Description

Image

Caption

1. Ceramic knife made of zirconia. © SlonikkinolS at en.wikipedia - (CC BY-SA 3.0) 2. Zirconia components.

The material

Zirconia, ZrO_2, is a ceramic with an exceptionally high melting point -- 2760 C when pure. It has the highest useful strength and toughness at room temperature of all the readily available ceramics. It is used (with 5% CaO) as a firebrick, and, in sintered form (with MgO or Y_2O_3 additives) for high strength, high temperature applications. The exceptional toughness is imparted by transformation toughening: a change in crystal structure from tetragonal to monoclinic, with an associated change in volume of the ZrO_2 crystals when subjected to stress at a crack tip. The volume expansion squeezes the crack shut, impeding crack growth. Transformation toughening is made possible by additions of magnesia, MgO, or yttria, Y_2O_3, to give PSZ (partially stabilized zirconia) or TZP (tetragonal zirconia polycrystal). Zirconia is also available as foam for thermal insulation and filtration, and as fibers, used to make fabrics that can tolerate temperatures up to 2425 C.

Compositional summary

ZrO_2, usually with additions of Y_2O_3, MgO and other oxides to enhance toughness.

General properties

Density		368	-	384	lb/ft^3
Price	*	8.46	-	12.2	USD/lb
Date first used		1962			

Mechanical properties

Young's modulus		29	-	36.3	10^6 psi
Shear modulus	*	8.7	-	12.5	10^6 psi
Bulk modulus	*	23.2	-	30.7	10^6 psi
Poisson's ratio		0.3	-	0.32	
Yield strength (elastic limit)		72.5	-	103	ksi
Tensile strength		72.5	-	103	ksi
Compressive strength	*	522	-	754	ksi
Elongation		0			% strain

Hardness - Vickers	1e3	-	1.23e3	HV
Fatigue strength at 10^7 cycles	* 43.5	-	72.5	ksi
Fracture toughness	5.46	-	7.28	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 5e-4	-	0.001	

Thermal properties

Melting point	4.62e3	-	4.89e3	°F
Maximum service temperature	2.19e3	-	2.73e3	°F
Minimum service temperature	-459			°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	1.16	-	2.43	BTU.ft/h.ft^2.F
Specific heat capacity	0.115	-	0.124	BTU/lb.°F
Thermal expansion coefficient	5.83	-	6.11	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	2e18	-	3e21	µohm.cm
Dielectric constant (relative permittivity)	12	-	25	
Dissipation factor (dielectric loss tangent)	* 8e-4	-	0.002	
Dielectric strength (dielectric breakdown)	* 102	-	152	V/mil

Optical properties

Transparency	Opaque			
Refractive index	2.1	-	2.17	

Processability

Castability	1			
Moldability	2	-	3	
Formability	1			
Machinability	1	-	2	
Weldability	1			
Solder/brazability	3	-	4	

Eco properties

Embodied energy, primary production	* 9.21e3	-	1.02e4	kcal/lb
CO2 footprint, primary production	* 4.59	-	5.07	lb/lb
Recycle	✘			

Supporting information

Design guidelines

Zirconia, ZrO_2, has the highest useful strength and toughness at room temperature of all the readily available ceramics. The fine grain size allows extremely smooth surfaces and sharp edges. This, combined with its exceptionally high toughness, make it attractive for blades for paper cutting, engine components and wear plates. 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

Stabilization of stabilized Zirconias is slowly lost on holding between temperatures of 1050K and 1450K. At ~1150K zirconia ceramics become electrically conducting.

Typical uses

Bearing wear sleeves; microtools and tweezers; knife blades; replacement for steel in surgical applications; electrical and thermal insulation at high and low temperatures; cutting applications; extrusion and drawing dies; catalyst supports; cylinder liners; turbo-charger blades and other engine components for automotive applications; wear plates, thermal barrier coatings for turbine blades.

Links

Reference

ProcessUniverse

Producers