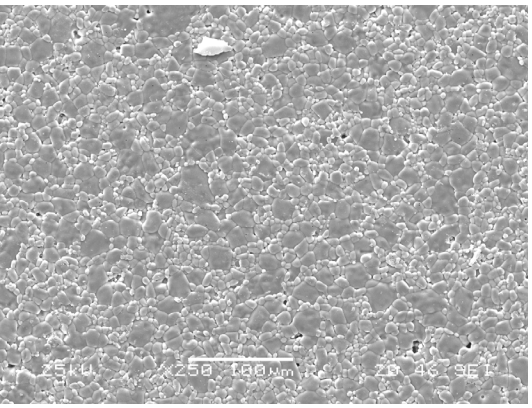
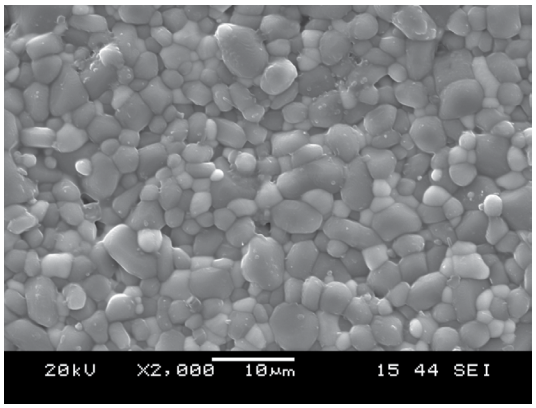
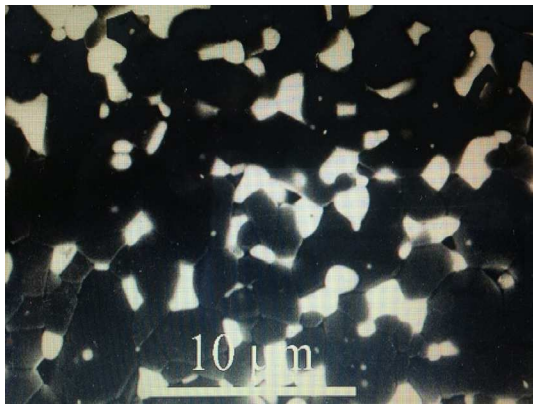
ZIRCONIA-TOUGHENED ALUMINA:
WHY ADDING ZIRCONIA INCREASES STRENGTH AND TOUGHNESS



ZTA-02



ZTA-14



ZTA-20

OVERVIEW

Zirconia Toughened Alumina (ZTA) ceramics offer an exceptional performance to price ratio. Like Yttria Stabilized Tetragonal Zirconia Polycrystal (YTZP), Zirconia Toughened Alumina (ZTA) belongs to a family of ceramics that have a toughening mechanism due to transformation of the crystal structure under an applied stress. Their microstructures have been tailored to produce a significant enhancement of structural properties over basic alumina materials.

These improved properties are the result of a combination of factors, most significantly a phenomenon known as "*transformation toughening*". ZTA's carefully tailored microstructure with a uniform dispersion of YTZP particles in an alumina matrix results in a more fracture resistant structure than alumina alone.

STC's family of ZTA's are produced to contain 2 - 20 volume percent of fine zirconia (ZrO_2) particles in an alumina (Al_2O_3) matrix. When placed under stress, these zirconia particles change their crystal structure from a tetragonal to a monoclinic structure. This transformation results in a 3 - 5 volume percent expansion, which compresses the surrounding crack in the alumina matrix. This captures or "pins" the crack and restricts its rate of propagation. The result is a stronger and tougher material than regular alumina.

ZIRCONIA TOUGHENING OF ALUMINA

Like Yttria-stabilized Tetragonal Zirconia Polycrystal (YTZP), Zirconia-Toughened Alumina (ZTA) belongs to a family of ceramics that have a self-sealing mechanism at work within them; their microstructures have been carefully adjusted to produce an effect known as ***transformation toughening.***

ZTA is produced to contain 10-20 vol% of fine zirconia (ZrO_2) particles in an alumina (Al_2O_3) matrix. When placed under stress, these zirconia particles change their crystal structure from a tetragonal to a monoclinic pattern - a transformation that results in a 3-5 vol% expansion, which compresses the surrounding alumina, making it more resistant to cracks.

