

Materials and Products for  
Mechanical Applications

## Automotive & Mechanical Applications



**Broad Base. Best Solutions.**

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**SGL GROUP**  
THE CARBON COMPANY

# SGL Group – The Carbon Company



We are SGL Group – The Carbon Company, one of the worldwide leading manufacturers of carbon-based products.

We have an in-depth materials, production, applications and engineering expertise, a comprehensive graphite and carbon fiber-based product portfolio, and an integrated value chain from carbon fibers to composites. We operate close to our customers through a global sales network and state-of-the-art production sites in Europe, North America and Asia. With this Broad Base, we offer Best Solutions to our customers with the help of our Company philosophy of SGL Excellence.



### SGL Excellence

We constantly aim to improve our products and services to meet our customers’ specific requirements. Our company-wide SGL Excellence Initiative and SIX SIGMA, which we apply as core methods, are state-of-the-art tools for bringing continuous improvement to all areas, including our processes, engineering know-how, product development and innovation, as well as the expertise of our workforce. We keep close contact with our customers, suppliers and logistic partners to help achieve this.

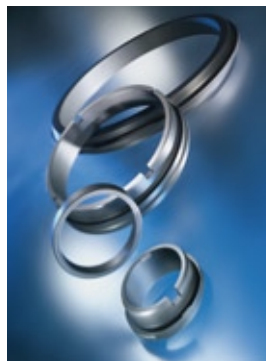


# Graphite Specialties

## Customized Products for Key Industries

The Business Line Graphite Specialties includes the four Business Segments Industrial Applications, Electronic Applications, High-Temperature Applications and Automotive & Mechanical Applications.

Our comprehensive range of materials extends from isostatically molded, extruded, die-molded and vibration-molded graphite through to carbon and graphite felt and carbon fiber-reinforced carbon. We optimize them to the needs of our customers by drawing on our expertise in the planning, design and processing of complex components made from these materials. Finishing options such as coating, impregnation and purification complete our product portfolio.



Production sites in Europe, North America and Asia supply our materials to our own machining centers, which are located close to our customers worldwide.

Our Business Segment Automotive & Mechanical Applications supplies carbon and graphite components to the automotive industry, the home appliances industry and mechanical engineering companies. Our customers include manufacturers of compressors, vacuum pumps, vane pumps, sealing systems and sliding elements, as well as processors of semifinished products.

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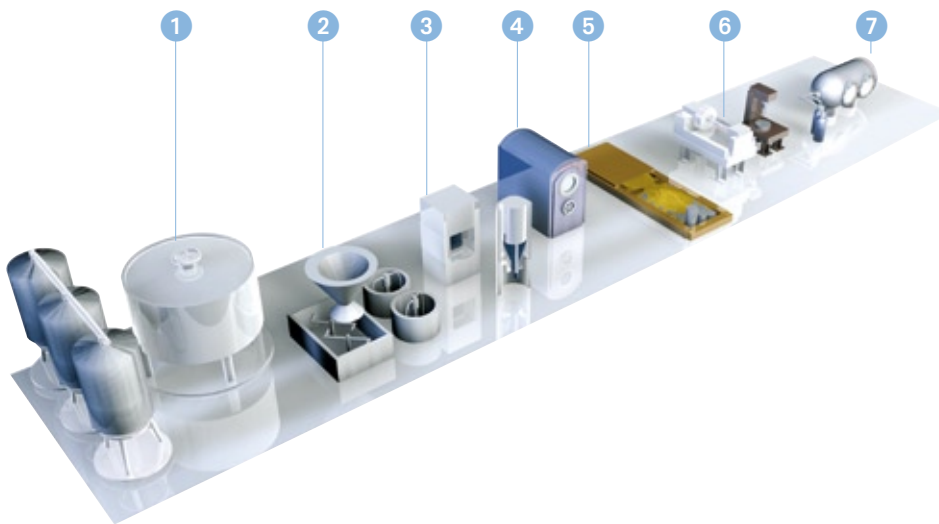


