PERSPECTIVE CATALYSTS FOR THE HYDROGEN OXIDATION REACTION IN FUEL CELLS (review)

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The decisive factors that must be taken into account when estimating the possibility of wide application of fuel cells are the cost and the effectiveness of the catalyst. It is well known that nowadays the noble metals (Pt, Pd) are mainly used as the catalyst in the reaction of the hydrogen oxidation, which prevents the wide application of fuel cell. The aim of the present lecture is to give the review of the recent investigations in the field of non-platinum catalysts (class 1) and catalysts containing minimum amount of noble metal due to improvements in the technology of their preparation (class 2). The analysis of the world-wide investigations concerning the mentioned subject has been performed using the modern key-words guided computer-aided methods of literature search.

The most effective catalytic materials appear to be the materials prepared in the form of a thin layer of active catalyst supported on the surface of carbon, ceramic or other porous materials with the highly developed surface. Some catalysts for the reaction of the electrochemical hydrogen oxidation both from class 1 as well as class 2 are presented in the table.

The most interesting are the catalysts that do not contain noble metals (Class 1). The *molybdenum and tungsten carbides* belong to that class [1-3]. Plasma treatment of the gas diffusion layer of some catalysts leads to the generation of the radicals with the high catalytic activity. The electrodes covered with polymeric membrane are used in solid polymeric fuel cells [4].

Bioorganic materials, like *hydrogenase*, may also be used as the catalysts of hydrogen oxidation. The catalyst basing on allochromatium vinosum [NiFe]-hydrogenase adsorbed on the electrode made from pyrographite and covered with active Ni-Fe layer appears to be as effective as the platinum catalyst is [5].

Recently, the improvements in technology, leading to the sharp reduction of the noble metal content in the catalyst (Class 2) attract also the strongly attention. Particularly the electrodes prepared by deposition of *Pd, Ni, Bi and La* on the surface of *Pt/C catalyst* [6], as well as the electrodes prepared by pulse electrodeposition of *Ru and Mo on platinum* at appropriate potentials have been elaborated [7]. It is well known that the presence of catalytic poisons (CO for example) in hydrogen gas exerts strong influence on the effectiveness and long-term stability of the electrodes containing Pt, Pd and other noble metals as a catalyst. The catalysts, showing limited susceptibility to the presence of CO have been presented in the literature [8, 9].

Table. Perspective catalysts for hydrogen oxidation

Catalyst	Method of preparation	Litera-ture
Class 1. Non-platinum catalysts		
Molybdenum carbide	gas-phase deposition	[1, 3]
Tungsten carbide (WC)	- // - // - // - // -	[2, 3]
Radicals of following composition: -OH, -OSO_3H, -COOH, -$OPO(OH)_3$	plasma treatment of gas diffusion layer	[4]
Allochromatium vinosum [NiFe]-hydrogenase	graphite supported adsorption Ni-Fe layer	[5]
Class 2. Catalysts with reduced Pt, Pd content		
Pt_xRu_y and $Pt_xRu_yMo_z$	pulse electrolysis	[7]
Pd-Pt/C, Ni-Pt/C, Bi-Pt/C, La-Pt/C	deposition of Pd, Ni, Bi, La on the Pt/C catalyst	[6]
Cr-Ni, La-Ni, Ti-Ni, Fe-Ni, Cu-Ni	deposition of respective metals on Raney nickel	[11]
Pt-Pd/Au/C Pt-Ru/Au/C	deposition of sub-monolayers of Pt on Ru and Au nanoparticles supported by carbon materials	[12]

Among the metal catalysts, the *Raney nickel,* deposited on the surface of graphite is widely known [10, 13]. The modification of Raney nickel with such metals like *Fe, Cr, Cu, La, Ti* [11], to increase its effectiveness has been proposed. The effectiveness of the doping metals follows the following series: *Cr>La>Ti>Cu>Fe.*

Interesting directions in the field of investigations of catalysts is the development of *multi-functional catalysts* that catalyse both the anodic hydrogen oxidation, as well as the cathodic oxygen reduction reactions. These catalysts are prepared mostly basing on noble metals. One of such catalysts is the material obtained by deposition of *a monolayer of Pt on Ru and Au* nanoparticles, deposited on the surface of *high-purity carbon material* [12]. Such catalyst increases the activity of electrode by 3-4 times in comparison with the commercial samples. The deposition of $Pt_{0.75}Pd_{0.25}$ *monolayer* on the gold particles distributed *on carbon matrix* allow to increase the catalytic activity of the oxygen reduction reaction by 2.5 times in comparison with typical Pt catalyst.

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