TARGET COMPREHENSIVE PROGRAM SCIENTIFIC RESEARCH NAS of UKRAINE

Development of scientific principles of obtaining, storage and use of hydrogen in autonomous energy supply systems

«DEVELOPMENT OF TAPE CASTING TECHNIQUE REGIMES FOR MANUFACTURING OF SOLID OXIDE FUEL CELLS»

project № 18

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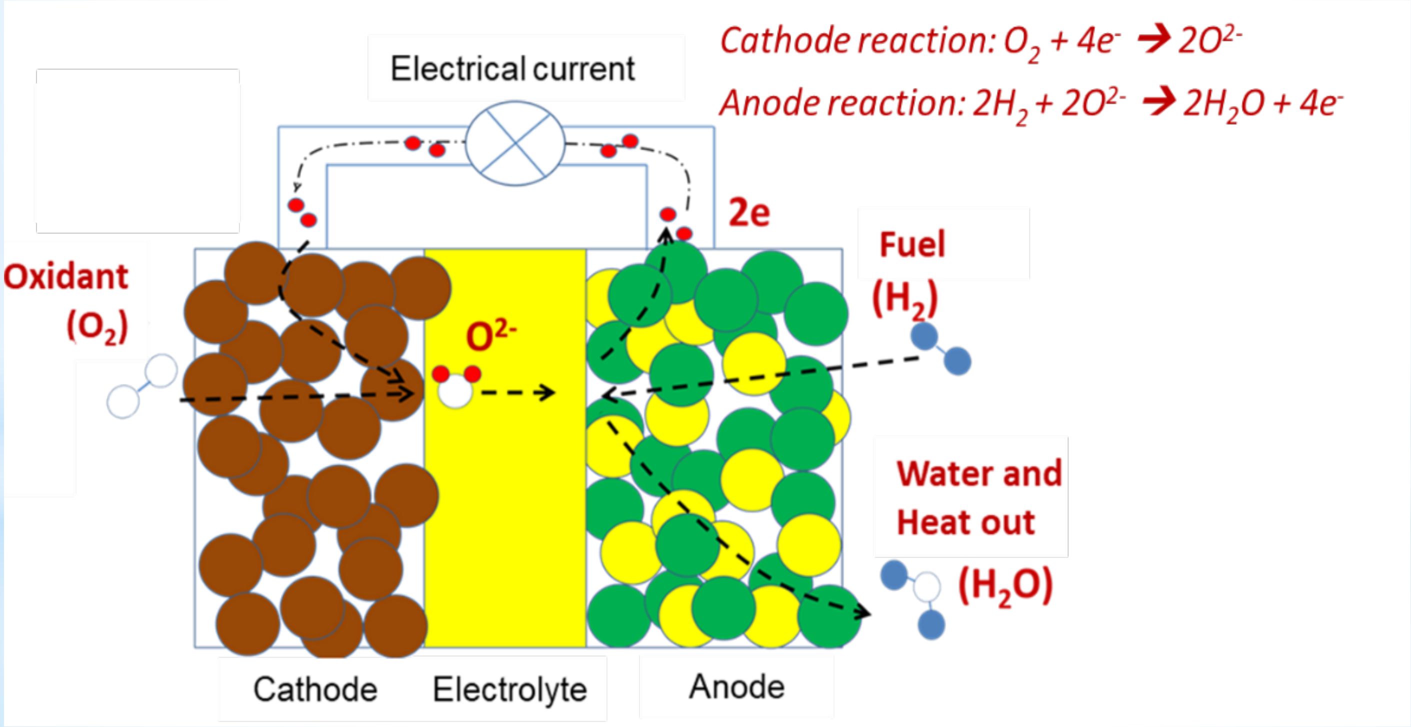
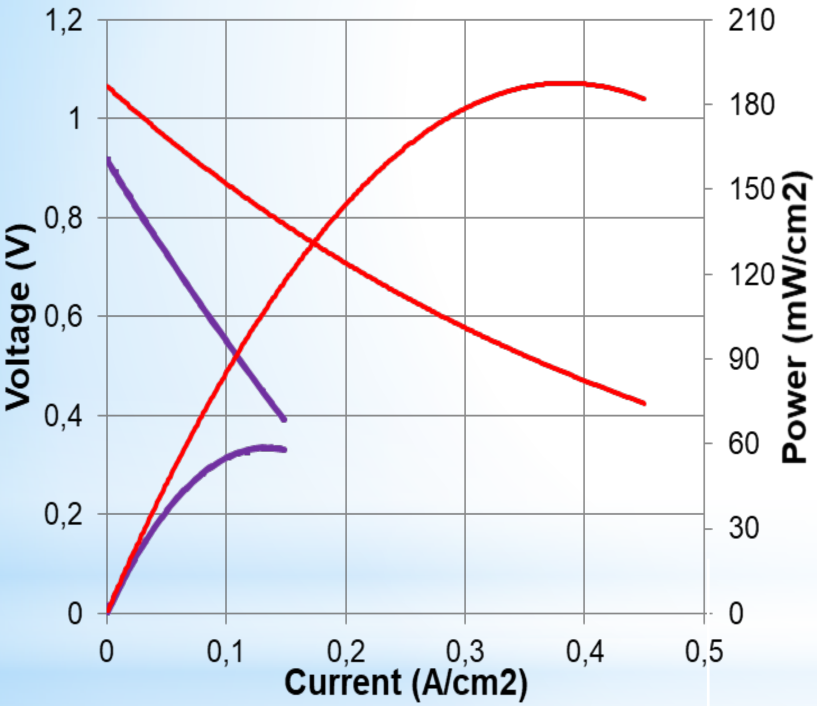
Solid Oxide Fuel Cells (SOFC) are power generators that can convert the chemical energy of a fuel gas into electricity and heat with the highest efficiency and low environmental pollution

