Development of titanium-based porous composites for anode substrates of solid oxide fuel cells

Viktoriya Podhurska[1], Dmytro Brodnikovskyi[2], Mykola Gadzyra[2], Bogdan Vasyliv[1], Yehor Brodnikovskyi[2], Serhii Lavrys[1], Orest Ostash[1], Oleksandr Vasylyev[2], Bora Timurkutluk[3]

[1] Karpenko Physico-Mechanical Institute of NASU, Lviv, Ukraine
[2] Institute for Problems of Materials Science of NASU, Kyiv, Ukraine
[3] Dept. of Mechanical Engineering, Nigde Omer Halisdemir University, Nigde, Turkey

Solid oxide fuel cells (SOFCs) are an efficient source of electricity for transport, stationary and mobile power stations, which are the main components of hydrogen energetics. At present, the key direction of increasing the efficiency and durability of SOFCs is the reduction of the operating temperature from 800–1000°C to 550–650°C. This can be done by replacing ceramic anode substrates (for example, of NiO–8YSZ system) with porous metallic anode ones. By the way, the thermal expansion coefficient of titanium alloys is in the range of $9\text{-}10\cdot10^{-6}$°C^{-1} that is close to the known for anode, electrolyte and cathode ceramic materials in a SOFC.

In this work, the microstructure and physico-mechanical properties of the candidate solid oxide fuel cell anode materials of the Ti–SiC (material 1 with 30% porosity) and TiC–AlON (material 2 with 35% porosity) systems were investigated in the initial state and after holding at 600°C in air or hydrogen. Scanning electron microscopy analysis revealed that the phase composition of material 1 presents titanium carbide TiC and titanium silicide Ti_5Si_3, whereas material 2 presents titanium carbide TiC, aluminum oxynitride AlON and alumina Al_2O_3. It was found that in the initial state flexural strength of materials 1 and 2 is 105 MPa and 110 MPa, respectively, whereas their electrical conductivity is $3.81\cdot10^5$ S/m and $4.88\cdot10^5$ S/m, respectively. At the same time, material 1 is fractured mainly by transgranular cleavage (Fig.1*a*), and material 2 is fractured by transgranular cleavage with some elements of intergranular cleavage (Fig.1*b*).

At 600°C and holding for 3 hours in air, the studied physico-mechanical characteristics of material 1 are 71 MPa and $3.05\cdot10^5$ S/m, while the fracture micromechanism remains the same. Corresponding characteristics of material 2 is 140 MPa and $4.88\cdot10^5$ S/m at the predominance of intergranular fracture of the TiC phase and microductile fracture of aluminum oxynitride AlON. At 600°C and holding for 3 hours in hydrogen, these characteristics of material 1 are 41 MPa and $3.39\cdot10^5$ S/m at significant changes in the fracture micromechanism with the appearance of a large number of intergranular secondary microcracks (Fig.1*c*). For material 2, they are 80 MPa and $4.88\cdot10^5$ S/m at the predominance of intergranular fracture (Fig.1*d*).

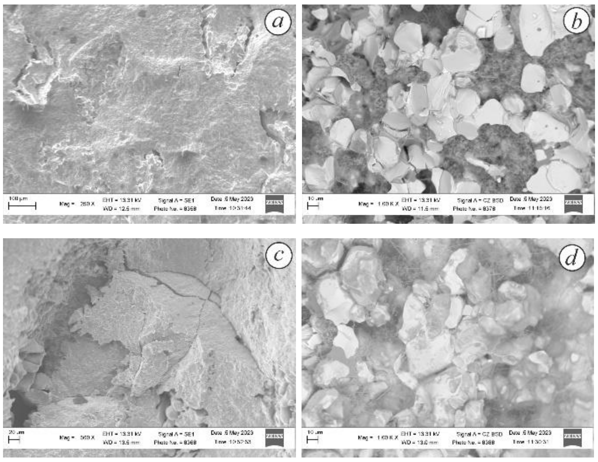

Figure 1. Microfractograms of material 1 (*a*, *c*) and material 2 (*b*, *d*) in the initial state (*a*, *b*) and after holding for 3h in hydrogen at 600°C (*c*, *d*).

Based on the obtained results, it was established that both investigated materials have a high level of electrical conductivity under different test conditions, but in terms of mechanical properties, the composite of the TiC–AlON system has an advantage over the composite of the Ti–SiC system.

Acknowledgements

The work was supported by the NATO project SPS G5949 “Light-Weight 600°C Solid Oxide Fuel Cells for Energy Security (LW-SOFC)”.

Dr. Viktoriya Podhurska works in the Department of Hydrogen Technologies and Materials of Alternative Power Engineering at Karpenko Physico-Mechanical Institute of NASU, Lviv, Ukraine. Dr. Viktoriya Podhurska obtained her Ph.D. degree in Materials Science in 2016. Her research interest covers studying the effects of the microstructure and material composition of anode and current collector materials on their mechanical and physical properties.

Viktoriya Podhurska, e-mail: podhurskavika@gmail.com tel: +38 0973138503