Bearing and Seal Technology

SiC30 – Silicon Carbide/Graphite Composite Material

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Business Unit Tribology

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Silicon Carbide/Graphite Composite Material

Production Method

The SiC30 material is achieved by impregnating a highly porous electrographite with molten silicon. The infiltration of silicon into the pores results in a simultaneous transformation of silicon and graphite into silicon carbide. This process continues until the pores are completely filled with silicon carbide and a small amount of free silicon.

Structure

Micrographs show an interpenetrating network of graphite and silicon carbide (residues of the coherent carbon structure and the pore system of the electrographite respectively). Free silicon exists mainly as small spots sealed by the silicon carbide and constitutes by no means a binder between silicon carbide and graphite.

Composition

The material consists mainly of approx. 62 % silicon carbide and approx. 35 % graphite, the content of free silicon amounting to approx. 3 % by weight. A conversion into parts by volume results in approx. 53 % silicon carbide, approx. 43 % graphite and approx. 4 % silicon. Approx. 95 % of the silicon carbide constituent consist of cubic β-silicon carbide modification.

Chemical Properties

The chemical resistance of SiC30 is exclusively determined by the components silicon carbide and graphite. The destruction of the structure of this material through a disintegration of a binder consisting of silicon or any oxide is excluded.

The material is resistant to:

- aqueous solutions of salts,
- organic reagents,
- strong acids (HF, HCl, H_2SO_4, HNO_3),
- hot inert gases.

SiC30 has limited resistance under the following media:

- Air and other oxidizing gases:
  At temperatures ≥ 600 °C C the graphite constituent is slowly burnt out, thus reducing the strength of the remaining SiC texture to approx. 50 % of that of the basic material.

- Molten metals:
  SiC and graphite are affected by various metals by forming silicides (e. g. cobalt, nickel) or carbides (e. g. aluminium, iron).

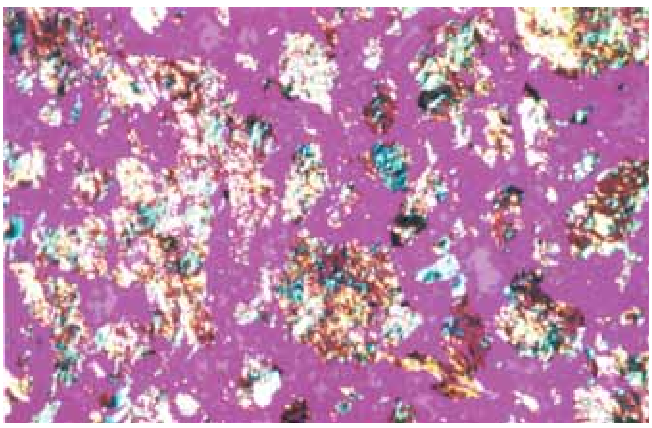
- Strong alkaline media:
  Strong alkaline solutions affect silicon carbide dependent on temperature, pressure and concentration. Above all, temperatures >100 °C and overpressure will lead to a slowly progressing destruction of the structure

Physical Properties

The most important physical data are listed in table 1 (page 7). In addition the following properties should be emphasized:

- High thermal resistance:
  The service temperature under inert gas or vacuum is determined by the sublimation of the silicon carbide (> 2300 °C) and not by the disintegration of a binder.

- High resistance to thermalshocks and temperature changes:
  With regard to these properties SiC30 resembles more a graphite material than brittle SiC ceramics. With SiC30, thermal tensions of the silicon carbide are collected and reduced by the “soft” graphite constituent.



Micrograph showing the structure of SiC30 material under polarized light

Chemical Resistance

SiC30 – An Extraordinary Silicon Carbide/Graphite Composite Material

Many SiC composite materials for tribological applications have a limited chemical resistance against highly corrosive media, as their binder phase, being oxidic or consisting of silicon, is attacked. Even in those media, SiC30 retains its physical and tribological properties.

