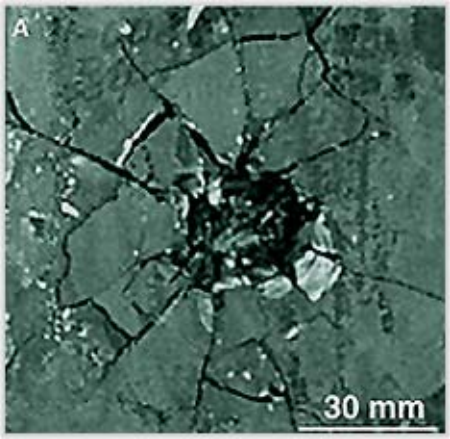
Boron carbide

Description

Image



Caption

1. The hardness and low density of B4C 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 (B4C) 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.

Composition (summary)

B4C

General properties

Density	147	-	159	lb/ft^3
Price	* 27.3	-	40.4	USD/lb
Date first used	1930			

Mechanical properties

Young's modulus	63.8	-	68.5	10^6 psi
Shear modulus	* 26.1	-	28.3	10^6 psi
Bulk modulus	* 36.5	-	39.2	10^6 psi
Poisson's ratio	0.18	-	0.21	
Yield strength (elastic limit)	* 50.8	-	81.2	ksi
Tensile strength	* 50.8	-	81.2	ksi
Compressive strength	375	-	825	ksi
Elongation	0			% strain
Hardness - Vickers	3.2e3	-	4e3	HV
Fatigue strength at 10^7 cycles	* 32.2	-	74.3	ksi
Fracture toughness	* 2.28	-	3.19	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 1e-5	-	3e-5	

Thermal properties

Melting point	4.3e3	-	4.54e3	°F
Maximum service temperature	* 1.34e3	-	3.14e3	°F
Minimum service temperature	-460			°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	23.1	-	52	BTU.ft/h.ft^2.F
Specific heat capacity	* 0.201	-	0.308	BTU/lb.°F
Thermal expansion coefficient				

	1.78	-	1.89	µstrain/°F

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)	* 127	-	203	V/mil

Optical properties

Transparency	Opaque			

Processability

Moldability	2	-	3	
Machinability	1	-	2	

Eco properties

Embodied energy, primary production	1.66e4	-	1.83e4	kcal/lb
CO2 footprint, primary production	8.23	-	9.1	lb/lb
Recycle	✕			

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