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HIGH-TEMPERATURE MATERIALS

No. 1
MATERIALS INDEX

by
Peter T. B. Shaffer

with a foreword by
Henry H. Hausner



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S

BORON CARBIDE

Formula weight:	55.29 g/mole	
Formula volume:	22.30 cc/mole	
Melting point:	2470 ± 20°C	(326)
	2450°C	(3, 127, 129, 227, 261, 298)
	2350 - 2500°C	(9)
	2350°C	(38, 39)
Boiling point:	>3500°C	(3)
X-ray density:	2.51 g/cc	
Pycnometric density:	2.50 g/cc	(127, 129)
	2.54 g/cc	(3)

CHEMICAL

Theoretical analysis:	21.7% carbon 78.3% boron	
Synthesis:	C + B ₂ O ₃ , electric furnace	(73)
Stable to 2250°C in helium		(227)
Stable to 540°C in oxygen		(227)
Air oxidation becomes severe 1100-1400°C		(227)
32 percent wt. change 3 hrs. in air at 1400°C		(227)
Maximum use temperature in air, 1000°C		(227)

ELECTRICAL

Resistivity:	0.3 - 0.8 ohm-cm	(127)
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MECHANICAL

Strength (MOR):	44,000 psi at rt	(45, 127)
	50,000 psi at rt	(38)
	42,000 psi at 650°C	(38)
	35,000 psi at 1100°C	(38)

MECHA

T

C

F

Y

Si

B

P

Sp

OPTICAL

Co

Sp

STRUCTU

Rh

C₃

ext

BORON CARBIDE

(Cont.)

MECHANICAL (cont.)

	Tensile:	22,500 psi at 980°C	(9, 227, 297)
(326)	Compression:	414,000 psi at rt	(2, 127)
, 129, 227, 261, 298)	Hardness:	Mohs : 9.32	(73)
(9)		: 9.3	(2, 88, 227)
(38, 39)		Vickers : 2400 kg/mm ²	(8)
(3)		: 3700 kg/mm ²	(8)
		Knoop 100 g : 2800 kg/mm ²	(8)
		Knoop 1000 g : 2230 kg/mm ²	(8)
(127, 129)	Young's modulus:	100 g : 3060 kg/mm ² (2580-3940)	(38)
(3)		65 x 10 ⁶ psi at 20°C	(5)
		64.79 x 10 ⁶ psi at rt	(126)
		65.2 x 10 ⁶ psi	(127)
		42 x 10 ⁶ psi	(227, 297)
(73)	Shear modulus:	26.83 x 10 ⁶ psi at rt	(126)
(227)	Bulk modulus:	36.80 x 10 ⁶ psi at rt	(126)
(227)	Poisson's ratio:	0.207	(126)
(227)	Speed of sound:	48,230 fps	(126)

OPTICAL

(227) Color: Black

Spectral emissivity: 0.65 μ: 0.76 at 880°C (158)
0.56 at 1880°C (158)

STRUCTURE

(127) Rhombic (127)

(45, 127) C₃ chains and B₁₂ icosahedra in a NaCl type structure,
(38) extended along a body diagonal (73, 378, 379)
(38)
(38)

(Cont.)

STRUCTURE (cont.)

Continuous network of boron atoms accounts for its low conductivity and great hardness

(1)

THERMAL

Conductivity:	0.065 cgs at 20°C	(227, 287)
	0.069 cgs at 20°C	(5, 127, 129)
	0.198 cgs at 425°C	(227, 2)
Expansion:	4.5 x 10 ⁻⁶ per °C; rt - 800°C	(227, 2)
	4.78 x 10 ⁻⁶ per °C; 25-500°C	(2, 5, 127, 129, 227)
	5.54 x 10 ⁻⁶ per °C; 25-1000°C	(329)
	6.02 x 10 ⁻⁶ per °C; 25-1500°C	(329)
	6.53 x 10 ⁻⁶ per °C; 25-2000°C	(329)
	7.08 x 10 ⁻⁶ per °C; 25-2500°C	(329)

