Application of crack growth resistance characteristics for assessing the degradation of fine-grained YSZ–NiO(Ni) anode materials in a hydrogen sulfide containing atmosphere

Vasyliv B.D.[1], Kulyk V.V.[2], Duriagina Z.A.[2,3], Kovbasiuk T.M.[2], Lemishka I.A.[2]

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

E-mail: mechengin1111@gmail.com

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

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

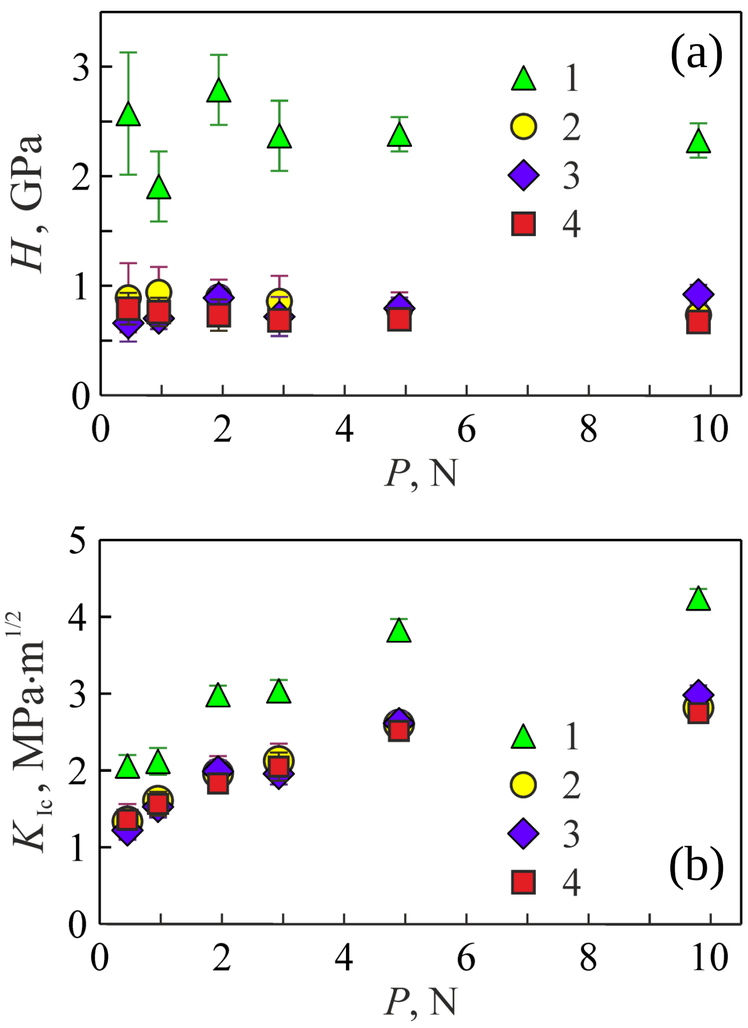
Introduction. One of the main areas of improvement of existing solid oxide fuel cell (SOFC) models is the formation of anode, cathode and electrolyte structures resistible against degradation in operating environments. The aim of this work is to study the effect of hydrogen sulfide content in a hydrogenous atmosphere on the microstructure, physical, and mechanical properties of YSZ–Ni cermets for SOFC anodes.

Experimental. To obtain the corresponding YSZ–Ni cermet structure, specimens of the YSZ–NiO anode ceramics were reduced in Ar–5 vol%H_2 mixture for 4 h at 600 °C under a pressure of 0.15 MPa. A part of reduced specimens was aged in "hydrogen sulfide in Ar–5 vol%H_2 mixture" atmosphere for 4 h at 600 °C under a pressure of 0.1 MPa. The atmosphere contained 7 or 18 vol%H_2S. After aging, the physical and mechanical behaviours of specimens were studied. Two different mechanical tests were performed: strength test under three-point bending and fracture toughness test by indentation method.

Results and Discussion. It was revealed that the atmosphere containing up to 7 vol%H_2S had a slight effect on the strength and electrical conductivity of the YSZ–Ni cermet.

The physical and mechanical properties of treated materials

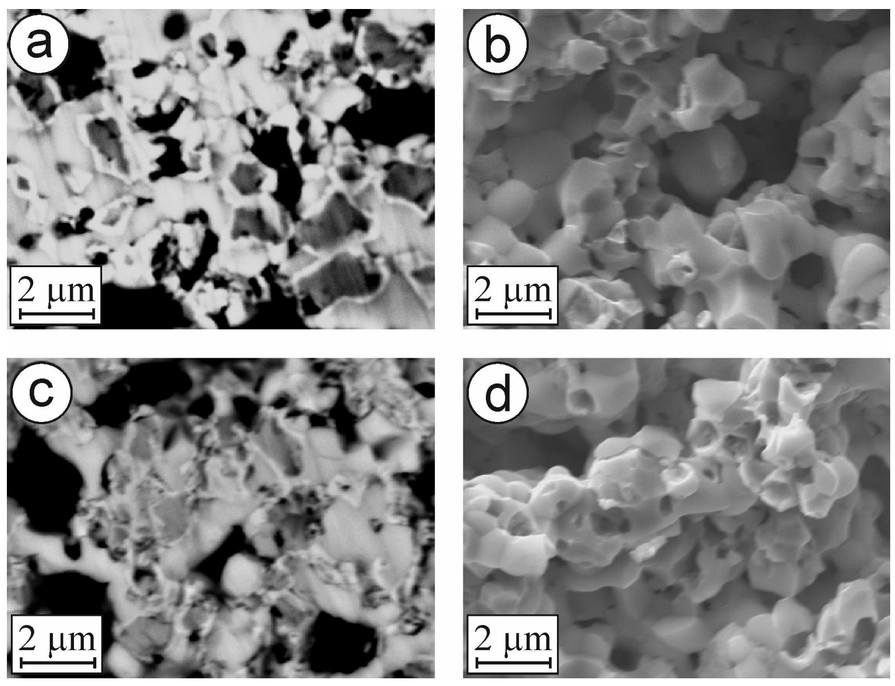
Mode marking	Mode (mixture composition in vol%; processing and aging at 600°C)		Mean values of the characteristics		
	Preconditioning for 4 h	Aging for 4 h	σ_f / σ_{f0} [%]	E / E_0 [%]	σ [S/m]
1	As-sintered		100	100	(*)
2	Processing in Ar–5% H_2	–	86	82	$(5.5–6.5)\cdot10^5$
3	Processing in Ar–5% H_2	Aging in Ar–5% H_2 with 7% H_2S	82	76	$(5.5–6.5)\cdot10^5$
4	Processing in Ar–5% H_2	Aging in Ar–5% H_2 with 18% H_2S	61	75	$(5.5–6.5)\cdot10^5$



Changes in mechanical characteristics of YSZ–NiO(Ni) anode material depending on the indentation load: (a) Vickers microhardness; (b) fracture toughness measured by the Vickers method

In contrast to this, an increased content of hydrogen sulfide (18 vol%H_2S) caused some changes in the YSZ–Ni cermet microstructure. As a result, multiple breaking of the zirconia-nickel bonds occurred.

As compared to the one-time reduced ceramics, microhardness and fracture toughness of the cermet remained at the same levels whereas its strength decreased by almost 30%.



SEM (a, c) microstructures (BSD images) and (b, d) fractography (SE images) of YSZ–Ni cermet specimens after aging in Ar–5 vol% H_2 gas atmosphere with an admixture of 7 vol% H_2S (a, b) and 18 vol% H_2S (c, d)