MICROSCALE HEAT TRANSFER IN ADVANCED PEM FUEL CELLS

S. A. Filatov, G. S. Kuchinsky, M. N. Dolgikh, O. S. Filatova, G. S. Ahremkova, V. E. Zhdanok
Hydrogen Power Laboratory
Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus,
P. Brovka, 15, Minsk, 220072, Belarus
Tel. +375-17-2842238; fil@hmti.ac.by

Abstract

The catalyst performance of novel fuel cell materials was studied by standard electrochemical tests. Improvement of nanoscale Pt-Ru catalyst on CNT support was shown. Provided experiments stated that CNT would be suitable materials for FC electrodes and catalyst supports with current density higher than 1 A/cm^2, heat loses can be reduced by 20 – 30 % and total performance of PEM stack can be improved significantly.

KEYWORDS

Fuel cell, carbon nanotubes, nanocatalyst, Pt-Ru, microscale heat transfer, gas distributed layer

Fuel cell today is most effective tool for generation of electrical and heat energy by converting chemical energy into electrical energy without combustion. This is especially true for fuel cells designed to directly run off hydrogen. The hydrogen powered proton exchange membrane fuel cells (PEMFC), which produce only water as a byproduct, is extremely useful for microelectronics and transport application because they can deliver high power in a relative small and light-weight device.

Next generation of advanced microscale fuel cells (μFC) development will strongly depend on two key advances – successful solution of microscale heat transfer in electrode material and catalyst layer of PEMFC and optimization of reagents flows in fuel cells [1–5]. So, our current activity includes: development of state-of-the-art macro- and microscale PEMFC, experimental study of heat transfer in FC and numerical simulation of microscale heat transfer in MEA and μFC, fig. 1.

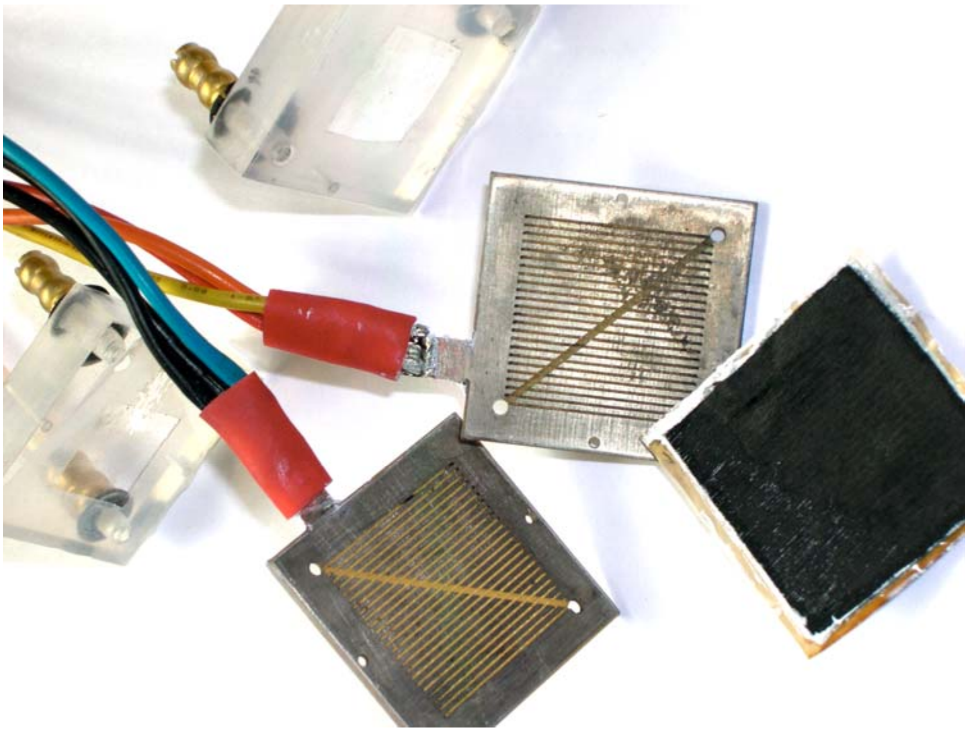
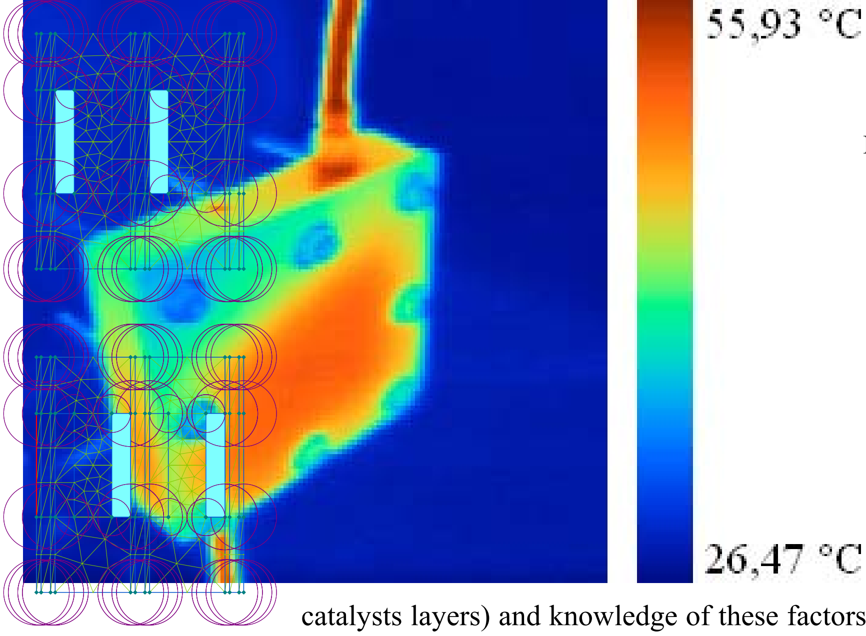


