of adhesives and binders and can be provided in an ultra-high purity to prevent product contamination.

Up to 3000 °C
Demonstrating its extraordinary properties, it can be used in ultra-high temperature applications ranging up to 3000 °C in an inert atmosphere or vacuum. Superior thermal and electrical conductivity makes it a suitable material for a wide range of parts and components in semiconductor production equipment, for example heat shields, insulation material, flexible layer, and sealing material. Flexible graphite foil can be produced to customer specifications.

SIGRAFLEX post purified foil is used for applications with ultra-high purity requirements. Even special customer specifications can be considered in the production of SIGRAFLEX products.

System supplier
SIGRAFLEX is often used in combination with SIGRATHERM rigid felts, SIGRABOND carbon fiber-reinforced carbon and SIGRAFINE artificial graphite.

Superior thermal conductivity even at ultra-high temperatures



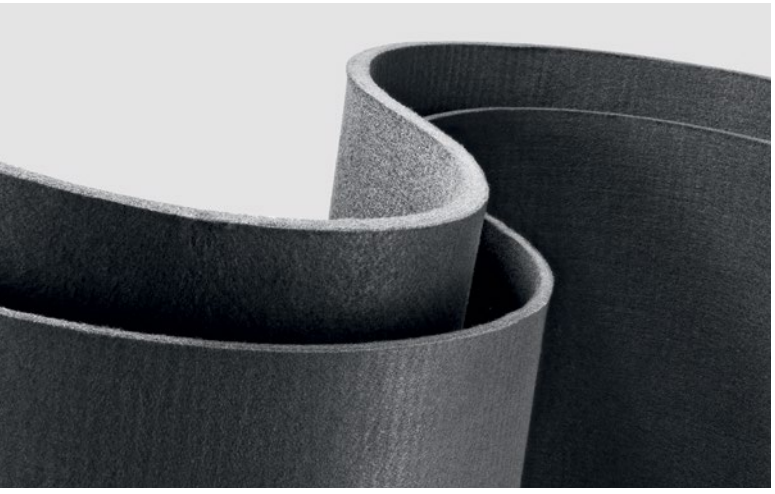
Material data of SIGRAFLEX® TH with a bulk density of 1.0 g / cm³

Typical properties*		Units	Values
Sublimation temperature		°C	> 3000
Temperature resistance	in air inert gas / vacuum	°C	approx. 400 approx. 3000
Specific electrical resistivity (20 °C)	ll surface ⊥ surface	µΩm	11 700
Thermal conductivity (20 °C)	ll surface ⊥ surface	$Wm^{-1}K^{-1}$	220 5
Specific heat capacity (20 °C)		$kJkg^{-1}K^{-1}$	0.7
Thermal expansion coefficient (20 – 1000 °C)	ll surface ⊥ surface	$10^{-6}K^{-1}$	approx. 1 approx. 50
Shore hardness (D)			30
Elongation at break		%	≥ 1
Tensile strength		N/mm²	≥ 4
Permeability coefficient for air	⊥ surface	cm²/s	2×10^{-5}
Coefficient of emission (1500 °C)			0.65
Ash content		%	approx. 0.1

Other values or dimensions on request.
* For any Engineering / Design purpose please always contact our technical sales team.

↑ SIGRAFLEX high-purity graphite foil

SIGRATHERM® graphite soft felts



↑ SIGRATHERM soft felt

↑ SIGRATHERM flexible carbon felts for the thermal insulation

Preferred choice for hot zone insulation
Our graphite soft felts offer a unique combination of thermal, chemical and textile properties. We supply SIGRATHERM soft felt in high purity and customer-specific dimensions, as well as pre-assembled packages for simplified product handling.