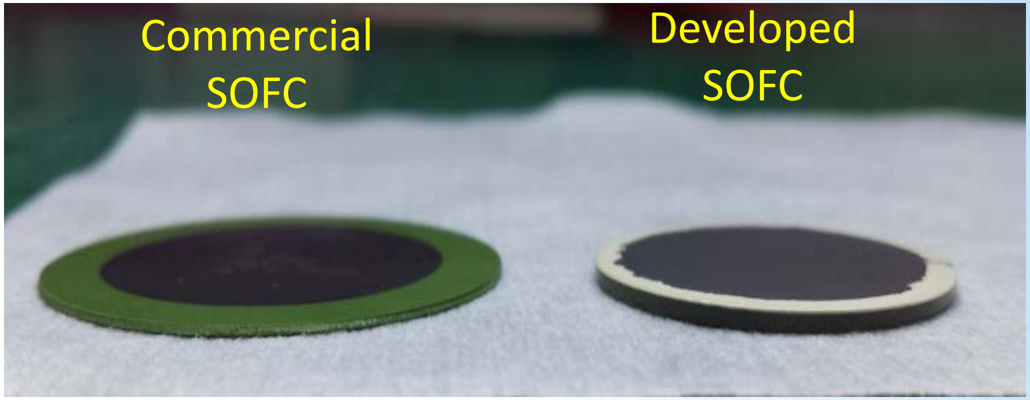
Solid oxide fuel cells are the most promising class of fuel cells due to their highest efficiency among other fuel cell types, feasibility of the fuel choice (C_mH_n, CO, H_2 etc.) and have no needs in noble materials for catalyst application.



Background

Project FP7 NANOMATEPC №608906,
«Deployment of Socially Beneficial Nano and Material Technologies in European Partnership Countries»





SOFC type	*Thickness, μ*		
	electrolyte	*anode*	*cathode*
Commercial SOFC	*10-15*	*370-400*	*15-20*
Developed SOFC	*25-30*	*900-1000*	*10-12*

The main aim of the project is the development of laboratory tape casting technique to produce solid oxide fuel cells based on zirconia powder (8YSZ) developed and produced in Ukraine.

The main project motivations are the following:

- Ukraine has one of the largest zircon-send deposits in the World – the basic raw material for production of stabilized zirconia powders.
- The tape casting technique is considered as the most promising for the SOFC production due to its relative simplicity and high productivity. This method ensures a relatively easy transition from laboratory technology to industrial production of SOFC.
- Elaborated tape casting techniques are the basement for the creation of industrial manufacturing of SOFC energy systems in Ukraine.

Development of stabilized zirconia powders

The laboratory method for production of zirconia powders with different stabilizers (8YSZ, 8Ce2YSZ, 1Ce10ScSZ, 10EuSZ, 10SmSZ, 10YbSZ, 10GdSZ and others) was developed.

The developed zirconia powder (8YSZ) were produced in necessary quantities to elaborate the tape casting technique for production of the SOFC anode and electrolyte films.