Unusually, even the stress field around a crack is enough to induce this transformation, so whenever a crack tries to advance in ZTA, the zirconia crystals expand, compressing the alumina matrix and squeezing the crack shut. Higher strengths are also favored in ZTA because the addition of zirconia particles encourages a smaller Al_2O_3 grain size.

MORE ABOUT ZIRCONIA-TOUGHENED ALUMINA

Both zirconia and alumina are relatively inert but monolithic zirconia can be vulnerable to chemisorption in the presence of water molecules. Recent research appears to indicate that ZTA composites fare much better under hydrothermal conditions. The properties under hydrothermal conditions will degrade as the percent of YTZP increases.

ZTA ceramics are used widely in applications where strength, toughness, chemical inertness and wear resistance are required. The relatively lower weight to volume ratios than typical zirconias and exotic metallic materials can also be advantageous.

SUPERIOR TECHNICAL CERAMICS PATENT NO. 8679995

Our research teams work to expand the ability of our materials to solve the challenges of the operating conditions you are designing for. Starting with select raw materials, our patented process provides consistent material properties that result in high quality, dependable ceramic components.

SPECIFICATIONS

	Property	ASTM Method	Units	ZTA-02 US Patent 8679995	ZTA-14	ZTA-20
General	Crystal Size (Average)	Thin Section	Microns	< 2	6	3
	Color	--	--	Off White	White	White
	Gas Permeability	--	atms-cc/sec	gas tight $<10^{-10}$	gas tight $<10^{-10}$	gas tight $<10^{-10}$
	Water Absorption	C 20-97	%	0	0	0
Mechanical	Density	C 20-97	g/cc	3.96	4.17	4.30
	Hardness	Vickers 500 gm	GPa (kg/mm^2)	14 (1440)	14.5 (1478)	14.4 (1470)
	Hardness	--	R45N	81	82	82
	Fracture Toughness	Notched Beam	MPam$^{1/2}$	5	6	6
	Flexural Strength (MOR) (3 point) @ RT	F417-87	MPa (psi x 10^3)	448 (65)	586 (85)	621 (90)
	Tensile Strength @ RT	--	MPa (psi x 10^3)	259 (38)	344 (50)	350 (51)
	Compressive Strength @ RT	--	MPa (psi x 10^3)	2413 (350)	2758 (400)	2758 (400)
	Elastic Modulus	C848	GPa (psi x 10^6)	358 (52)	338 (49)	338 (49)
	Poisson's Ratio	C848	--	0.23	0.23	0.23
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10^{-6}/C	6.7	6.0	6.0
	C.T.E. 25 - 300° C	C 372-96	x 10^{-6}/C	8.1	7.0	7.0
	C.T.E. 25 - 600° C	C 372-96	x 10^{-6}/C	8.3	7.1	7.1
	Thermal Conductivity @ RT	C 408	W/m K	27	24	24
	Max Use Temp	--	Fahrenheit (°F)	2732	2730	2730
		--	Celsius (°C)	1500	1500	1500
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	230	250	250
	Dielectric Constant @ 1 MHz	D 150-98	--	10.5	12.5	12.5
	Dielectric Constant	D 2520-95	--	--	--	12.4
	@ Gigahertz			--	--	9.4
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0003	0.0006	0.0006
	Dielectric Loss	D 2520-95	--	--	0.0005	0.0005
	@ Gigahertz			--	9.4	9.4
	Volume Resistivity, 25°C	D 257	ohms-cm	> 1 x 10^{14}	> 1 x 10^{14}	> 1 x 10^{14}
	Volume Resistivity, 300° C	D 1829	ohms-cm	3 x 10^{12}	1 x 10^{10}	1 x 10^{10}
	Volume Resistivity, 500° C	D 1829	ohms-cm	6 x 10^{10}	2 x 10^9	2 x 10^9
	Volume Resistivity, 700° C	D 1829	ohms-cm	6 x 10^9	2 x 10^8	4 x 10^8

APPLICATIONS

ZTA ceramics are used widely where high strength and erosion resistance is needed. Components such as pump pistons, wear sleeves, spraying nozzles, steering nozzles, and valve control discs are ideally suited for this material.

RELATED SERVICES**

- Powder Preparation
- Forming (Mechanical Pressing, Extrusion, Isostatic Pressing)
- Green Machining
- Firing / Sintering
- Grinding
- Polishing / Lapping
- Glazing / Coating
- Metalizing and Plating
- Metrology