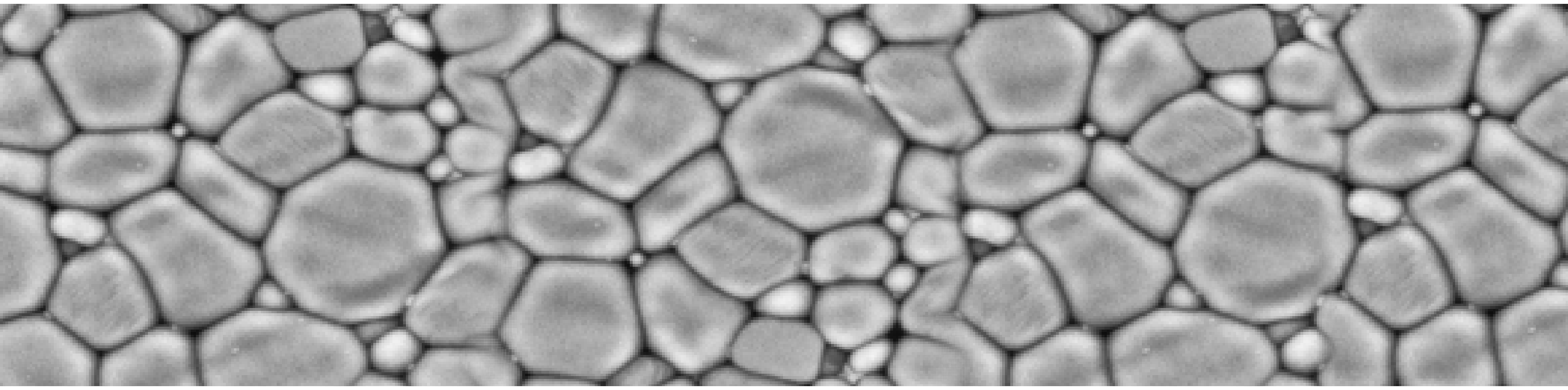
Superior Technical Ceramics
Engineering. Partnership. Solutions.

CERIA STABILIZED ZIRCONIA: WHY CSZ HAS A SUPERIOR RESISTANCE TO LOW-TEMPERATURE DEGRADATION THAN YTZP OR MSZ?



OVERVIEW

Stabilized zirconia ceramics - such as Yttria-stabilized Tetragonal Zirconia Polycrystal (YTZP) - are so strong and durable, they have been called the 'ceramic analogue of steel'. However, they can be vulnerable to low-temperature degradation, particularly in moist environments. This White Paper explains how, for YTZP and MSZ, the transformation toughening phenomenon can be undone under certain environmental conditions. It also describes the protective characteristics held by Ceria Stabilized Zirconias that make them more resistant to low-temperature degradation than YTZP and MSZ. The key is the presence of oxygen vacancies in the crystal structure - or rather, the lack of these in CSZ ceramics - which offers a protective effect.

TRANSFORMATION TOUGHENED ZIRCONIAS

In an earlier White Paper we explained how doping with oxides such as Yttria, Magnesia and Ceria can markedly improve the strength and toughness of Zirconia ceramics by stabilising a particular crystal structure called the tetragonal phase (t-ZrO_2).

In these stabilized Zirconias, such as YTSP or CSZ, the stress field around a crack is enough to prompt a highly localised phase transformation and volume expansion which squeezes the crack shut.

Given that it is the presence of the tetragonal phase t-ZrO_2 which allows this self-sealing mechanism to work, it is easy to see how the strength and toughness of stabilized Zirconias is completely dependent upon the stability of the tetragonal phase, t-ZrO_2.

The correct choice of dopant oxide is therefore crucial if the ceramic is to remain stable in moist environments.

LOW-TEMPERATURE DEGRADATION

Both research and practice have shown that the stability of the tetragonal phase t-ZrO_2 in Yttria-stabilized Tetragonal Zirconia Polycrystal is limited in the presence of water. At even low to moderate temperatures, the tetragonal phase (t-ZrO_2) transforms to the monoclinic (m-ZrO_2), not only in a tiny region ahead of a crack, but all across the exposed surface. Because the monoclinic crystal structure is bigger by volume, this extensive phase transformation causes cracking and severe wear or failure.