Also different stabilized zirconia powders were used for preparation of the ceramic samples to study their electrical and mechanical properties.

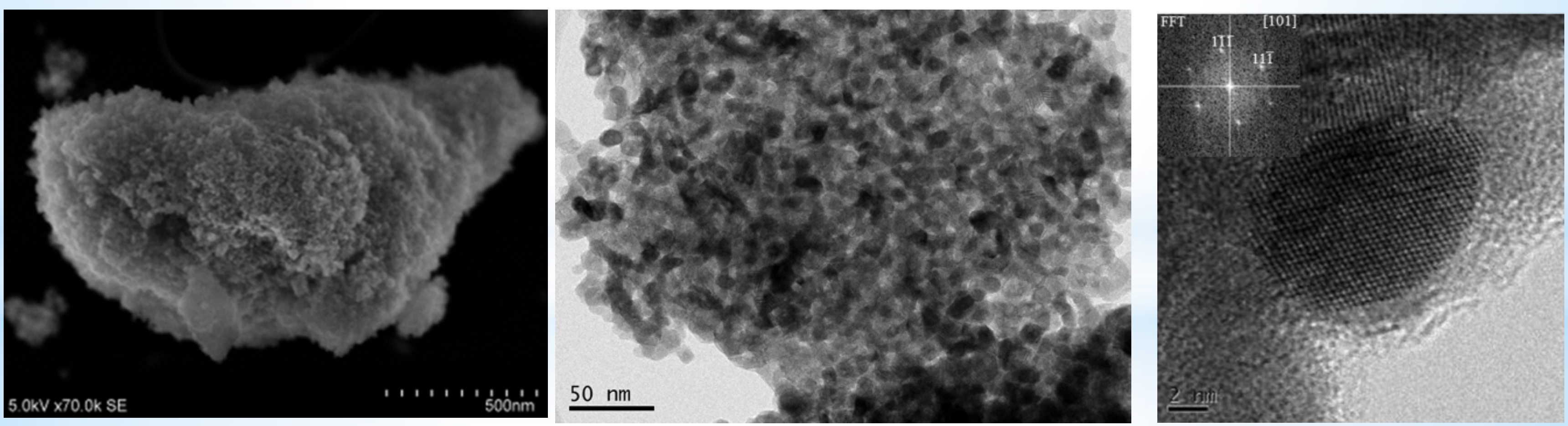
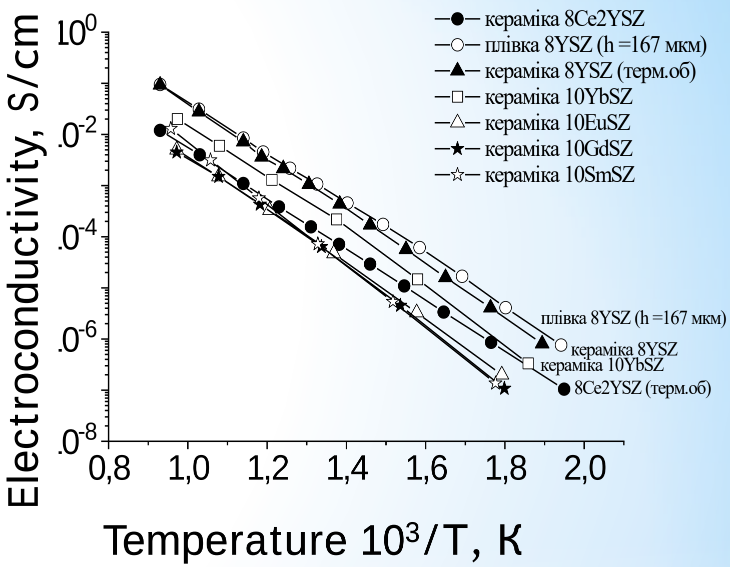


Figure. TEM images of the synthesized zirconia powders.

