



Schunk Carbon Technology

SiC30 – Silicon Carbide / Graphite Composite Material

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SiC30 - An Extraordinary Silicon Carbide/Graphite Composite Material

Applications

The main fields of application of the SiC30 material are sliding rings and bearings for use in media with a poor lubricating capacity. The combination of excellent properties of graphite (good emergency-running properties, thermal shock resistance, etc.) and silicon carbide (hardness, strength, abrasion resistance) combined with an exceptional structure allows solving problems that would not be possible with other materials. The best results are often achieved with the material pairing of SiC30 to SiC30.

Production

The material SiC30 is produced by impregnating a highly porous electro-graphite with molten silicon. At the same time that the silicon penetrates into the pores, there is a chemical reaction that changes the silicon and carbon into silicon carbide. The process continues until the pores are closed by the silicon carbide that has been formed.

Composition

The main components of the material are silicon carbide with about 62% and about 35% graphite; the proportion of free silicon is about 3% (in each case, part by weight). This represents a volume share of about 53% silicon carbide, about 43% graphite and about 4% silicon. The silicon carbide is present to about 95% in the cubic β -SiC modification. SiC30 is completely free of boron and is thus also suitable for applications in the manufacture of silicon for the electronics industry.

Structure

The unique thing about the structure is an interpenetrating network of graphite and silicon carbide (relics of coherent carbon structure or the pore system of the electro-graphite). Free silicon is merely present in the form of small islands that are enclosed in the silicon carbide phase.

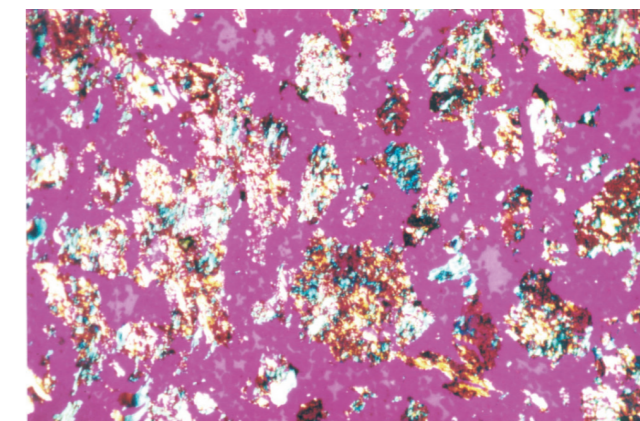


Figure 1: Structural pattern of graphite and silicon carbide

Physical Properties

Bulk density	[g/cm ³]	2.65
Porosity	[Vol.-%]	-
Flexural strength	[N/mm ²]	140
Compressive strength	[N/mm ²]	500
Young's modulus (dyn.)	[kN/mm ²]	140
Hardness	consists of a hard SiC- and a soft graphite phase	
Temperature resistance	oxidizing atmosphere	°C
	inert atmosphere	°C
Coefficient of thermal expansion		α 20 - 200 °C
		[10 ⁻⁶ /K]
		α 20 - 1000 °C
	[10 ⁻⁶ /K]	4.0
Thermal conductivity	[W/mK]	125
Spec. electr. resistance	[μΩm]	120

These data are provided as typical values based on our experience. As with any raw material or manufacturing process, variations can occur. Consequently, such values are not guaranteed and are subject to change without notice.

Table 1: Physical Properties of SiC30 (Typical Data)

Running behavior under marginal lubricated conditions

Emergency running properties of hard sliding materials such as silicon carbide ceramics can be excellently characterized with a high-pressure face seal test (see Figure 2).

Sliding speed: 9.35 m/s
 Balance ratio: 0.79
 Media: demineralized water
 Media temperature: 20 - 95° C
 Media pressure: 5 - 100 bar

During the testing process, the pressure on and temperature of the media were successively increased, thereby generating inadequate lubrication conditions. The gage for determining the emergency running properties is the duration that it took to achieve a seal pairing of the tested material under these severe conditions without abrupt power peaks.