The outstanding chemical resistance of SiC30 is determined by its constituents silicon carbide and graphite.

The outstanding chemical resistance of SiC30 has been proven by demanding tests. Sliding rings as well as testing bars were treated with a mixture of 77 % HF (solution 40 %) und 23 % HNO_3 (solution 65 %) for seven days.

An excellent dimensional stability and only a slight weight loss were observed. The flexural strength of SiC30 remained nearly constant with σ_{FS} = 150 MPa.

SiC30 sliding rings

Microscopic investigations show that only small amounts of free silicon were leached out at the material's surface. The substantial phases (silicon carbide and graphite) have proven to be absolutely resistant against corrosive media.

Grooved SiC30 bearings

Blister Resistant

SiC30 – The Blister Resistant Silicon Carbide/Graphite Composite Material

Blister formation is probably the most frequent cause of failure for face seals with hard-soft pairings. In tribological applications, the use of materials with excellent dry or emergency running properties is highly important. Such properties are typical characteristics of carbon materials. Up to now, a blister resistant carbon material has not been available. Our material SiC30 is blister-free.

- SiC30 avoids blistering
- SiC30 is the only blister resistant "carbon material"
- SiC30 is the only "SiC material" with emergency running properties
- SiC30 as counterpart material significantly improves the blister resistance of carbon graphite

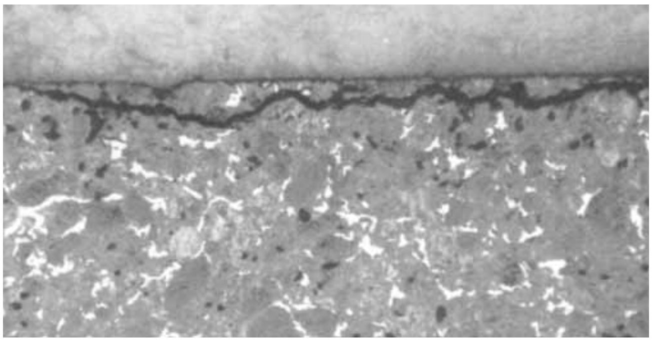
Blister resistance indexes (I_{BL}) and coefficients (K_{BL}) have been defined for evaluation of the damage by blister formation. The following table shows the visible defects through blistering and the assigned coefficients K_{BL}.

	Number of defects		
Types of visible defects	**1**	**(2 – 4)**	**(≥ 5)**
Picking outs on outer/inner diameter	1	1	2
Small blisters (≤ 1.5 mm)	1	2	3
Large blisters (> 1.5 mm)	2	3	4
Picking outs on the running surface	2	3	4
Cracks	4	4	4

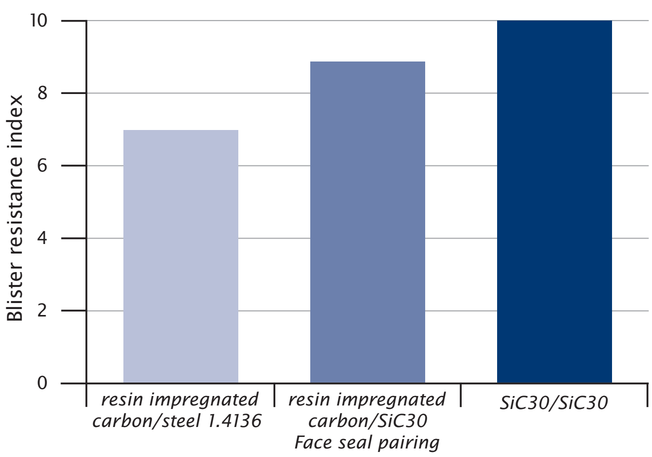
The blister resistance index I_{BL} is calculated using $10 - \Sigma K_{BL}$