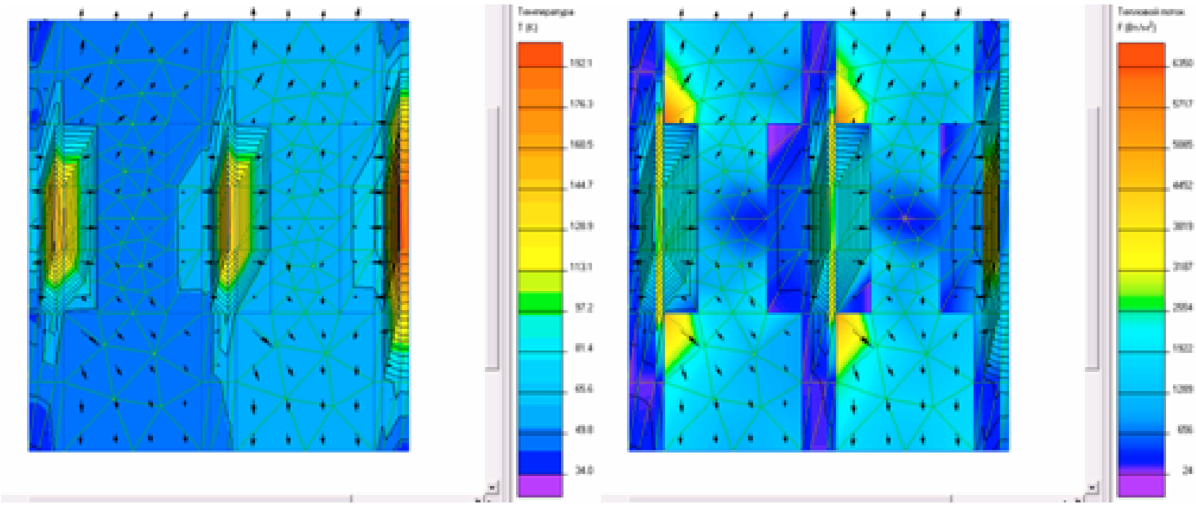
Fig. 1. Microscale test fuel cell



Significant role at technical implementation belongs to heat transfer inside microchannels of electrodes, where one of the μFC reactants moves. Their exact selection allows optimization of a temperature operational mode of the MEA (membrane electrode assembly, PEM with catalysts layers) and knowledge of these factors allows essential increasing of efficiency. Another important point is how these channels are arranged one to each other, since the exact selection of the channels form and their positional relationship makes possible at the best to eliminate a gradient of MEA temperature. This can be calculated numerically by QuickField 5.0 software for different environment condition, figs. 2–6.