# Manufacture of

## Carbon, Graphite and RIDURID®

### Carbon and graphite

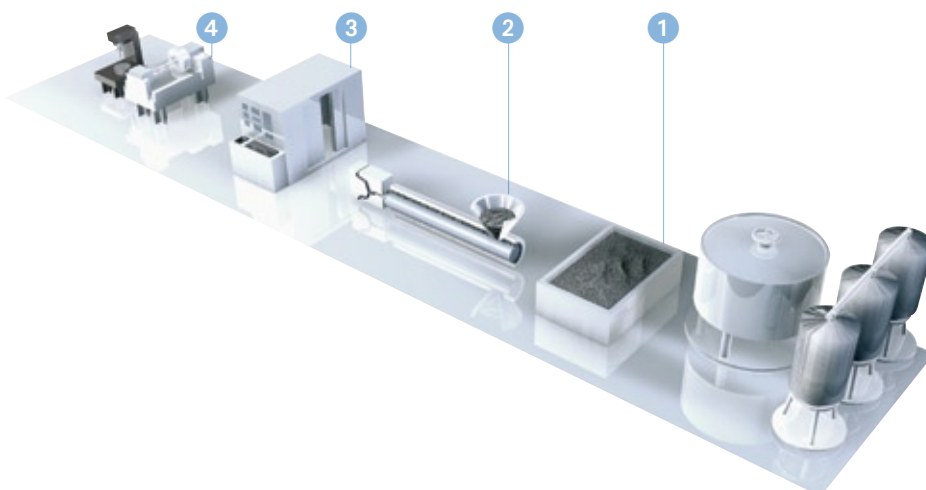
The production stages for carbon materials are comparable to those for ceramics. Products baked at approx. 1,000 °C are known as hard carbon, hard burned carbon or carbon graphite. The product yielded by thermal treatment above 2,500 °C is called electrographite.



- 1 Raw materials**  
High-grade raw materials from reliable sources
- 2 Processing**  
Crushing, milling, sieving, mixing, homogenizing
- 3 Shaping**  
Isostatic molding, extrusion, die molding
- 4 Baking**  
Carbonization, redensification
- 5 Graphitizing**  
Formation of ordered graphite lattice
- 6 Machining**  
Mechanical processing of materials: sawing, turning, milling, grinding, drilling, lapping, polishing
- 7 Refining**  
Impregnation

### RIDURID®

RIDURID is a graphite-filled thermoset. It is manufactured from granules composed of different constituents. The granules are injection-molded or compressed, depending on the production technology involved.



- 1 Processing**  
Mixing
- 2 Shaping**  
Injection molding, extrusion
- 3 Post-treatment**  
Tempering, conditioning, processing
- 4 Machining**  
Mechanical processing of materials: sawing, turning, milling, grinding, drilling, lapping, polishing

# Specialty Graphite

## A Material with Exceptional Properties

### Specialty graphite

Specialty graphites are materials whose matrix consists of carbon graphite components. They feature good dry-running properties when used in tribological systems. Their graphite lattice structure comprises carbon atoms arranged in planar hexagonal rings with an interlayer distance of 0.335 nm. Owing to the weakness of the van der Waals attractive forces, these planes can be quite easily displaced relative to one another. The physical parameters of carbon materials are governed by the production processes illustrated on page 4. The shaping process depends mainly on the output number to be manufactured: Large batches are pressed to size or injection-molded (depending on the tool dimensions), whereas small batches are machined from larger semifinished products.

### Oxidation resistance

Graphite can be used in an oxidizing atmosphere at up to approx. 500 °C. The application limits of impregnated variants depend on the type of impregnation involved. For specific applications, we supply graphite materials with oxidation inhibitors, which allow the oxidation resistance to be raised to temperatures of 600 °C.