Figure 2: High-pressure face seal test rig

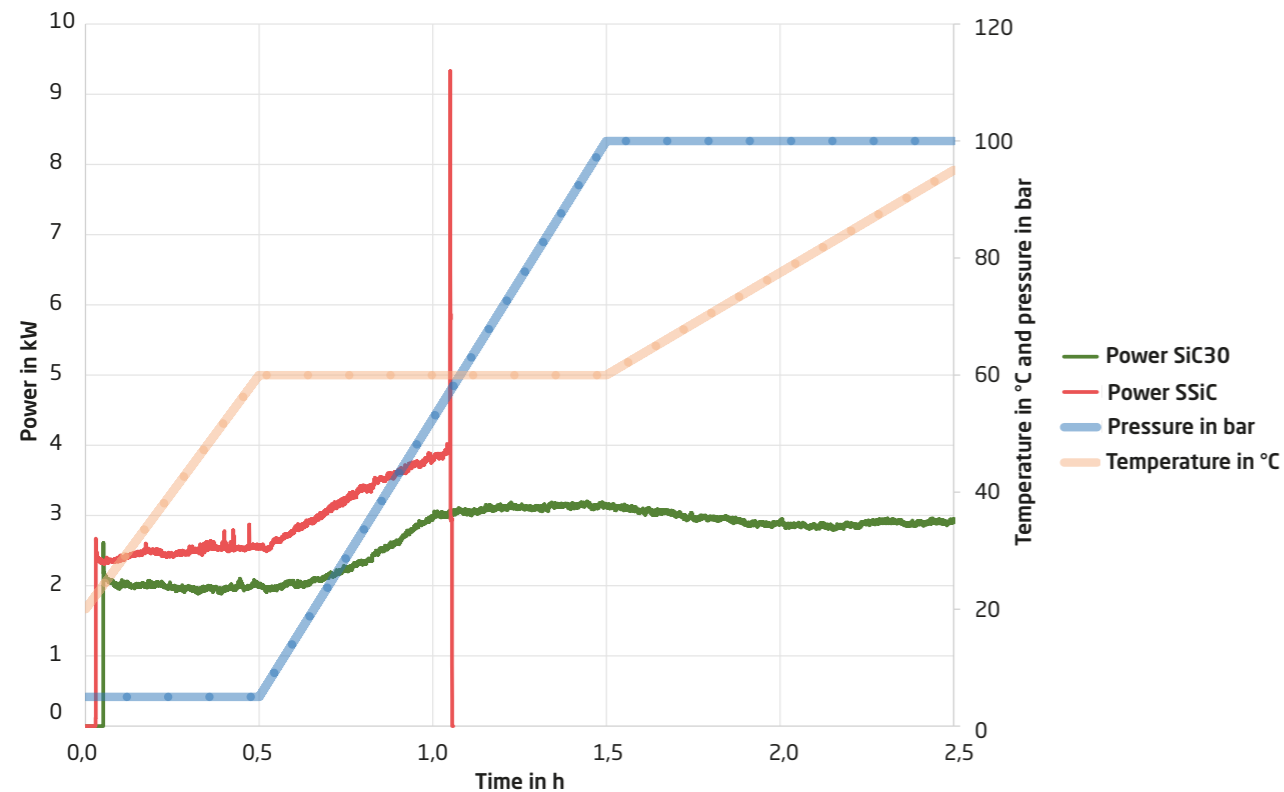


Figure 3: Diagram of the test run with SiC30 and SSiC

For materials that have absolutely no or a poor amount of emergency running capabilities, the friction increases sharply at an early stage and marks the end of the test. The diagram in Figure 3 illustrates this with the example of a commercially available sintered silicon carbide (SSiC). SiC30, however, does not show this effect in any way. Lubrication is also maintained under critical conditions, an effect of the high graphite content in conjunction with a unique material structure (see Figure 5).