a) *b)*

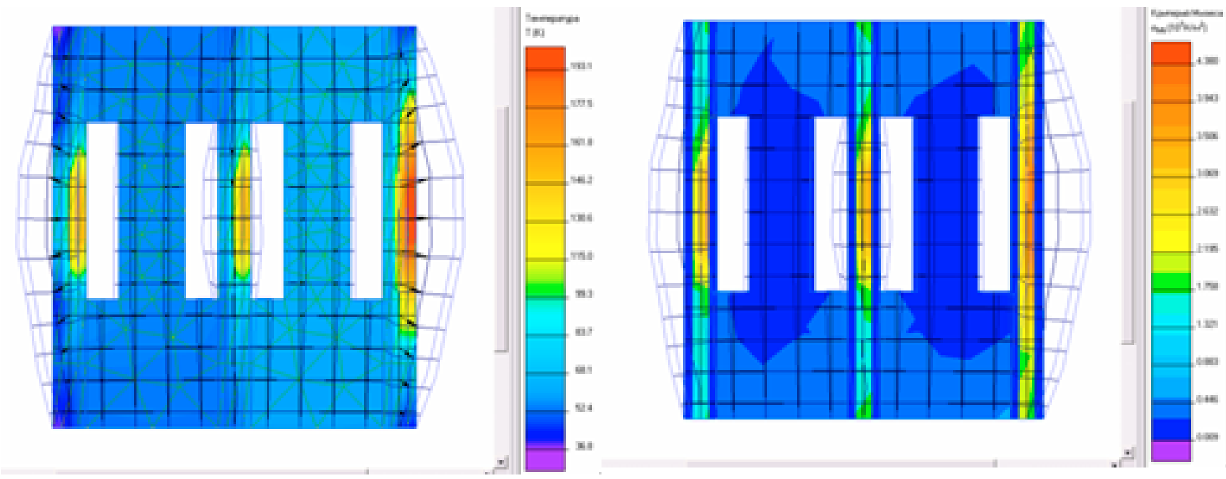
Fig. 2. Calculation grid and channels (*a*) and IR thermography image of PEMFC (*b*)



a) *b)*

Fig. 3. 2D temperature (*a*) and 2D heat flux density (*b*) distribution in cross section of μFC

Analysis of temperature distribution on fig. 3 by comparison of experimental date shows impossibility of obtaining of the optimal temperature (80–90 °C) for PEM FC with current density of 0.8–1.0 A/cm^2 without special heat exchangers based on microscale heat pipes and intercoolers techniques. Overheating of PEMFC may cause malfunction of FC, fig. 4. Using of heat pipes cooler can reduce this risk, fig. 5.