### Food safety

Many of our machine element brands have been approved for use in the food and drinking water sector. The relevant tests have been conducted by institutes in Germany and abroad.

### Other properties

- High mechanical strength
- Good sliding properties
- High thermal stability
- High thermal shock resistance
- Low wettability
- High corrosion resistance
- High thermal conductivity
- Good electrical conductivity



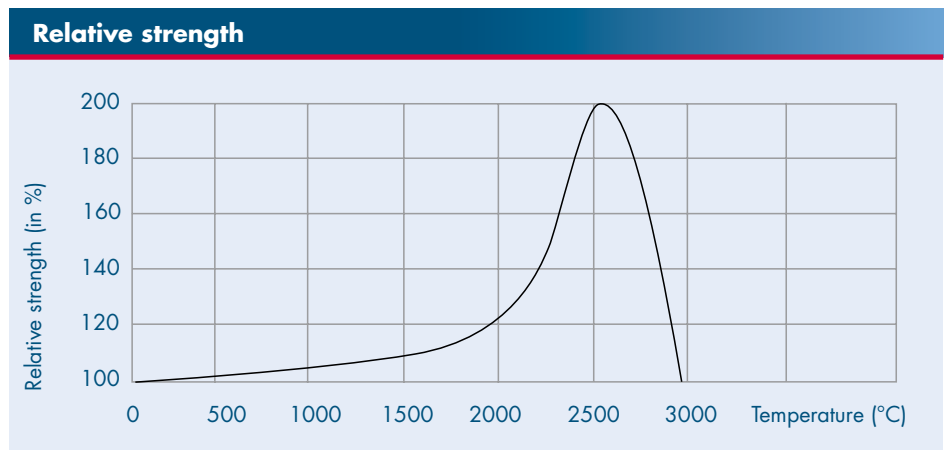
### Chemical resistance

Carbon products are insoluble and do not melt. They are resistant to virtually all media such as organic solvents, anti-freezing agents, refrigerants and technical resins. Carbon is also highly resistant to organic media such as alkalis and most acids. The corrosion resistance of synthetic resin- or metal-impregnated carbon components is governed by the pH value. As a general rule, synthetic resin-impregnated carbon materials are resistant to acid media, whereas metal-impregnated variants can withstand alkaline attack.

# Benefits Provided under Extreme Conditions

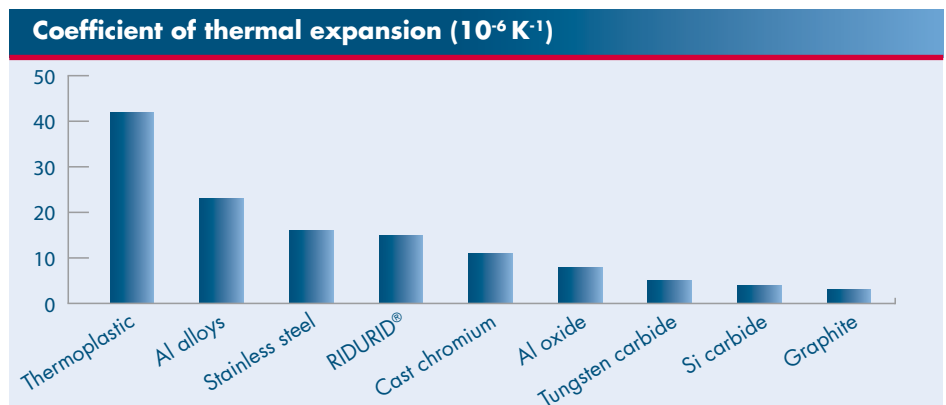
## Mechanical strength

Unlike most materials, the mechanical strength values of carbon and graphite increase with rising temperatures and reach their maximum value at approx. 2,500 °C in the case of graphite. The value corresponds to an increase of some 100 % compared to the figure measured at room temperature. Carbon materials should be designed to withstand pressure in order to take advantage of their maximum strength potential.