It may be decades after the discovery of low-temperature degradation in stabilized zirconias, but research into the exact nature of the process is very much ongoing. For example, research work has identified that no less than three different hydrogen defects are present and that a complex involving a hydrogen defect and an oxygen vacancy plays an important role.

What is certain, however, is that the primary factor is the presence of oxygen vacancies in the Zirconia itself. Water radicals are thought to invade the surface and destabilize the tetragonal phase by sitting in these oxygen vacancies. It is the presence of these oxygen vacancies in YTZP and MSZ that make these particular Zirconias vulnerable to low-temperature degradation.

THE SUPERIOR DEGRADATION PROPERTIES OF CERIA STABILIZED ZIRCONIA

The key factor in favor of Ceria Stabilized Zirconia is that there are no oxygen vacancies to make the tetragonal phase vulnerable in this way. No oxygen defects form in Ceria Stabilized Zirconia because the tetravalent Cerium substitute the Zr4+ ions directly.

With no oxygen vacancies to make the crystal structure vulnerable, Ceria Stabilized Zirconia is able to withstand low-temperature degradation better than YTZP and MSZ. This is why CSZ is often chosen over YTZP or MSZ when low-temperature degradation is a factor. As a result, CSZ is a top candidate when choosing a ceramic material for high-strength and toughness in moist, challenging environments.

APPLICATIONS

CSZ ceramics offer material properties suitable for hot and humid or highly caustic conditions. Perfect suited for instrumentation, sensors, flow control, insulators and other components.

MSZ RELATED SERVICES**

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

SPECIFICATIONS

CSZ ceramics offer material properties suitable for hot and humid or highly caustic conditions. Perfect suited for instrumentation, sensors, flow control, insulators and other components.

	Property	ASTM Method	Units	CSZ
General	Crystal Size (Average)	Thin Section	Microns	3
	Color	--	--	Yellow
	Gas Permeability	--	atms-cc/sec	gas tight $<10^{-10}$
	Water Absorption	C 20-97	%	0
Mechanical	Density	C 20-97	g/cc	6.20
	Hardness	Vickers 500 gm	GPa (kg/mm^2)	11.7 (1200)
	Hardness	--	R45N	78
	Fracture Toughness	Notched Beam	MPam$^{1/2}$	12
	Flexural Strength (MOR) (3 point) @ RT	F417-87	MPa (psi x 10^3)	551 (80)
	Tensile Strength @ RT	--	MPa (psi x 10^3)	337 (49)
	Compressive Strength @ RT	--	MPa (psi x 10^3)	2000 (290)
	Elastic Modulus	C848	GPa (psi x 10^6)	200 (29)
	Poisson's Ratio	C848	--	0.25
Thermal	C.T.E. 25 - 100° C	C 372-96	x 10^{-6}/C	6.9
	C.T.E. 25 - 300° C	C 372-96	x 10^{-6}/C	8.1
	C.T.E. 25 - 600° C	C 372-96	x 10^{-6}/C	10.5
	Thermal Conductivity @ RT	C 408	W/m K	3.5
	Max Use Temp	--	Fahrenheit (°F)	1000
		--	Celsius (°C)	537
Electrical	Dielectric Strength (.125" Thick)	D 149-97A	V/mil	250
	Dielectric Constant @ 1 MHz	D 150-98	--	30.0
	Dielectric Loss @ 1 MHz	D 150-98	--	0.0010
	Volume Resistivity, 25°C	D 257	ohms-cm	$> 1 \times 10^{13}$
	Volume Resistivity, 300° C	D 1829	ohms-cm	1×10^{10}
	Volume Resistivity, 500° C	D 1829	ohms-cm	1×10^{6}
	Volume Resistivity, 700° C	D 1829	ohms-cm	5×10^{3}

CONTACT US

For more information call or email us. You can also learn more about our extensive capabilities at www.ceramics.net

Superior Technical Ceramics
600 Industrial Park Rd.
St. Albans, VT 05478
Tel (802) 527-7726
Fax (802) 527-1181
sales@ceramics.net