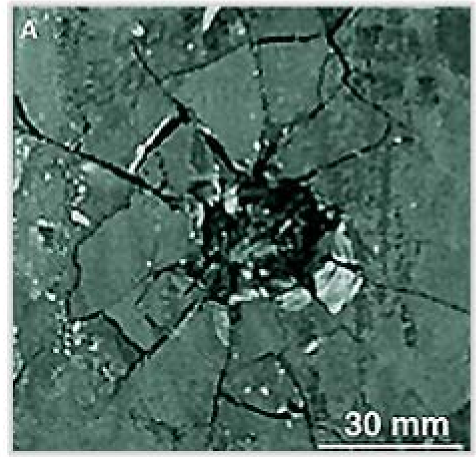
Description

Image



Caption

1. The hardness and low density of B_4C allow body armor that is 50% lighter than steel. © Prof. K. Hemker and Dr. Mingwei Chen, Johns Hopkins University 2. Impacted boron carbide.

The material

Boron carbide (B_4C) is nearly as hard as diamond and vastly less expensive (though still not cheap). Its very low density and high hardness make it attractive for the outer layer of bulletproof body armor, as nozzles for sandblasting and as an abrasive.

Compositional summary

B_4C

General properties

Density		2.35e3	-	2.55e3	kg/m^3
Price	*	60.1	-	89.2	USD/kg
Date first used		1930			

Mechanical properties

Young's modulus		440	-	472	GPa
Shear modulus	*	180	-	195	GPa
Bulk modulus	*	252	-	270	GPa
Poisson's ratio		0.18	-	0.21	
Yield strength (elastic limit)	*	350	-	560	MPa
Tensile strength	*	350	-	560	MPa
Compressive strength		2.58e3	-	5.69e3	MPa
Elongation		0			% strain
Hardness - Vickers		3.2e3	-	4e3	HV
Fatigue strength at 10^7 cycles	*	222	-	512	MPa
Fracture toughness	*	2.5	-	3.5	MPa.m^0.5

Mechanical loss coefficient (tan delta)	* 1e-5	-	3e-5	

Thermal properties

Melting point	2.37e3	-	2.51e3	°C
Maximum service temperature	* 727	-	1.73e3	°C
Minimum service temperature	-273			°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	40	-	90	W/m.°C
Specific heat capacity	* 840	-	1.29e3	J/kg.°C
Thermal expansion coefficient	3.2	-	3.4	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Poor conductor			
Electrical resistivity	1e5	-	1e7	µohm.cm
Dielectric constant (relative permittivity)	4.8	-	8	
Dissipation factor (dielectric loss tangent)	* 0.0015	-	0.01	
Dielectric strength (dielectric breakdown)	* 5	-	8	1000000 V/m

Optical properties

Transparency	Opaque

Processability

Moldability	2	-	3
Machinability	1	-	2

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Acceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	

	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Limited use
O2 (oxygen gas)	Acceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent			
Rural atmosphere	Excellent			
Marine atmosphere	Excellent			
UV radiation (sunlight)	Excellent			

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Excellent
Tolerance above 850 C (1562 F)	Excellent

Primary material production: energy, CO2 and water

Embodied energy, primary production		153	-	169	MJ/kg
CO2 footprint, primary production		8.23	-	9.1	kg/kg
Water usage	*	87.5	-	262	l/kg
Eco-indicator 99		863			millipoints/kg

Material processing: energy

Grinding energy (per unit wt removed)	*	208	-	229	MJ/kg

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	*	15.6	-	17.2	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✗	
Recycle fraction in current supply	0.1	%
Downcycle	✓	
Combust for energy recovery	✗	
Landfill	✓	
Biodegrade	✗	
Toxicity rating	Non-toxic	
A renewable resource?	✗	

Environmental notes

Technical ceramics that are used in the pure state, as B4C usually is, are very energy intensive.

Supporting information

Design guidelines

Boron carbide starts as a powder, is pressed (with a polymer binder) to the desired shape, then fired at a high temperature, burning off the binder and causing the powder to sinter. Technical ceramics are formed by the following steps.(a) Pressing, isostatic pressing, powder extrusion (for bars and tubes) or powder injection molding (for intricate, high-volume parts).(b) Green-machining in the unfired state, using standard tools.(c) Firing or "sintering" typically at 1550 - 1700 C for 12 to 20 hours; the part shrinks by about 20%.(d) Diamond grinding to achieve tighter tolerance and surface finish: +/- 10 microns is achievable. The cost of a ceramic part is greatly increased if it has to be diamond-ground. Thus design for net-shape sintering, eliminating step (d) is highly desirable. The standard tolerance for as-fired dimensions is +/- 1% or 125 microns, whichever is greater.

Technical notes

Boron carbide is exceptionally hard, light and wear resistant. Its neutron-absorbing properties make it useful for nuclear shielding.

Typical uses

Slurry nozzles; light weight body armor; pestles and mortars for hard materials; shot blast nozzles; ceramic tooling dies; ballistic tiles; diamond tool dressing; precision tool parts; thread spinning nozzles.

Links

Reference

ProcessUniverse

Producers