Electrical conductivity of the ceramic camples: 8Ce2YSZ, 8YSZ, 3YSZ, 10YbSZ, 10EuSZ, 10GdSZ, 10SmSZ

Method of synthesis	Material	Activation Energy, eV	Electrical conductivity at different temperatures, S/cm		
			600°C	700°C	800°C
Hydrothermal	8Ce2YSZ	1,015	$1{,}1\cdot10^{-3}$ $(1{,}3\cdot10^{-3})$*	$4\cdot10^{-3}$ $(4{,}5\cdot10^{-3})$*	$1{,}2\cdot10^{-2}$ $(1{,}4\cdot10^{-3})$*
Co-precipitation	8YSZ	0,98	$5{,}2\cdot10^{-3}$	$2{,}7\cdot10^{-2}$	$9{,}3\cdot10^{-2}$
	8YSZ (плівка, h= 167 мкм)	1,03	$8{,}5\cdot10^{-3}$	$3{,}1\cdot10^{-2}$	$9{,}5\cdot10^{-2}$
	3YSZ	-	$1\cdot10^{-3}$	-	-
	10YbSZ	1.067	$3\cdot10^{-3}$ $(5{,}6\cdot10^{-3})$*	$1{,}1\cdot10^{-2}$ $(2{,}1\cdot10^{-2})$*	$3{,}5\cdot10^{-2}$ $(6{,}5\cdot10^{-2})$*
	10EuSZ	1.065	$6{,}7\cdot10^{-4}$ $(1{,}4\cdot10^{-3})$*	$2{,}5\cdot10^{-3}$ $(5{,}3\cdot10^{-3})$*	$9\cdot10^{-3}$ $(1{,}9\cdot10^{-2})$*
	10GdSZ	1.11	$6{,}3\cdot10^{-4}$ $(1{,}2\cdot10^{-3})$*	$2{,}5\cdot10^{-3}$ $(4{,}8\cdot10^{-3})$*	$8{,}5\cdot10^{-3}$ $(1{,}6\cdot10^{-2})$*
	10SmSZ	1.2	$9\cdot10^{-4}$ $(1{,}7\cdot10^{-3})$*	$5\cdot10^{-3}$ $(9{,}6\cdot10^{-3})$*	$2\cdot10^{-2}$ $(3{,}8\cdot10^{-2})$*



* In order to compare conductivities of ceramic samples with different porosity, measured total conductivity has been normalized by porosity using V.I. Odelevsky's equation :

$\sigma = \sigma_c(1 - 1.5P)$,

σ – conductivity of a porous body;

σ_c – conductivity of a compact body;

P – total porosity.

*Andrievskyi R.A. Introduction to powder metallurgy. Frunze: Ilim (1988) P. 174 (in Russian).

The tape-casting regimes for SOFC component production

Tape casting is an important technology, which allows to manufacture thin elastic tapes of high density with predetermined thickness and uniform distribution of powder in a volume of the tape.

The method is widely used as a basis for manufacturing of many modern electronic devices and permanently upgraded. For the last time, manufacturing SOFC by the tape casting technique became as important task due to its high performance, low cost and environmental friendliness.