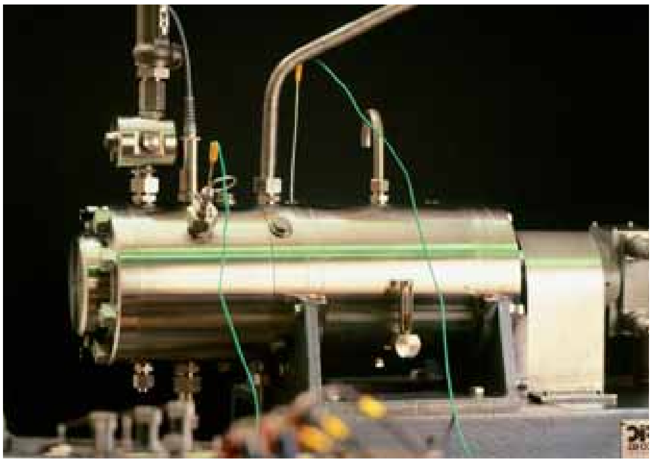
Blister resistance material	blister resistance index $I_{BL} = 10$
Not runnable, as material was destroyed	blister resistance index $I_{BL} = 0$

Special face seal test rigs allow a defined generation of blister formation.



Typical appearance: Blistering on a carbon graphite seal





Evaluation rig for blister tests with high viscosity oil as sealed medium

Thermal Shock Behaviour

SiC30 – A Thermal Shock Resistant Silicon Carbide Material

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 resistance of tribological materials against thermal shock can be determined by a hot/cold test and, thus, defines maximum changes in temperature which the material is able to bear without damage.

The Testing Procedure

The test samples are heated up to a defined temperature and subsequently cooled in iced water. As the obtained changes in temperature depend on the samples' geometry as well as on the condition of edges and surfaces, the results are classified, and the changes in temperature determined for SSiC are established as reference.

The termal shock resistance of SiC30 is superior to that of all current ceramics used in tribological applications.

Classification of Thermal Shock Resistance

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

SiC30 bearings

Silicon Carbide/Graphite Composite Material

Applications

The main application fields for SiC30 are sliding rings and bearings for the use under non lubricating media. The combination of the positive properties of graphite (good emergency running properties, resistance to temperature changes) and silicon carbide (hardness, strength, resistance to abrasion) allows to solve problems which cannot be eliminated by other materials. Good results are obtained by mating SiC30 with SiC30, too.

Excellent results can be achieved with SiC30 bearings in pumps for the chemical industry and with SiC30 seal rings in applications with the risk of blistering of seal faces.

Design Recommendations

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. Due to the processing equipment the outer diameter of rings is limited to 280 mm.

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

- no sharp changes in cross section,
- avoidance of large shoulders and undercuts,
- wall thicknesses should be 20 mm max.
- limitation of cuts, grooves and bores to a minimum.

The loading capacity of SiC30 elements can be increased considerably by shrinking-in into steel holders.

SiC30 sliding rings

Table 1: Physical Properties of SiC30 (Typical Data)

Bulk density	[g/cm³]	2.65
Porosity	[Vol. -%]	0.5
Flexural strength	[MPa]	140
Young's modulus (dyn.)	[GPa]	140
Hardness	consists of a hard SiC- and a soft graphite phase	
Coefficient of thermal expansion		
α 20 – 200 °C	[10^{-6}/K]	3.0
α 20 – 1000 °C	[10^{-6}/K]	4.0
Thermal conductivity	[W/mK]	125
Spec. electr. resistance	[$\mu\Omega$m]	120
Gas tightness (test press. N_2)	[bar]	10

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 2: Recommended Dimensions for Components made of SiC30

Wall thickness	Cylindrical bearings		Rings	
	max. height	max. Ø	max. height	max. Ø
15 – 20 mm			20 mm	285 mm
10 – 15 mm			35 mm	285 mm
7 – 10 mm	100 mm	150 mm	35 mm	200 mm
5 – 7 mm	70 mm	80 mm	20 mm	120 mm

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