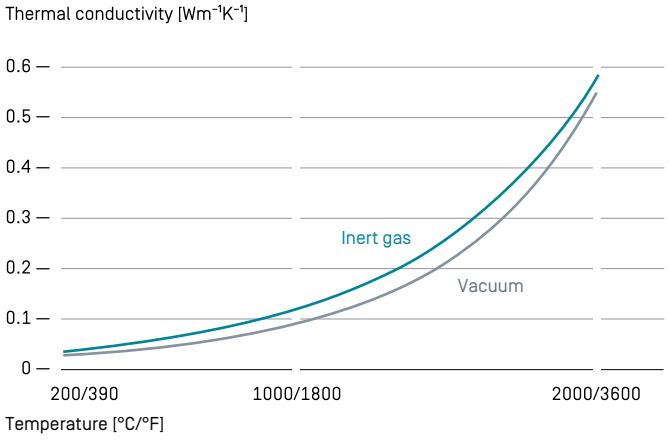
Homogeneous thermal insulation
Our special manufacturing process gives SIGRATHERM graphite soft felts very low thermal conductivity. Together with an extremely uniform thickness and density distribution throughout the roll length, we guarantee a consistently high insulation.

Material data of SIGRATHERM® GFA

Typical properties*	Units	GFA 5/10/15
Thickness	mm (in)	6 (1/4) / 11.5 (1/2) / 16 (5/8)
Area weight	g/m²	500 / 1000 / 1500
Width (max.)	mm (in)	1350 (53)
Length	m (ft)	25 – 30 (82 – 98)
Ash content	ppm	1000
Ash content (purified grade)	ppm	< 20
Max. application temperature	°C (°F)	2000 (3600) vacuum / inert gas

* For any Engineering / Design purpose please always contact our technical sales team.

Very low thermal conductivity between room temperature and silicon melting point (1414°C) (inert gas / vacuum atmosphere)



Material data of SIGRAFIL® D2 – 3k Yarn

Typical properties*	Units	Values
Diameter	mm	2.0
Ash content	%	< 0.5
Weigth/m	g	1.8

* For any Engineering / Design purpose please always contact our technical sales team.

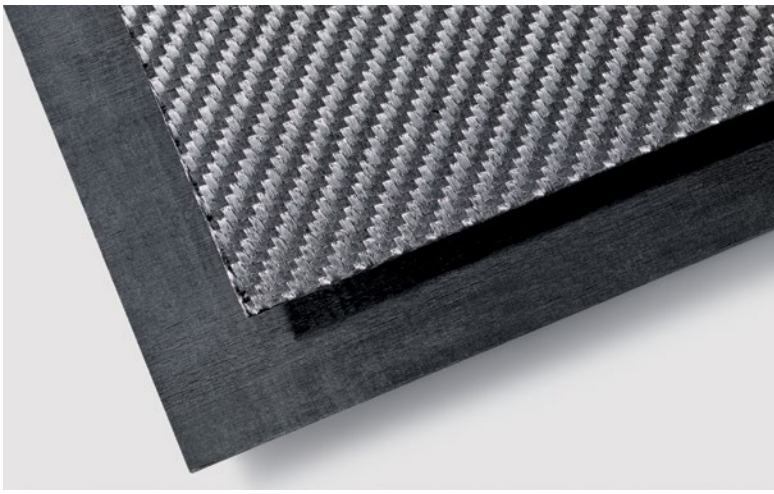
SIGRABOND® carbon fiber-reinforced carbon (C/C)

For lightweight, rigid and durable structural parts
Our SIGRABOND carbon fiber-reinforced carbon materials show a very high mechanical load bearing capacity at a very light weight. They are extremely resistant against corrosion and demonstrate high thermal stability.

A variety of grades for different applications
We produce C/C plates in three different grades: SIGRABOND Standard, Premium and Performance. SIGRABOND Standard plates are used for wafer-carriers in PECVD systems and guarantee a constant and precise positioning of the wafer in the deposition reactor.