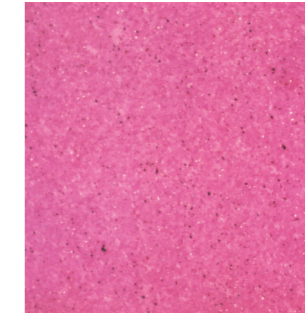


Figure 4: SSiC structure

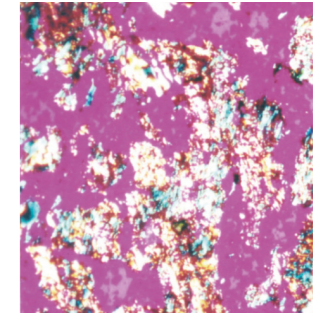


Figure 5: Structural pattern of graphite and silicon carbide

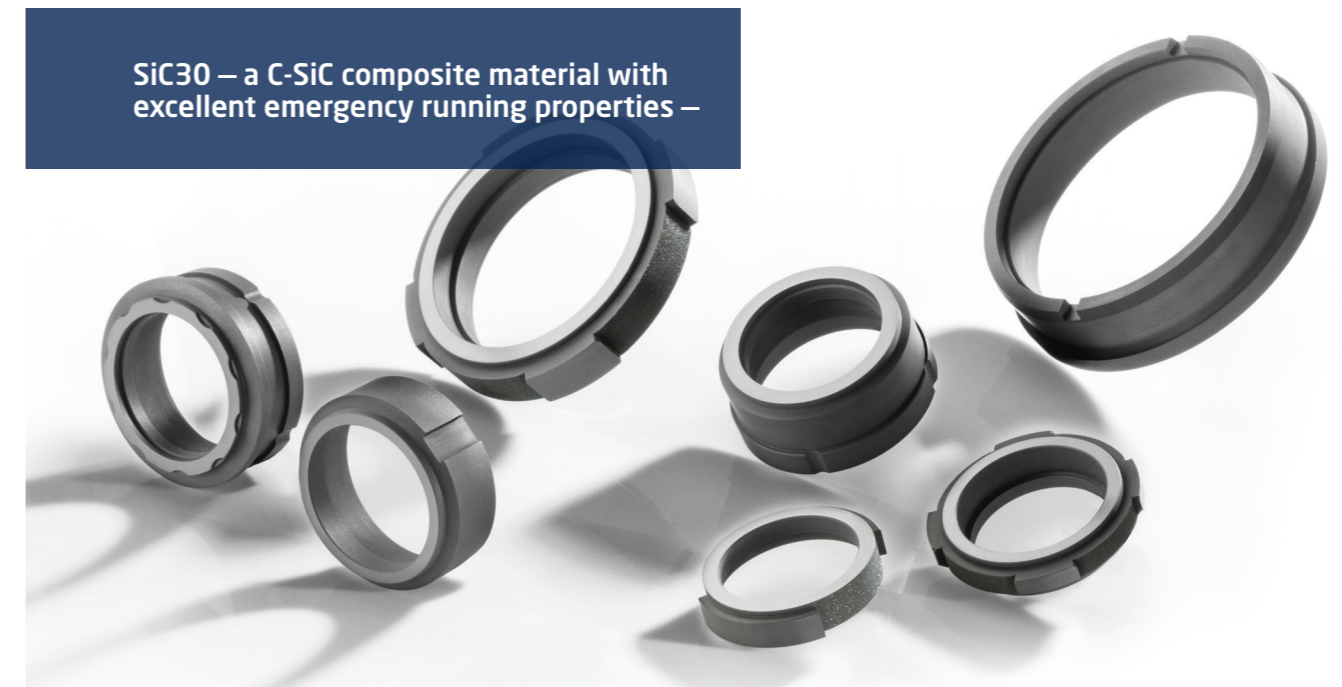


Figure 6: Sealing rings of SiC30

Blister Resistant

Blistering is one of the most common causes of failure for carbon sealing rings in sliding gaskets.

