Estimation of the role of nano-sized stabilizing powders in gaining high-level crack growth resistance of partially stabilized zirconia

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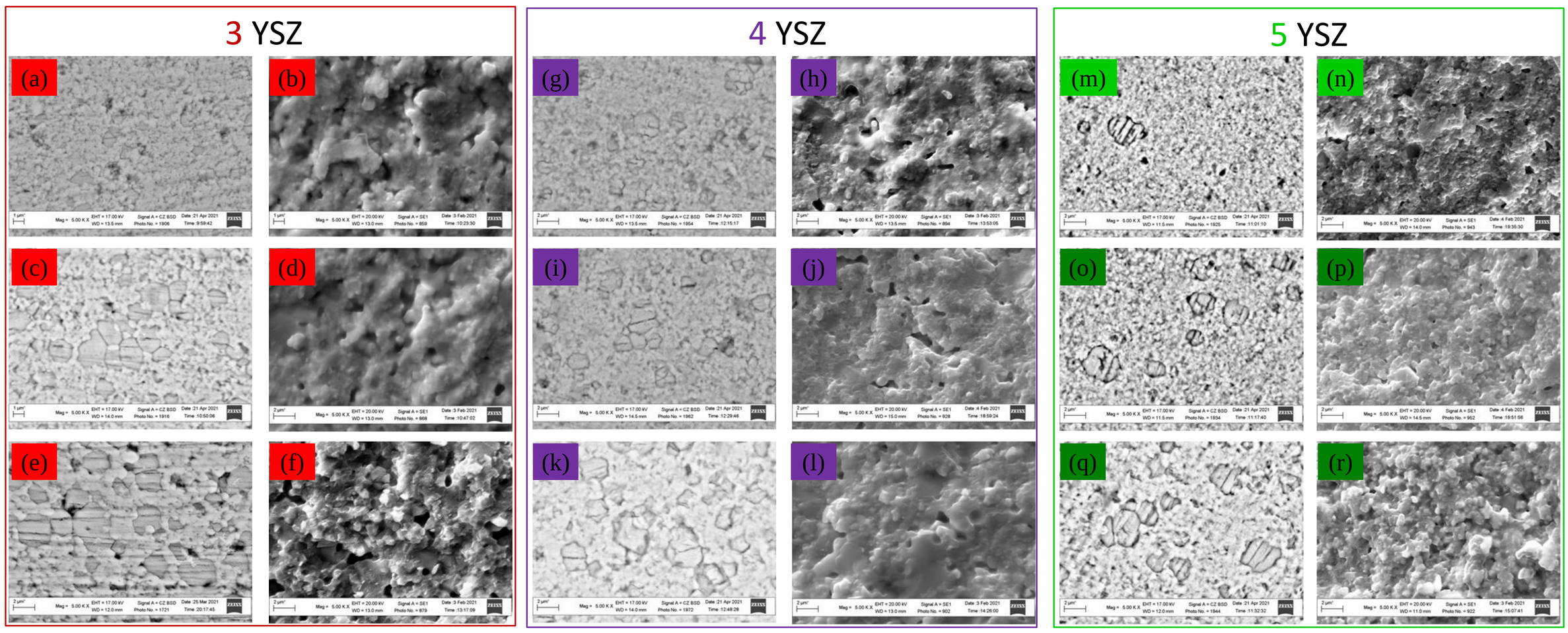
Introduction. Nowadays, zirconium oxide (ZrO_2) is widely used for applications in high temperature structural materials. These materials may have applications such as cracking furnaces, catalytic cracking units, fired heaters, hydrogen reformers, utility boilers, ammonia reformers, air heaters, etc. Zirconium oxide (zirconia) is often more useful in its phase stabilized state. Products made of yttria-stabilized zirconia ceramics are characterized by improved strength and crack growth resistance.

Sintering modes and average values of SENB fracture toughness of the investigated material variants

Variant	Content of Y_2O_3, mol%	Sintering mode		Parameter
		Temperature, °C	Time, h	K_{Ic}, MPa·m$^{1/2}$
1	3	1450	2	5.8
2	3	1500	2	6.0
3	3	1550	2	7.8
4	4	1450	2	5.7
5	4	1500	2	6.9
6	4	1550	2	6.2
7	5	1450	2	10.8
8	5	1500	2	9.3
9	5	1550	2	9.9

Experimental. In this work, ZrO_2 ceramics partially stabilized with 3, 4, and 5 mol% Y_2O_3 (hereinafter: 3YSZ, 4YSZ, and 5YSZ) have been studied. Three sintering temperatures were used to prepare beam specimens of each series: 1450 °C, 1500 °C, and 1550 °C. Single-edge notch beam test and fracture toughness test by indentation method were performed and fracture toughness of the material was estimated.

Results and Discussion. In the case when the sufficient amount of the metastable tetragonal phase is present, an applied stress, magnified by the stress concentration at a crack tip, can cause the tetragonal phase to convert to monoclinic, with the associated volume expansion. This phase transformation can then put the crack into compression, retarding its growth, and enhancing the fracture toughness. For materials studied in this work, a distinct transformation toughening effect was found for 5YSZ ceramics.



SEM (a, c, e, g, i, k, m, o, q) microstructures (BSD images) and (b, d, f, h, j, l, n, p, r) fractography (SE images) of specimens of (a-f) 3YSZ ceramics, (g-l) 4YSZ ceramics, and (m-r) 5YSZ ceramics sintered at (a, b, g, h, m, n) 1450 °C, (c, d, i, j, o, p) 1500 °C, and (e, f, k, l, q, r) 1550 °C

Based on the microstructure and fracture surface analyses it was found that nano-sized stabilizing powders play a crucial role in gaining high-level crack growth resistance of partially stabilized zirconia.