## Thermal expansion coefficients of various materials

Good physical compatibility is achieved by mating materials having identical or similar coefficients of thermal expansion. The expansion coefficient can be adjusted to the application by choosing specific formulation constituents.



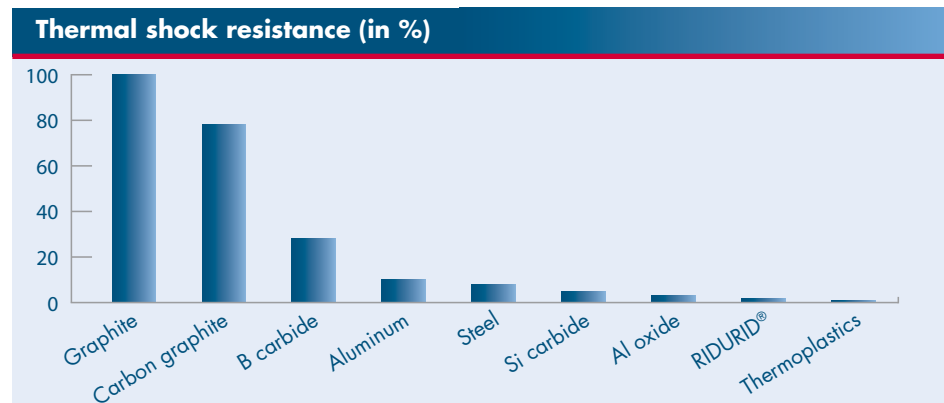


## Thermal shock resistance of various materials

Graphite features the highest thermal shock resistance of all familiar materials. The most significant change in thermal shock resistance can be achieved by changing the material's thermal conductivity.

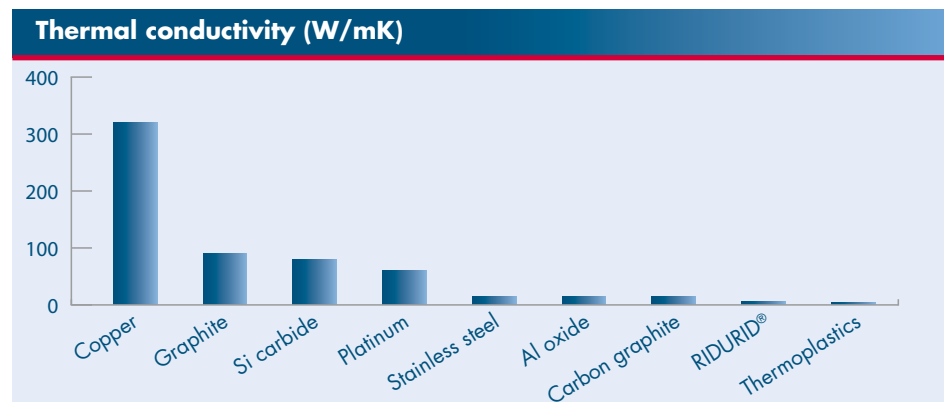
Thermal shock resistance is defined as:

$$\delta = \frac{\text{Strength} \times \text{thermal conductivity}}{\text{Coefficient of thermal expansion} \times \text{E-modulus}}$$



## Thermal conductivity

With 12 W/mK and 100 W/mK, carbon and graphite materials display thermal conductivity values similar to those of metals. This is why they have established themselves as mating materials in friction systems.



## Coefficient of friction

The coefficient of friction is determined by both the mating materials and prevailing stresses. A distinction is made between dry, mixed and wet friction behavior.



# The Cost-Effective Solution

## for Mechanical Applications

### Counterface materials

Counterface materials for carbon materials can be grouped into metals, oxides and carbides. The technically or economically best solution depends on the choice of suitable counterface materials. These can be combined to produce hard-soft and hard-hard mating surfaces. Carbon is an exceptional material in that it is suitable for both dry and wet running, if selected properly.