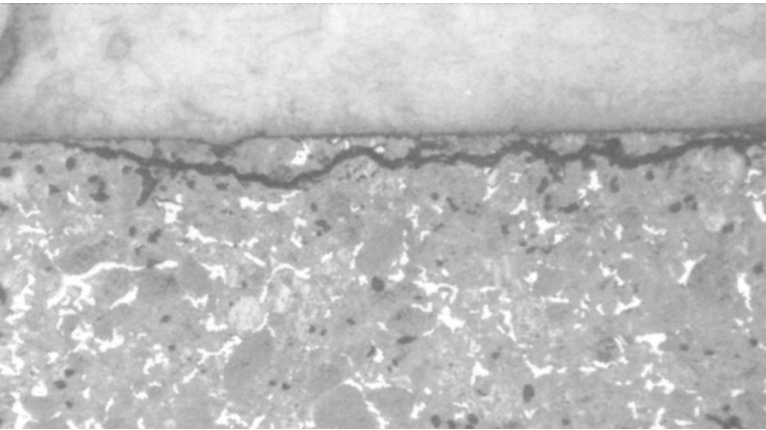


Figure 7: Typical appearance of blistering on a carbon graphite sliding surface

However, in tribological applications, materials with dry or emergency-running properties - and thus on carbon materials - are often indispensable. There is no carbon material that is completely blister resistant.

Blistering can be generated with the help of special seal ring tests. Blister resistance indexes (I_{BL}) have been defined to evaluate the damages caused by blister formation:

Blister resistance index $I_{BL} = 10$

↪ Blister resistant material

Blister resistance index $I_{BL} = 0$

↪ not operable, because material has been destroyed

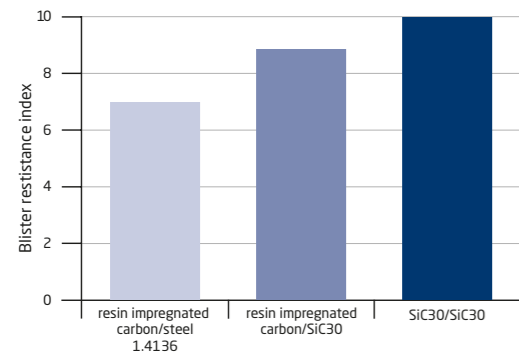


Figure 8: Results of a series of blistering tests

The results in Figure 8 show that the SiC30 material as a hard sliding partner has significantly improved the blistering resistance of carbon materials and that, when used as a "soft carbon material" in a pairing, it can completely prevent blistering.

- ↪ SiC30 avoids blistering
- ↪ SiC30 is the only blister resistant "carbon material"
- ↪ SiC30 as counterpart material significantly improves the blister resistance of carbon graphite

Thermal Shock Behaviour

The thermal shock resistance as a characteristic material property is proportional to the material's strength and thermal conductivity but in inverse proportion to its Young's modulus and coefficient of thermal expansion.

The Testing Procedure

The resistance of tribological materials to thermal shock can be determined, among other things, by means of a comparative hot / cold test and defined maximum temperature differences that the material in the following test has survived unscathed. For the test, identical specimens were heated to pre-defined temperatures and then submerged in ice water. The results were standardized; the temperature difference found for SSiC was selected as a reference value.

Classification of Thermal Shock Resistance

Material	Relative Thermal Shock Resistance
SSiC (sintered-silicon carbide)	1
SiSiC (reaction-bonded silicon carbide)	1
SiSiC-C (reaction-bonded graphite loaded silicon carbide)	1.15
SiC30	1.3



Figure 9: SiC30 bearings

Chemical Resistance

Many ceramic materials for tribological applications have limited chemical resistance to highly corrosive media since their oxide or silicon-based bonding phase would corrode.