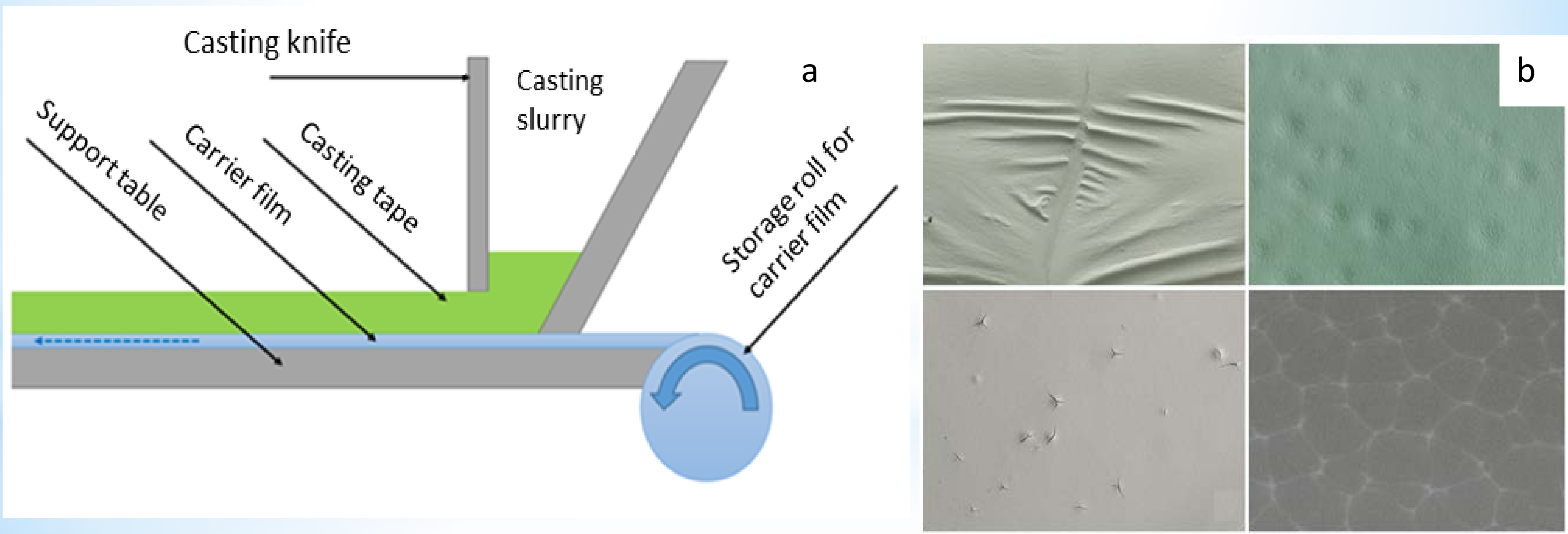


Figure. Principal scheme of tape casting technique (a) and CEM images of examples of the casted tape defects (b).

As a result of the work, suspensions with an optimal component composition for manufacturing of non-defect types for SOFC anode and electrolyte were formulated. It was found that increasing the viscosity of the suspensions will result in thicker and stronger tapes, however, high viscosity creates difficulty in mixing and increases the suspension irretrievable losses. The control of anode and electrolyte film thickness could be achieved by step-by-step lamination of thin films. The obtained tapes were successfully laminated and sintered into an SOFC

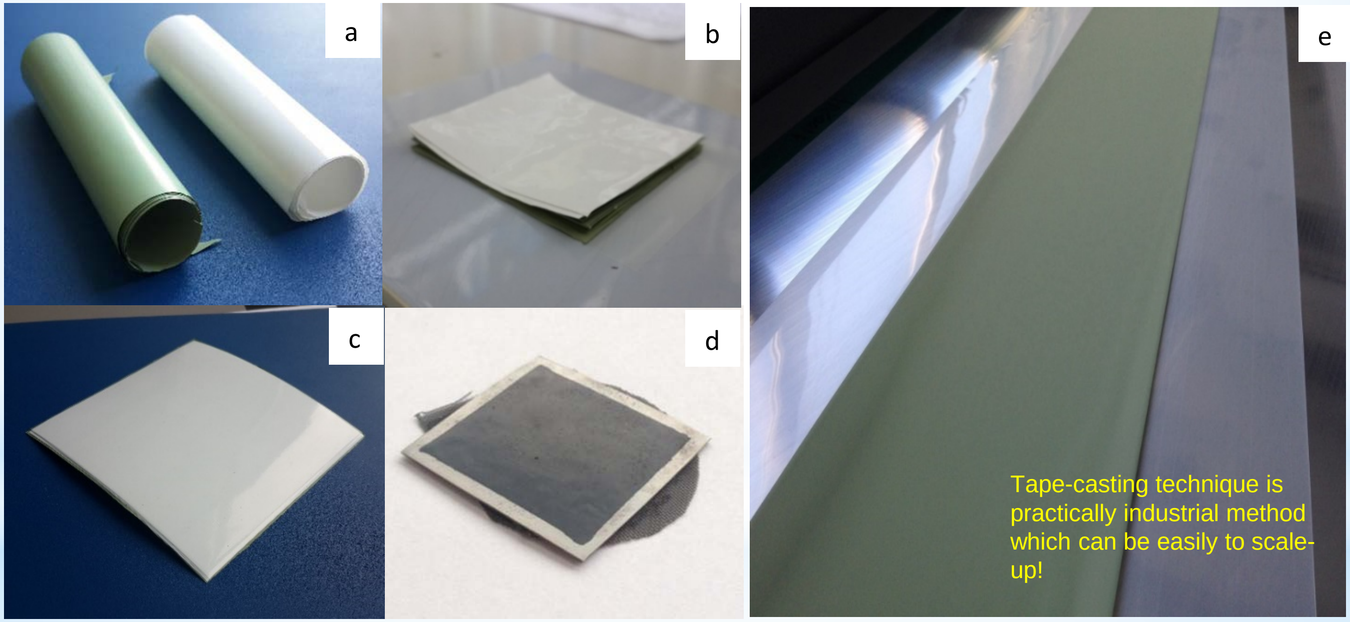
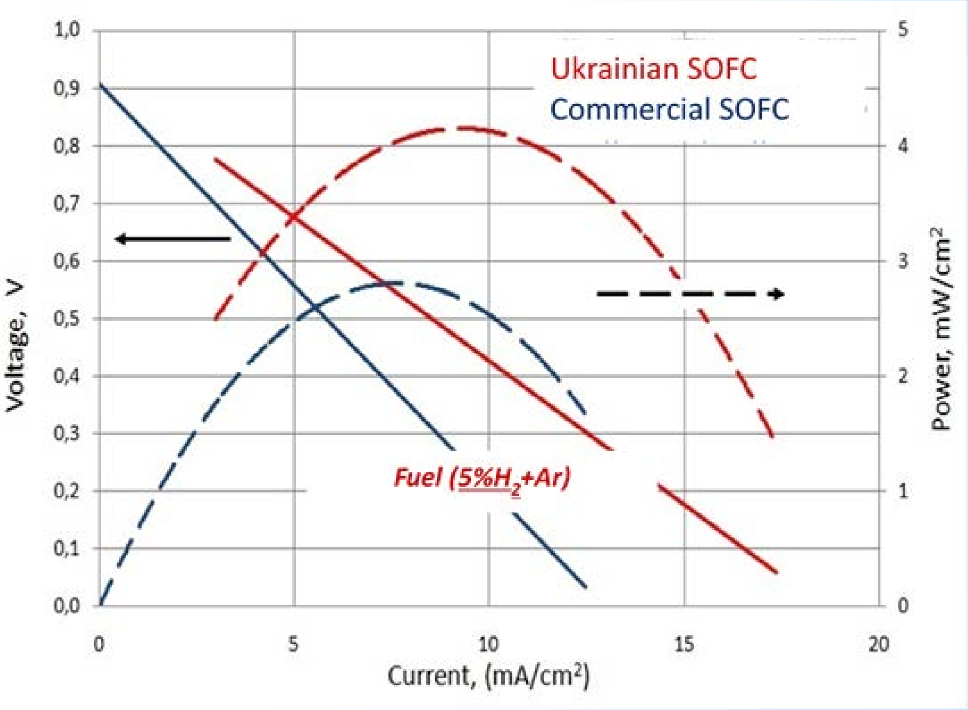