Efficient protection
We also produce rotationally symmetrical components, such as crucible susceptors and tubes, from our grade SIGRABOND FilWound. Our tubes can be used as heat shields in CZ units. Thin-walled C/C tubes are also used to encapsulate SIGRATHERM insulation material and protect it against highly corrosive atmospheres like Si-O gaseous environments.

All of our SIGRABOND C/C parts can be gas purified to meet the requirements of the photovoltaic industry.



↑ SIGRABOND Performance and SIGRABOND Standard

Material data of our SIGRABOND® carbon fiber-reinforced carbon

			Plates	Rotationally symmetric parts
Typical properties*	Units	Performance	Standard	FilWound
Bulk density	g/cm³	1.5	1.5	1.4
Flexural strength	MPa	300	150	depending on lay-up
Flexural modulus	GPa	80	60	
Interlaminar shear strength	%	8	8	
Ash content	ppm	≤ 1000	≤ 1000	≤ 1000
Ash content (purified)	ppm	≤ 10	≤ 10	≤ 10
	mm	1220 x 1220 / 2450 x 1220	1220 x 1220 / 2450 x 1220	–
Length/Width	in	48 x 48 / 96 x 48	48 x 48 / 96 x 48	–
$Diameter_{max}$/$Length_{max}$	mm (in)	on request	on request	2000/2500 (79/98)
Thickness	mm (in)	1.8 – 15 (0.07 – 0.6)	1.7 – 30 (0.03 – 1.2)	–
$Wall\ thickness_{max}$	mm (in)	–	–	100 (4)
Maximum application temperature	°C (°F)	2000 (3600) vacuum / inert gas		

* For any Engineering / Design purpose please always contact our technical sales team.

Successful together

At SGL Carbon, we can do more than simply provide graphite blocks or build-to-print parts. We work with our Application and Technology Department and our customers to craft tangible solutions that bring real value.

Close collaboration and an in-depth understanding of our customers' processes are key to helping us develop forward-looking smart solutions.

This has given rise to most of our innovations – such as our new ISO graphite grade R6520.

Improving performance in silicon crystal growth

Czochralski growth is a delicate technology for mass production of monocrystalline silicon ingots that are used for silicon wafer production. It's essential to have a constant high yield rate of top-quality ingots to be successful in business of silicon wafers for solar cells.

We worked together with our Application and Technology team and in close collaboration with our customers to identify the ideal material grade for CZ hot zone parts which can be (re-)produced in large quantities with high-end quality.

The outcome of our work is our new ISO graphite grade SIGRAFINE R6520. Hot zone parts made of it have considerably improved the long-term yield rate of top-quality wafers of our customers from the semiconductor and photovoltaic industry. This is a great example of our attitude towards our work: "successful together".

Smart Solutions

Be it materials, components or production processes, we focus our thinking and actions on the customer and keep an eye on the big picture. Our solutions already anticipate the future today.

The following examples show a selection of our unique product range.

Mobility

- Lightweight components and structural parts based on fiber-reinforced composites for automotive and aerospace manufacture
- Graphite anode material for lithium-ion batteries in electric vehicles
- Carbon-ceramic brake disks for sports cars and luxury sedans

Energy

- High-temperature solutions based on specialty graphites and fiber materials for the photovoltaic industry
- Carbon fiber materials for rotor blades
- Gas diffusion layers for fuel cells
- Systems for more efficient heat exchange and heat recovery
- Carbon fibers for pressurized gas containers

Digitization

- Carbon, graphite, and CFC components for polysilicon and monocrystal pulling in the semiconductor industry
- High precision, coated graphite carriers for the production of LEDs

→ State-of-the-art green production with the world's largest isostatic press

SGL Carbon

We are leaders in the development and manufacture of products based on carbon, graphite, carbon fibers, and fiber-reinforced composites. In partnership with our customers, we develop intelligent, trendsetting, and sustainable solutions that deliver a clear benefit.

With our in-depth material, engineering, and application know-how, we make a substantial contribution to the major future topics mobility, energy, and digitization.

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