CHEMICAL

Formula we
Formula vo
Melting poi
Pycnometr:

Theoretica
Decompos
Hydrolysi
Absorbs t
Reacts re
Hydrolyz

BERYLLIUM CARBIDE

Formula weight: 30.05 g/mole

Formula volume: 15.8 cc/mole

Melting point: d > 2100°C (3)
 d 2100°C (38, 227)
 d 2050°C (227, 298)
 d 2150°C (227, 261)

Pycnometric density: 1.9 g/cc at 20°C (3)

CHEMICAL

Theoretical analysis: 40.0% carbon
 60.0% beryllium

Synthesis: a. Be + C or an organic material at 1300°C (380, 381, 382, 383, 384)
 b. BeO + C, at 1930°C (380, 381, 382, 383, 384)

Stable in dry air at rt (227)

Slowly decomposed by water (3)

Slowly decomposed by acids (3)

Rapidly decomposed by alkalis (73)

Yields methane on hydrolysis (73)

Be₂C at 2100°C decomposes yielding graphite (380, 381, 382, 383, 384)

Dissociates in argon at 2150°C (227)

Stable to dry oxygen to 1000°C (227)

Stable in dry hydrogen to 1000°C

Absorbs N₂ above 1200°C, to give Be₃N₂ which decomposes at 1100°C (227, 305)

Reacts with NH₃ above 1200°C (227)

Reacts with CO₂ above 1375°C (227)

MECHANICAL

Strength: Cc

Hardness: M

Young's modu

Poisson's rat.

OPTICAL

Color: Bric

STRUCTURE

Forms regul

Antifluorite
8 Be atoms

THERMAL

Conductivity:

Expansion:

Be₂C

Be₂C

M CARBIDE

(Cont.)

MECHANICAL

Strength: Compression: 105,000 psi at rt (88, 227, 319)

Hardness: Mohs: 9+ (2, 88, 227)

Young's modulus: 45 x 10⁶ psi at 20°C, 6-8% porous
45.6 x 10⁶ psi at 0°C (88, 227, 319)

Poisson's ratio: 0.01 (88, 227, 314)

OPTICAL

Color: Brick red (73)

STRUCTURE

Forms regular octahedral crystals (73)

Antifluorite structure, each C surrounded cubically by 8 Be atoms (73)

THERMAL

Conductivity: 0.056 cgs at 20°C
0.054 cgs at 100°C (227, 313)
0.050 cgs at 20-425°C (227, 2, 289, 88)

Expansion: 10.8 x 10⁻⁶ per °C; 38-982°C
10.1 x 10⁻⁶ per °C; 25-500°C (329)
10.4 x 10⁻⁶ per °C; 25-800°C (227, 2)

(3)
(38, 227)
(227, 298)
(227, 261)

383, 384)

383, 384)
(227)

(3)

(3)

(73)

(73)

383, 384)

(227)

(227)

27, 305)

(227)

(227)

BORON

Formula weight:	10.82 g/mole	
Formula volume:	4.63 cc/mole	
Melting point:	2300°C 2050°C 2300 ± 300°C 2150°C	(3) (127) (227, 298)
Boiling point:	2550°C	(3)
Vapor pressure:	4.94 x 10 ⁻⁶ mm of Hg at 1238°C	(227, 244)
X-ray density:	2.34 g/cc	(127)
Pycnometric density:	2.32 g/cc	(3)

CHEMICAL

Reactivity:	Insoluble: H ₂ O, alcohol	(3)
	Soluble: HNO ₃	(3)

ELECTRICAL

Resistivity:	7000 ohm-cm	(127)
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MECHANICAL

Strength: Bending:	76,000 psi	(127)
Hardness: Mohs:	9.3	(248)
	Knoop 100g: 2500 kg/mm ²	(127)
	3340 kg/mm ² (3140-3750)	(38)

STRUCTURE

Below 1100°C, essentially a close packed cubic array of B₁₂ icosahedra. (248)

B

BORON

STRUCTURE (cont.)