Figure. Type casted films of anode (green) and electrolyte (white) (a); cut anode and electrolyte types into square-shaped samples for further half-cell preparation (b); laminated types in half-cell (c); sintered SOFC (d); drying of just casted anode type (e).

Comparison of the developed SOFC with commercial one.

The tape-casted SOFC (electrolyte 8YSZ, anode NiO – 8YSZ, cathode LSM – 8YSZ) made using elaborated laboratory technology and commercially available anode-supported SOFC (electrolyte 8YSZ, anode NiO – 8YSZ, cathode LSM – 8YSZ) were tested with the stand for measuring of fuel cells electrical properties ("Scribner Teledyne Medusa RD 890CL" USA), at the same conditions. The tests of SOFC were performed at 800 °C, and fuel mixture 5 % H_2 – 95 % Ar and air were fed into the anode and the cathode, respectively.



The SOFC developed demonstrates much higher level of power density (4.2 mW/cm^2) in comparison with the commercial one (2.8 mW/cm^2) at the same testing conditions (800 °C, 5 % H_2+Ar, air).

Conclusions

A lot of different studies focused on the development of new promising materials for SOFC application have been already done. Despite that, zirconia-based materials remain the most common in use because they meet many requirements and have relatively low cost. Currently, progress in development of SOFC is primarily concentrated on the development and implementation of new methods of SOFCs production to improve their structure and optimize properties of its components, rather than through the introduction of new materials.

The next stage in the introduction of hydrogen energy and fuel cells in the economy of Ukraine should be the creation and testing of pilot technologies for production of SOFC combine heat and power (CHP) systems. Extensive demonstration activities should attract new investment in this field. The main attention should be focused primarily on the creation of pilot productions of stabilized zirconia powders and fuel cells from them and creation of SOFC-CHP systems prototypes.

Today, there is an intellectual and raw material basis for the organization of high-tech production of power generation facilities based on SOFC in Ukraine. Production and implementation of fuel cell technology in Ukraine can make a precedent for the "economic miracle" that took place in Germany, Japan and Korea due to high-tech productions.