Commonly employed counterface materials are made from ceramically coated metal, but fully ceramic materials are also being used. The abrasion resistance and thus service life of mating materials are higher the harder the counterface materials are.

### The main counterface materials used are:

- Carbon
- Cast chromium
- Steel
- Aluminum alloys
- Aluminum oxide
- Tungsten carbide
- Silicon carbide

### Impregnation

Synthetic resin, metal and salt impregnations enhance the materials' mechanical strength, leak tightness and wear behavior.

### Contribution to environmental protection

Alternatives to metal-impregnated materials are our non-impregnated all-carbon materials.





# Recommended Uses

## and Production Processes

### Recommended uses

Carbon is an ideal material for use under special operating conditions, e.g. if

- the operating temperatures are outside the permitted range for lubricating oil or grease;
- the product to be sealed should not be contaminated by lubricant;
- the machine elements are in contact with oil solvents or media that do not provide sufficient lubrication;
- the corrosion resistance of other materials is not sufficient.



### Production processes

Semifinished products

Molding process	Max. dimensions
Die molding	$\varnothing$ 235 x 200 mm $\varnothing$ 270 x 60 mm 330 x 140 x 60 mm
Isostatic molding	1230 x 510 x 330 mm $\varnothing$ 1250 x 500 mm
Extrusion	$\varnothing$ 20 x 1000 mm
Pressed to size	$\varnothing$ 80 x 50 mm
RIDURID®	385 x 235 x 10 mm $\varnothing$ 77 x 8 mm $\varnothing$ 30 x 110 mm

Finished products

Technology	Notes
Machining	Small-batch production Complex geometry
Pressed to size	Large-batch production Simple to moderately complex geometries
Injection molding	Complex geometries

In addition to the semifinished products listed in the table, we supply granules and graphite powder for compound production.



## Dynamic Sealing Elements



Owing to their tribological behavior, carbon materials are used in dynamic sealing elements under both dry- and mixed-running conditions. A distinction is made between the following designs:

- **Axial seals**

such as carbon seal faces, ball valve sealing rings, steam joint rings.

- **Radial seals**

such as multi-segment packings to seal shafts on ventilators, ships' propellers and water turbines, as well as metal-sleeved carbon rings for compressors.

- **Motion control rings and segments**

for controlling automated production processes.

### Typical applications

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Carbon seal faces for mechanical seals used in the automotive industry.



Multi-segment radial sealing rings for water turbines.



# Components for Compressors and Vacuum Pumps



Graphite's good dry-running properties ensure maximum performance when combined with various counterface materials.

Suitable counterface materials are:

- Gray cast iron
- Steel
- Sintered steel
- Cast aluminum
- Ceramics
- Other carbon graphite materials

- **Vanes and axial end disks**

for dry-running and fresh oil-lubricated rotary vane compressors and vacuum pumps.

- **Seal rings and metal-sleeved rings**

to seal the shafts of rotary compressors such as rotary screw compressors, root compressors and radial blowers.

- **Piston rings and guide rings**

for oil-free operating piston compressors.

## Typical applications

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Rotors in graphite-filled high-performance plastic for vacuum pumps.



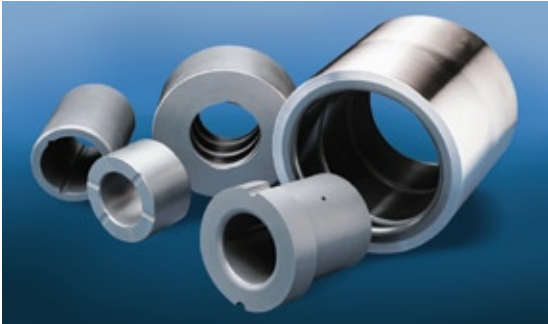
Piston rings and guide rings for piston compressors and packing rings to seal piston rods.