Above 1100°C, a number of complex structures have been identified. (248)

(3)

(127)

(227, 298)

THERMAL

(3)

Expansion: 8.29×10^{-6} per °C; 20-1000°C (227)

8°C (227, 244)

8.22×10^{-6} per °C; 25-500°C (329)

(127)

8.24×10^{-6} per °C; 25-1000°C (329)

(3)

Heat of vaporization: $\Delta H_{v298} = 132$ kcal/mole (206)

(3)

(3)

(127)

(127)

(248)

(127)

(38)

of B₁₂

(248)

BERYLLIUM

Formula weight:	9.02 g/mole	
Formula volume:	4.97 cc/mole	
Melting point:	1330°C	(161, 227, 298)
	1284°C	(3)
Boiling point:	2767°C	(3)
Vapor pressure:	4.68 x 10 ⁻⁶ mm of Hg at 1130°C	(227, 244)
	10 ⁻³ mm of Hg at 1093°C	(227, 315)
Pycnometric density:	1.816 g/cc	

THERMAL

Expansion: (cont)

CHEMICAL

Reactivity:	Slight reaction in hot H ₂ O	(3)
	Soluble in dilute acids and alkalis	(3)

MECHANICAL

	Complete review by White	(227, 319)
	Data sheets available	(227, 292, 293)

STRUCTURE

	Hexagonal close packed, mean Be-Be distance 2.25A	(248)
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THERMAL

Conductivity:	0.394 CGS	(88, 185, 227)
Expansion:	11.5 x 10 ⁻⁶ per °C; r. t.	(185, 227)
	13.4 x 10 ⁻⁶ per °C; 20-255°C	(227)
	15.9 x 10 ⁻⁶ per °C; 20-492°C	(227)

Be

Be

BERYLLIUM

(Cont.)

THERMAL

Expansion: (cont.)

(161, 227, 298)

18.75×10^{-6} per °C; 20-1000°C

(227)

(3)

15.8×10^{-6} per °C; 25-500°C

(329)

(3)

18.5×10^{-6} per °C; 25-1000°C

(329)

f Hg at 1130°C (227, 244)

f Hg at 1093°C (227, 315)

(3)

alis

(3)

(227, 319)

(227, 292, 293)

ice 2.25A

(248)

(88, 185, 227)

(185, 227)

°C

(227)

°C

(227)

DIAMOND

Formula weight:	12.01 g/mole	
Formula volume:	3.4188 ± 0.00001 cc/mole	(553)
Melting point:	s. >3500°C 3700°C	(3)
Boiling point:	4200°C	(3)
Pycnometric density:	3.51 g/cc	(3)

THERMAL (cont.)

Expansion: (co

α linear = 0.

α volume = 0.

MECHANICAL

Hardness: Mohs	: 10	
Vickers	: 10,600 kg/mm ²	(8)
Knoop 100 g	: 8000-8500 kg/mm ²	(8)
1000 g	: 5500-7000 kg/mm ²	(8)

OPTICAL

Color:	colorless if pure	
Form:	cubes, octahedra	
Refractive index:	2.4195	(3)

STRUCTURE

Cubic		
C - C distance	1.54 A	(248)
a =	3.56688 ± 0.00009 A at 298.16°K	(553)

THERMAL

Expansion:	3.48 x 10 ⁻⁶ per °C; to 1000°C	(7)
	4.10 x 10 ⁻⁶ per °C; to 1400°C	(7)

C
DIAMOND

THERMAL (cont.)

(553)

Expansion: (cont.)

2.57×10^{-6} per °C; 25-500°C (329)

(3)

3.53×10^{-6} per °C; 25-1000°C (329)

(3)

4.38×10^{-6} per °C; 25-1500°C (329)

(3)

α linear = $0.09613 \times 10^{-5} + 3.522 \times 10^{-9} T - 0.0888 T^{-2}$ (553)

α volume = $0.2884 \times 10^{-5} + 10.57 \times 10^{-9} T - 0.2665 T^{-2}$ (553)

298 - 973°K (553)

(8)

(8)

(8)

(3)

(248)

(553)

(7)

(7)