The effect of sintering temperature on crack growth resistance characteristics of fine-grained partially stabilized zirconia determined by various test methods

Kulyk V.V.[1], Duriagina Z.A.[1,2], Vasyliv B.D.[3], Vavrukh V.I.[1], Kovbasiuk T.M.[1], Lyutyy P.Ya.[1], Tepla T.L.[1]

[1] Department of Materials Science and Engineering, Lviv Polytechnic National University, 12 S.Bandera str., Lviv 79000, Ukraine.

E-mail: kulykvolodymyrvolodymyrovych@gmail.com

[2] Department of Materials Engineering, The John Paul II Catholic University of Lublin, 14 Racławickie Al., Lublin 20-950, Poland.

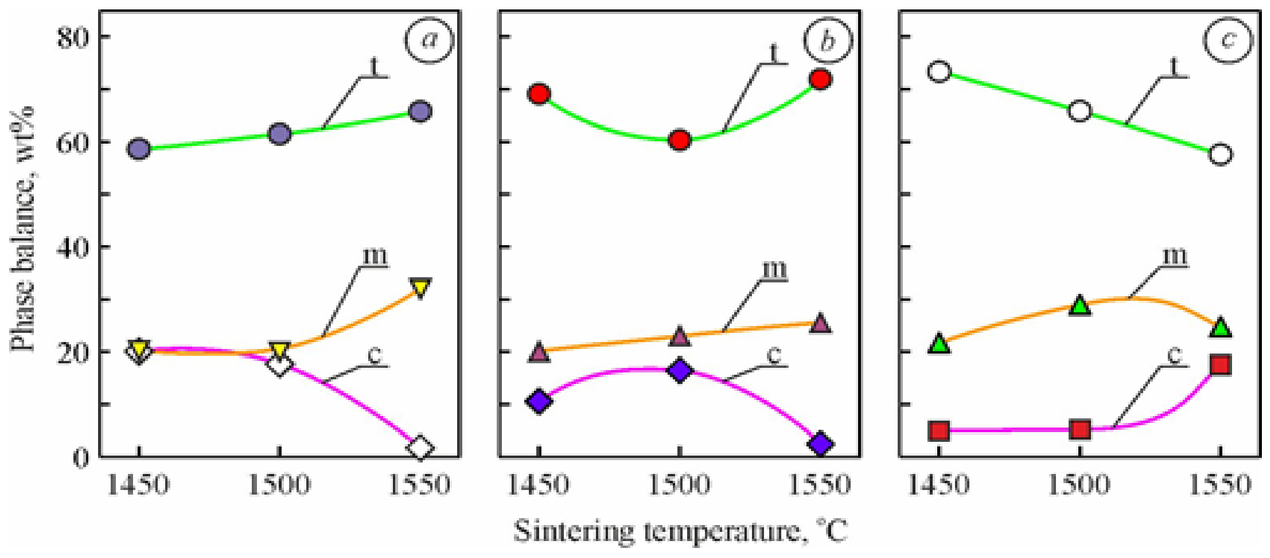
[3] Department of Hydrogen Technologies and Alternative Energy Materials, Karpenko Physico-Mechanical Institute of the NAS of Ukraine, 5 Naukova str., Lviv 79060, Ukraine.

Introduction. Zirconium oxide (zirconia) is widely used for applications in high-temperature structural materials. However, upon heating, zirconia undergoes disruptive phase changes. By adding small percentages of yttria, these phase changes are eliminated, and the resulting yttria stabilized zirconia material has superior thermal, mechanical, and electrical properties. The transformation toughening mechanisms allows getting higher strength and crack growth resistance of such ceramics.