Further applications:

- Vanes and end disks for dry-running vane pumps.
- Pneumatic pump units for central locking systems, servo locks, seating-comfort systems and household applications.

# Bearings and Sliding Elements

## For Dry- and Wet-Running Applications



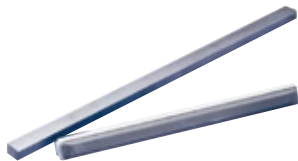
Bearings and sliding elements made of carbon materials are used in particular where lubrication is impossible for various reasons. Potential applications are offshore technology, mechanical engineering (e.g. textile and food processing machinery, die-cutting and pressing in automotive engineering) and, as a general rule, any application involving fairly high operating temperatures.

The good sliding properties and chemical resistance of our carbon materials make them suitable for bearings and seals in pumps. They are used wherever

- the materials are in contact with fat-dissolving agents,
- the use of other materials is impossible because of severe corrosive attack,
- liquids with no lubricating action such as water and gasoline need to be pumped,
- temperatures are outside the range permitted for lubricating oils.

### Typical applications

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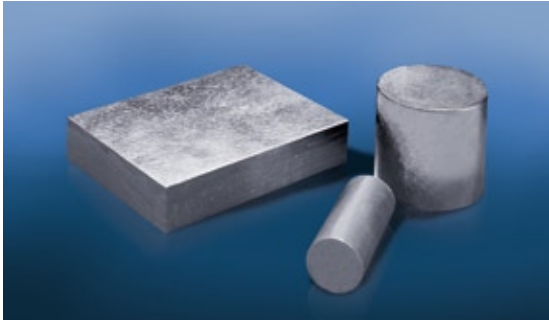
Sliding rails used as guides in textile machinery.



Axial, collar and radial bearings with lubrication grooves for submerged pumps.



## Semifinished Products, Powder and Granules



Our specific carbon materials for machine elements are also available to graphite processors – as semifinished products in finely graduated dimensions. Plastics compounders can be supplied with carbon and graphite fillers with reproducible application-specific properties.

Our standard range of semifinished products includes materials with or without impregnation.

### Typical applications

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Granules as base material for the manufacture of synthetic resin-bonded materials.



Powder as filler for plastic compounds.



# Production Sites and Customer Service

## Business Line Graphite Specialties

The three pillars of our production system are high quality, adherence to deadlines and our highly motivated and competent workforce. We demonstrate this claim in three continents (Europe, the Americas and Asia) to get maximum benefit from both cost-effectiveness and close customer contact.

### Our services

- Close customer contact through a global marketing network covering more than 90 countries
- Professional technical and individual advice provided at customers' own sites
- Detailed design proposals to solve customer-specific problems
- Application-oriented training in key applications and special literature
- Extensively equipped laboratories for analyses
- Reliable and flexible delivery service

#### **SGL Group**

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# Trademarks of the SGL Group, Graphite Specialties

**RIDURID®**

Graphite-filled  
high-performance plastic

**RINGSDORFF®**

Isostatically pressed and  
die-molded specialty graphites

**SIGRAFORM®**

Extruded and vibration-molded  
specialty graphites

**SIGRAMENT®**

Extruded specialty graphites  
for electric heating elements

**SIGRAMENT® MNC**

Extruded tubular graphite  
heating elements

**SIGRASIC®**

Carbon fiber-reinforced  
silicon carbide (C/SiC)

**SIGRABOND®**

Carbon fiber-reinforced  
carbon and graphite

**SIGRATHERM®**

Carbon and graphite felts  
and carbon wool for thermal  
insulation

**SIGRAFLEX®**

Graphite foils and  
laminated sheets

**SIGRAFIL® D2-3K**

Carbon fiber-based  
carbon cord

**CRYSTA-SIL®**

Crystalline silicon carbide  
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products for semiconductor  
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