

PALLADIUM AS A CATALYST FOR PEM FUEL CELLS

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Introduction

One of the tasks for commercialization of proton exchange membrane (PEM) fuel cells is development of non-expensive electrocatalysts. Today mainly platinum (Pt) is used as an electrocatalyst for oxygen and hydrogen reaction in PEM fuel cells. However the cost of Pt is rather high and natural resources of Pt are rather limited. Due to last one it is expected that than large-scale production of PEM systems will be started, the cost of Pt on the market should increased essentially. Of course, these facts restrain commercialization of PEM fuel cells. Thus, there is the real necessity for development of non-platinum catalysts. One of the best candidates for this role is palladium (Pd). Electrochemical activity of Pd is rather high, Pd is in 4 times cheaper then Pt and reserves of Pd in nature are large.

The goal of present work is development of nano-structured Pd-based electrocatalysts for hydrogen electrode of PEM fuel cells.

Experimental technique

Comparative analysis of various methods of synthesis Pd-based catalyst was provided. For instance, Pd reduction from its salts by formaldehyde, ant acid, ethylene glycol, sodium borohydride, and also by hydrogen flow have been used. As a catalyst carrier Vulcan XC-72, AD-100 acetylene black (produced in Russia), carbon nano-tubes and nano-fibers, and other kinds of carbons were used. For preventing by autocatalytic growth of particles polyvinylpyrrolidone was applied.

Pt-Pd- and Pd-catalysts (10-40% wt) on Vulcan XC-72 and carbon nano-tubes (reduction by formaldehyde with addition of ethylene glycol) has shown rather good performances. The specific surface of obtained catalyst, measured by potentiodynamic method, was more than 60 m²/g.

With use of the synthesized PtPd catalyst on Vulcan XC-72 with different Pt/Pd-ratio membrane-electrode assemblies have been prepared and successfully tested. The best performance has the catalyst with Pt 5% wt + Pd 5% wt. So, for instance, the current density of PEM fuel cell at voltage 0.7 V was more than 1 A/cm² (see Fig. 1).

Beside this membrane-electrode assembly

based on Pd10/V catalysts was successfully tested (Fig. 1). Operation time achieved by now is more than 200 hours.

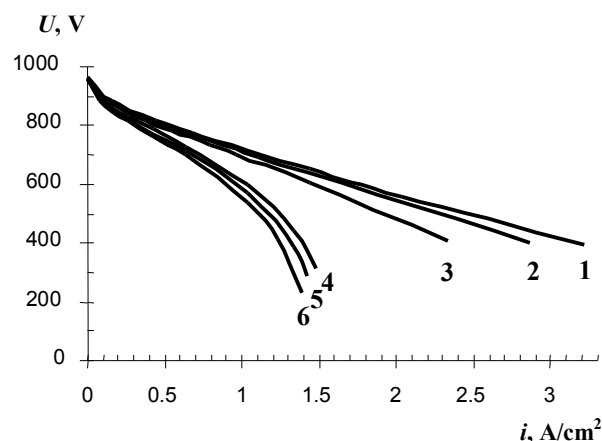


Fig. 1. Current-voltage curves for PEM fuel cell with various catalysts. $S_{\text{cell}}=7 \text{ cm}^2$, membrane Nafion-112 (50 μm), gas diffusion layer 280 μm , $\text{PO}_2(\text{air})=3.0 \text{ Bar}$, $\text{PH}_2=2.5 \text{ Bar}$, $t=75^\circ\text{C}$. Cathode catalyst: Pt40/V10 (0.5 mg/cm² of Pt).

Anode catalyst:

- 1, 4 – Pt40/V (0.5 mg/cm² of Pt);
 - 2, 5 – PtPd10/V (0.125 mg/cm² of Pt-Pd);
 - 3, 6 – Pd10/V (0.125 mg/cm² of Pd);
- (V – Vulcan XC-72; V10 – Vulcan XC-72 with 10 wt % of PTFE; 1-3 – H₂-O₂; 4-6 – H₂-air).

Mathematical model

Beside experimental work physical-chemical model of PEM fuel cell with electrocatalytic layer based on non-Pt (or with reduced Pt content) catalysts has been developed.

For electrocatalytic layer description a number of new approaches such as percolation theory, theory of wetting etc. were applied. The proton current in a membrane and electrocatalytic layer was calculated using Nernst-Planck equation. Thermal processes were described by the corresponding equations of heat transfer. For the description of mass transfer in channels of bipolar plate and gas diffusion layer Stephan-Maxwell equation was used. Distribution of gas flows in channels was described by means of Navier-Stokes equation for quasi-stationary flow. For solutions of the task original software developed by the authors has been used.

With use of the model some recommendations

on structure and composition of electrocatalytic layers based on binary and ternary solid solutions of Pt, Pd and other metals were done.

The experimental data obtained with use of various electrocatalytic layers rather good confirm results of calculations.

Conclusion

Thus, as a result of present work Pd-based

electrocatalyst with low noble metal loading, high activity, stability and specific surface had been synthesized.

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