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SOFC: Prospects of development

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One of the main conditions for the transition to hydrogen energy is development of reliable, high-performance and cost-effective fuel cells, in which chemical energy is converted directly into electrical energy. The advantages of solid oxide fuel cells (SOFC) are: high electrical efficiency (50 - 60)%, in cogeneration with thermal energy the efficiency may reach 90%, and high operating temperatures (700 - 900 °C), which allows us to use practically any hydrocarbon fuel.

Keywords: SOFC, fuel cell, hydrogen energy.

Introduction

In the framework of the scientific and technical program "Development of Hydrogen Energy and Technology in the Republic of Kazakhstan" in the years (2015-2017), supported by the Ministry of Education and Science of the Republic of Kazakhstan, L.N.Gumilyov ENU in cooperation with IEF UB RAS, initiated works on the SOFC development. They include solution of research tasks on selection of material components and working out of the methods of manufacturing of solid oxide fuel cells, and the development and creation of a modern test stand for SOFC.

World electricity consumption grows every year, at the same time the developed countries have headed for creation of more environmentally friendly power. Widely developed generators on renewable energy sources still have a small share in world power generation of 6,3% [1]. Besides also other shortcomings are inherent in them: regional restriction of their effective use and periodic operating mode. The main power generation is made on thermal (66,7%), gidro- (16,4%) and atomic (10,6%) power stations [1]. At the same time the thermal power stations burning hydrocarbonic fuel (coal, oil, gas) are the main source of ecological pollution.

Solid oxide fuel elements (SOFC), high-temperature electrochemical devices of direct transformation of chemical energy of fuel to electric energy, are environmentally friendly sources of current. The efficiency of SOFC can reach 60% with the use of only electricity and up to 90% with the combined use of electrical and thermal energy. In addition, high operating temperatures allow SOFC to use virtually any hydrocarbon as fuel, which does not require the cost of changing the infrastructure, as in the case of hydrogen. However high working temperatures are also the reasons of the problems complicating development and production of SOFC: strict requirements to materials of fuel cells, and, therefore, limitation of the choice and complexity of productions; degradation of the used materials; high cost. In this paper, based on analysis of current SOFC designs and industrial prototypes of devices based on them an attempt to predict the prospects of using SOFCs in various segments of the global energy industry.

Constructions of SOFC

A detailed description of the principle of operation and structure of SOFC, as well as the materials used to create them, can be found in [2]. Constructions of SOFC are usually divided into three large groups: microtubular, tubular and planar. Microtubular construction has not found wide distribution, so we will not consider it further. But modification of the tubular structure - microtubular SOFC, in our opinion, deserves a separate grouping. Advantages and disadvantages of each design are summarized in figure 1.

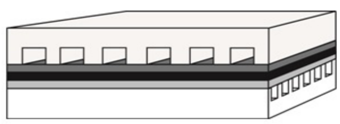
Construction	Advantages	Disadvantages
Tubular 	Resistance to thermal loads Sealing is simpler than for planar SOFCs	Low power density High internal resistance
Microtubular 	Quick Start High power density Resistance to thermal loads	The complexity of the connection in the battery Difficulty with sealing
Planar 	High density of power Simplicity of assembly in the battery	Low resistance to thermal loads Difficulty with sealing

Figure 1. Construction of SOFC

Figure 2 shows a comparison of specific volumetric capacity (Wv) batteries of different manufacturers on the power generated by them (W). It can be seen that there is a tendency to increase the specific volumetric power of the batteries with a decrease in their power, which, apparently, is associated with a decrease in ohmic losses. At the same time, SOFC batteries of the same power, even the most obvious and popular planar design, differ significantly in their specific characteristics, which is related to the materials used and design features. Nevertheless, according to the decrease in the specific volumetric power, the designs of the SOFC batteries are lined up in a row: microtubular, planar, tubular.