Chemical composition and sintering modes of variants of the investigated material

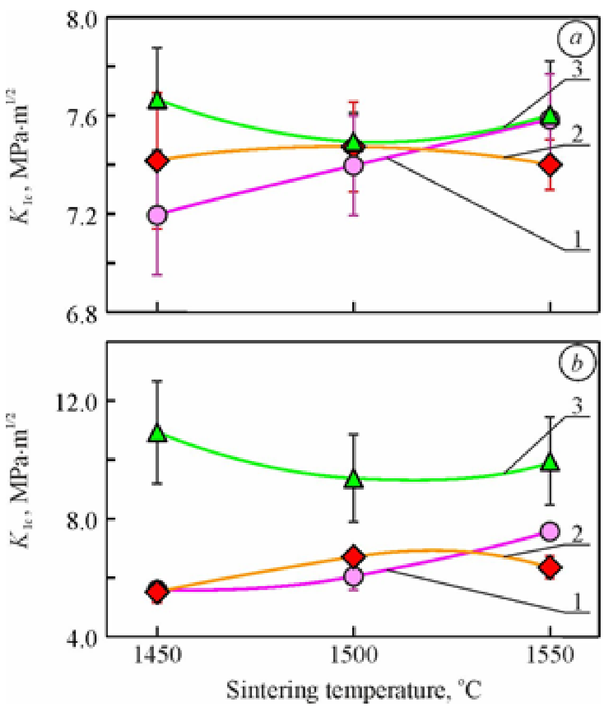
Variant	Content of Y_2O_3, mol%	Sintering mode	
		Temperature, °C	Time, h
1	3	1450	2
2	3	1500	2
3	3	1550	2
4	4	1450	2
5	4	1500	2
6	4	1550	2
7	5	1450	2
8	5	1500	2
9	5	1550	2

Experimental. In this work, yttria stabilized zirconia ceramics sintered at various temperatures have been studied (Table). The series of beam specimens of ZrO_2 ceramics partially stabilized with 3, 4, and 5 mol% Y_2O_3 were prepared using a conventional sintering technique. Two different mechanical tests were performed: single-edge notch beam test under three-point bending and fracture toughness test by indentation method. In both cases, fracture toughness was calculated using obtained experimental data.

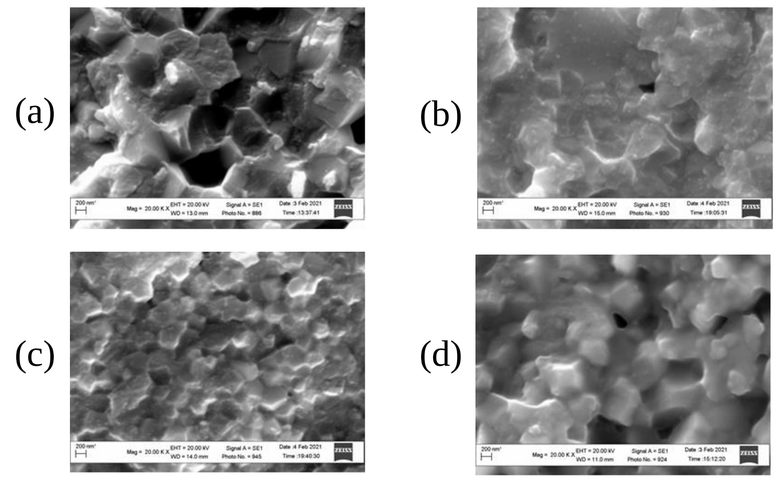


Changes in zirconia phase balance of the investigated materials of variants (a) 1–3, (b) 4–6, and (c) 7–9 depending on the sintering temperature (see Table). Phase marking: t – tetragonal, m – monoclinic, c – cubic

Results and Discussion. Based on the constructed dependences of fracture toughness on sintering temperature for the specimen series it was revealed that both the yttria percentage and sintering temperature affect the mechanical behavior of the ceramics. The maximum transformation toughening effect was revealed for ZrO_2–5mol% Y_2O_3 ceramics.



Changes in fracture toughness of 3YSZ, 4YSZ, and 5YSZ ceramics (curves 1–3, respectively) depending on the sintering temperature: (a) Vickers indentation method under the indentation load of 9.81 N; (b) SENB method under three-point bending



SEM fractography (SE images) of specimens of (a) 3YSZ ceramics sintered at 1550°C, (b) 4YSZ ceramics sintered at 1500°C, (c) 5YSZ ceramics sintered at 1450°C, and (d) 5YSZ ceramics sintered at 1550°C

Based on the studies of microstructure and fracture surface images and also X-ray diffraction analysis it was concluded that transformation toughening of such ceramics is accompanied by distinct changes in the fracture surface morphology.