SiC30 does not have any oxidic phases and also does not have any accessible free silicon. The excellent chemical resistance of the SiC30 material has been confirmed in sophisticated testing. To do this, sliding rings and specimens were treated with a mixture of 77% HF (40% solution) and 23% HNO₃ (65% solution). This solution is a very strong solvent for silicon. No dimensional changes were detected and there was only a slight loss in weight. The flexural strength of the SiC30 material remained virtually unchanged. Results of bench tests show that the sliding rings from SiC30 maintain their excellent tribological properties even after the aforementioned acid treatment. Microscopic examinations proved that only small amounts of free silicon on the surface were released, which is not a bonding phase in SiC30. The relevant phases (silicon carbide and graphite) are fully resistant.

The material is resistant to:

- aqueous salt solutions,
- organic reagents,
- strong acids (HF, HCl, H₂SO₄, HNO₃),
- hot inert gases.

Only in the following media SiC30 is partially resistant:

- extreme temperatures of air and other oxidizing gases:
At temperatures >500° C, the graphite content „burns out“ slowly. But even the remaining structure of SiC still has 50% of the strength of the base material.
- molten metals:
Various metals corrode SiC and graphite with the formation of silicides (e.g. cobalt, nickel) and carbides (aluminum, iron).
- strongly alkaline media:
Depending on the temperature, pressure and concentration, silicon carbide can only be corroded by the strongest alkalis.

Designing with SiC30

Rotationally symmetric components or rectangular plates are suitable geometries. For different components the recommended dimensions are summarized in table 2. If possible, deviations from these guidelines should be avoided or at least discussed with our technical application service beforehand.

With regard to producability and cost the following recommendations should be observed:

- no sharp changes in cross section
- avoidance of large shoulders and undercuts
- limitation of cuts, grooves and bores to a minimum

SiC30 can easily be shrunk to fit into steel frames and, compared to SiC materials, is significantly more tolerant to edge load.

Wall thickness	Cylindrical bearings		Rings	
	max. height	max. Ø	max. height	max. Ø
15 - 20 mm			20 mm	280 mm
10 - 15 mm			35 mm	280 mm
7 - 10 mm	100 mm	150 mm	35 mm	200 mm
5 - 7 mm	70 mm	80 mm	20 mm	120 mm

Table 2: Recommended dimensions for components made of SiC30



The chemical resistance of SiC30 is determined solely by the components of silicon carbide and graphite and is therefore almost universal.

Figure 10: SiC30 Slide bearing

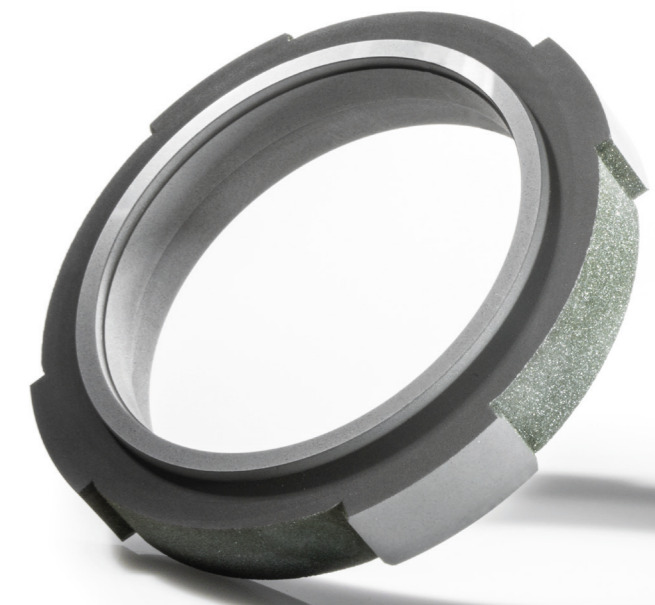


Figure 11: SiC30 sliding ring

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