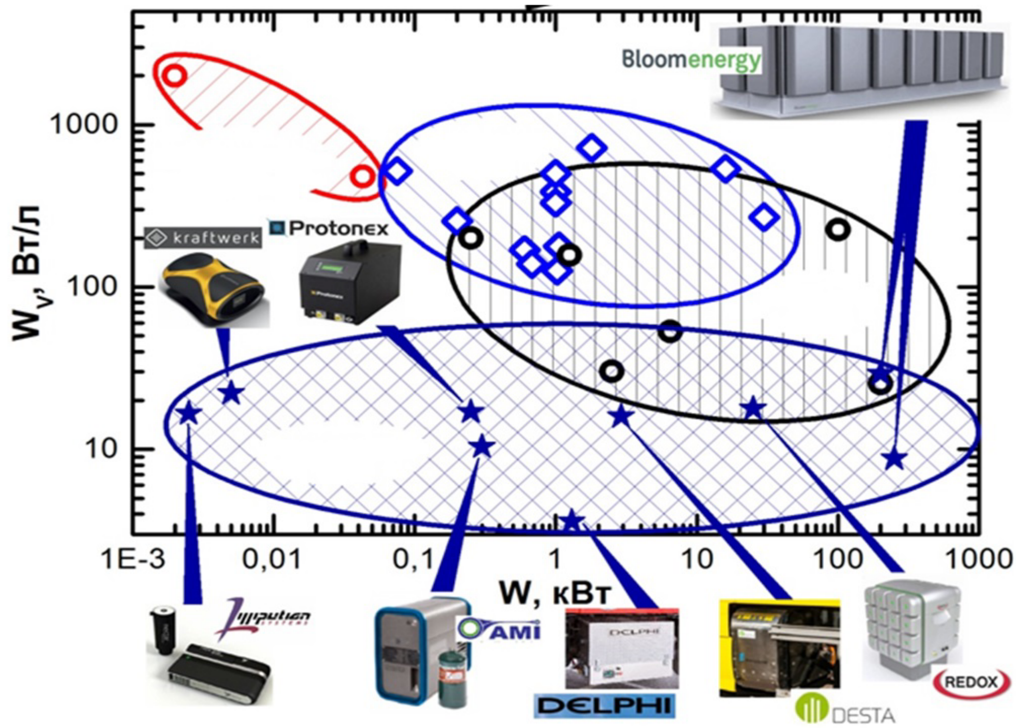


Figure 2. Characteristics of industrial prototypes of SOFC batteries.

Perspectives of development of SOFC

The consumer cannot use the SOFC battery without a number of additional devices, such as devices for preparing and supplying fuel and oxidizer, heat exchangers, controllers, etc. (balance of plant). The completed, ready-for-use device will be called a generator based on SOFC (G-SOFC). As can be seen from figure 2, the specific volumetric power of the generators is significantly inferior to the characteristics of the batteries and for the entire power range its values lie in a narrow range of (10-30) Wt/ l. The majority of portable generators are maked on the SOFC microtubular structure. However, assembling on the basis of microtubes of larger generators is likely to be unprofitable for two reasons: first, the labor input of process of the process, and secondly, the "loss" of a quick start. The latter is due to the uneven heating of the large battery volume, which leads to the occurrence of mechanical loads and thereby to an increase in the probability of breakage. So to start eZell1 Wmax = 5 W (Kraftwerk) it takes less than a minute [3], whereas for the D350 W = 300 W (Ultra Electronics) the startup time is 15 minutes [4]. At this time the planar design seems to be most suitable for the creation of a G-SOFC with a power of more than 1 kW for any stationary application. Examples include the EnGen-2500 (SOLID power) co-generation station for heat and electricity (m-CHP) for a private home and a stationary Bloomenerdgy power station. The use of SOFC on transport is limited to auxiliary power units, although with the current development of technology, G-SOFCs can already compete with diesel locomotives in terms of their mass-size characteristics, far exceeding their ecological compatibility. Despite the high potential of SOFC [5], the situation on the automotive sector is likely to remain unchanged in the near future. Constraining factors are: long start-up time and mass-dimensional characteristics of G-SOFC. To replace the internal combustion engine with a power of 70 kW (V $\sim$ 300 L, m $\sim$ 200 kg), a G-SOFC of about 2300 liters and weighing about 800 kg will be required. (The mass estimate is based on the best specific gravity of planar SOFCs implemented in the UPM-571 (Bloomenergy) - 88 W/kg [6].) It does not take into account the volume and mass of the electric motor and battery needed to operate the car.

Conclusion

The analysis showed that the most suitable design of SOFCs for portable devices up to 1 kW is microtubular, while for more powerful generators a planar design. However, currently commercially available designs do not allow to realize the full potential of SOFC and require further development. In addition, it is necessary to optimize the maintenance systems of G-SOFC to increase their specific characteristics.

The authors studied the SOFC production including the effect of small amounts of codopants (Y, Ce, Gd, Er, La, Mn, Co, Cu, Zn) on the preparation and properties of the two-layer electrolyte ZrO_2 - CeO_2, and the influence of the structure on the characteristics of cathode, based on $La_{0.6}Sr_{0.4}Fe_{0.8}Co_{0.2}O_3$, and anode, based on NiO materials. The test stand includes an oven, a gas system, controlling and measuring systems. Modern precision components and equipment in the test stand enabled us to determine and control all measured parameters with high accuracy.

The model fuel cell manufactured according to the results of research had specific powers 1.2, 0.88 and 0.6 W/cm^2 at temperatures of 900, 850 and 800 °C, which is comparable with the best world analogues.

Acknowledgments

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References

[1] 2016 Key world energy statistics. IEA, **80** (2016).
[2] Fuel Cell Handbook, 7th ed. (EG&G Technical Services, Inc, 427, 2004).
[3] S. Kuhn, Hannover Messe, 2014 (http://hellokraftwerk.com).
[4] Datasheet P/N 90192A-PDS-D350 (Rev A. Ultra Electronics Limited, 2016).
[5] S.I. Nefedkin, A.S. Lipilin, Alternative energy and ecology, **77** (2011).
[6] Datasheet DOC-1006828 (Rev. A. Bloom Energy Corporation, 2015).