a) *b)*

Fig. 4. 2D deformation (*a*) and mechanical stress (*b*) in cross section of μFC

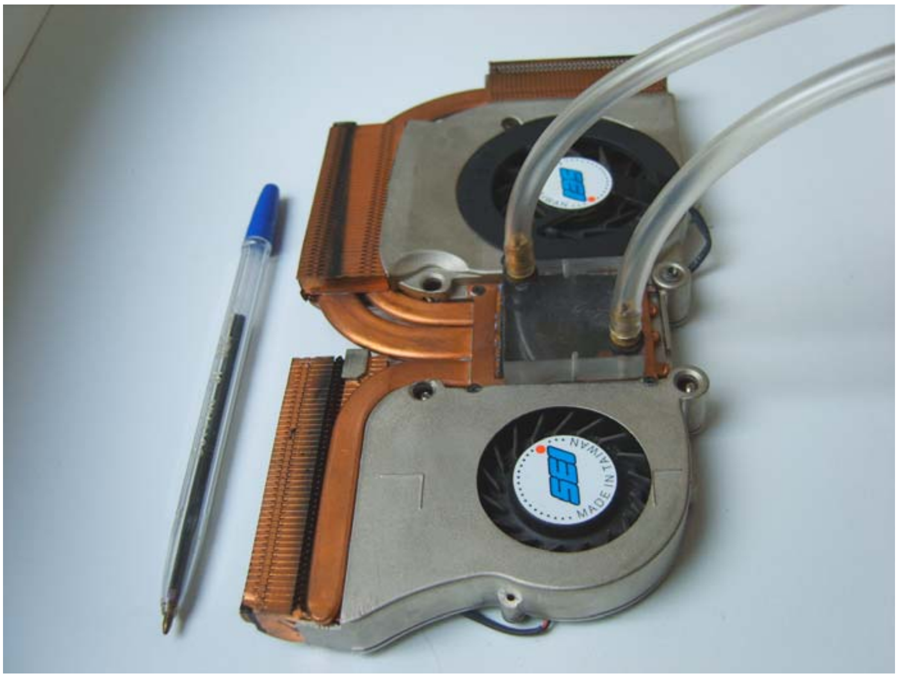


Fig. 5. PEMFC with microscale heat pipes cooler

Optimization of microscale heat transfer in electrode assembly by improving of catalyst layer also can reduce heat dissipation in PEMFC. A layer of platinum based catalyst and a gas-porous electrode support material are arranged on both sides of the membrane (PEM), forming the anode and cathode of the cell. Mass transport losses can also be minimized by reducing the thickness of the catalyst layers and using Pt at 2–3 nm clusters, Fig. 6. For a specific platinum loading, e.g., 0.2 mg/cm^2, a catalyst with 60 % of Pt forms a thinner layer as compared with a similar catalyst with 40 % of platinum. Results show that catalysts with higher platinum concentrations offer performance advantages at high current densities where mass transport phenomena usually dominate. The electrode layer must exhibit good electronic conductivities to minimize resistive losses in the cell. Commonly used carbon supports (Conductex® 975 and Vulcan® XC-72 or other) are good conductors of electrons, but using of carbon nanotubes (CNT) give much better results.

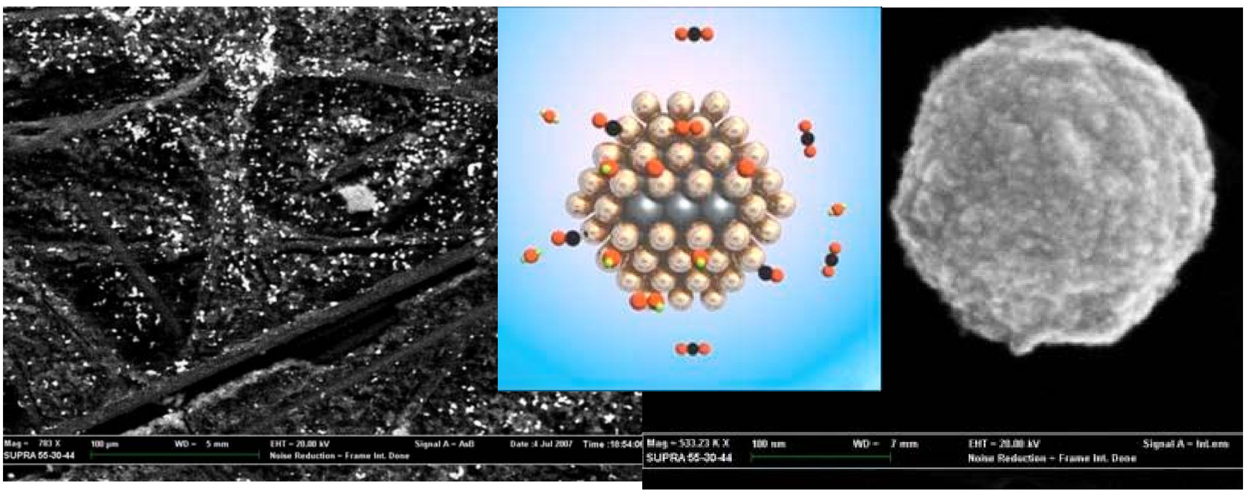


Fig. 6. Pt/Ru catalyst on carbon gas distribution layer (GDL) with CNT coating (a, scale 100 mkm) and single Pt/Ru catalyst particle SEM image (b, scale 100 nm). Model of Pt/Ru catalyst [6] from is also shown (center)

The catalyst performance was studied by a polarization curve by measuring the character voltage peaks produced by catalyst electrochemical reaction in test cell. The catalyst support by CNT with unique structural, mechanical and electrical properties can improve efficiency of hydrogen transport and temporal storage also as electrical conductivity of electrode layer. More specifically, the high accessible surface area, low electrical resistance, and high chemical stability suggest that CNT would be suitable materials for electrodes and catalyst supports in fuel cell applications with current density higher than 1 A/cm^2. In experiments provided we also found that heat loses in PEMFC with GDL layer covered by CNT reduce on 20–30 % and can improve performance of PEM stack.

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