DEVELOPMENT OF MINI FUEL CELLS FOR PORTABLE ELECTRONIC DEVICES

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Introduction

At present time there is a growing interest in development of new power sources based on mini fuel cells (MFC) for cellular phones, notebooks and other portable electronic devices. Power consumption of such devices is growing continuously, and energy capacity of modern lithium-ion and lithium-polymer rechargeable batteries is becoming insufficient. Besides, there is a high demand in charging devices for batteries that can be used in the field, when electrical supply network is unavailable (tasks of Department of Defense, rescue services, etc.).

Results and discussion

In case of micro- power sources for portable electronic devices the mass and dimensions of such unit are its most critical parameters. Therefore, polymer electrolyte membrane fuel cells (PEMFC) are most suited for such applications. Membrane-electrode assembly (MEA) is the key element of PEMFC. MEA consists of ion conductive polymer electrolyte membrane and two electrodes, that are applied to both sides of the membrane. Electrodes consist of catalyst particles and particles of polymer electrolyte that catalyze corresponding reaction. Electrolyte is a polymer that is proton conductive. Assembly of anode-electrolyte-cathode is thus a single unit and is very thin and lightweight.

In present work an analysis of possibility and availability of using of different fuels in such mini fuel cells was conducted. During the analysis we have taken into account thermodynamic properties of fuel reagents (ΔG^0 of electrochemical oxidation reaction, EMF and operating voltage of a single cell, specific energy density of the reagent), physical properties (boiling temperature, volatility, combustibility), completeness of electrooxidation on existing electrocatalysts, toxicity of the reagent. Besides, factors such as properties of polymer electrolyte membranes used (their permeability with the given reagent, complexity of water balance maintenance), properties of the reaction products, fuel cost, availability of its mass-production have strong impact on the choice of fuel.

At present time mini fuel cells using methanol as a fuel are almost ready for commercial production. The advantages of using methanol as a fuel are good energy density, completeness of its electrooxidation on existing catalysts. ΔG^0 of the methanol oxidation reaction is -698,5 kJ/mol, its specific energy density is 6,1 kW*h/kg. Methanol is very cheap and is mass-produced for chemical synthesis and different other purposes. The most crucial problem of direct methanol fuel cells (DMFC) is methanol permeability of common polymer membranes. Methanol flux from anode to cathode results in so-called "mixed potential" on air electrode, that reduces operating voltage of the cell (and, thus, electrical power and efficiency) and also results in considerable fuel loss. However, some of the world-leading companies (Toshiba, Hitachi) claim that they have been able to overcome this problem.

In spite of considerable success in development of direct methanol fuel cells, the possibility of wide applicability of methanol as a fuel is a serious question. First of all it is caused by its toxicity. In Russian Federation standards of methanol content in air are comparatively stringent. Maximum permissible concentration (average daily) of methanol is 0,5 mg/m^3. As a result of this, search of alternative fuel reagents for mini fuel cells is a task of great interest.

In mini fuel cells reagents such as liquid hydrocarbons (ethanol, propanol, ethylene glycol), and also water solution of sodium borohydride can be used. In case of sodium borohydride the following overall reaction takes place in polymer electrolyte fuel cell:

$$NaBH_4 + 2O_2 = NaBO_2 + 2H_2O$$

At +25°C ΔG^0 of this reaction is -1296.9 kJ/mol, EMF of the cell is very high – 1,64 V.

Hydrogen instead of liquid reagents can also be used in mini fuel cells. In this case no high-pressure cylinders with hydrogen gas or steam reforming of hydrocarbons will be used. In systems with power higher then 20-30 W (notebooks, for example) one can use reversible metal hydrides for hydrogen storage. But more attractive option is the use of chemical reactions that release hydrogen, for example, reaction of

aluminium or alkaline metal hydrides with water. It was shown, that if suitable catalysts would be found, ethanol will be the best choice as a fuel for micro fuel cells up to 5-10 W power. Use of hydrogen produced from aluminium or alkali metal hydrides in reaction with water is a promising option for higher-power applications (30-200 W). In case of stand-alone battery chargers for military and life-saving service's tasks development of MFC using water solution of sodium borohydride or hydrogen as a fuel is very promising.

In RRC "Kurchatov institute" we have measured permeability of different polymer electrolyte membranes on methanol and alternative reagents. Installation for measurement of membrane permeability in operating conditions of a fuel cell has been developed. It was shown that sulphonated polysulphones have the least methanol permeability, but at present their mechanical properties are unsatisfactory. Methods of modification of existing perfluorinated membranes to decrease their methanol permeability have been proposed. We have been able to decrease methanol permeability of membranes of МФ-4СК - type by 2,5-3 times. Current densities of 250 mA/cm^2 were achieved.

Conclusions

Thus, investigations conducted in Russian Research Center "Kurchatov Institute" in collaboration with Moscow State university of engineering ecology show, that use of ethanol, hydrogen produced from chemical hydrides and water solution of sodium borohydride as a fuel is advisable in MFC. In order to solve the problem of fuel permeation through proton-conducting polymers non-perfluorinated membranes (for example, based on polysulphones) can be used. Membrane modification using inorganic proton-conducting electrolyte additives (heteropolyacids) is also very actual. Composite electrocatalysts based on platinum metals and oxides are promising for alcohols oxidation, bifunctional catalysts are to be developed for direct sodium borohydride cells.

References

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