

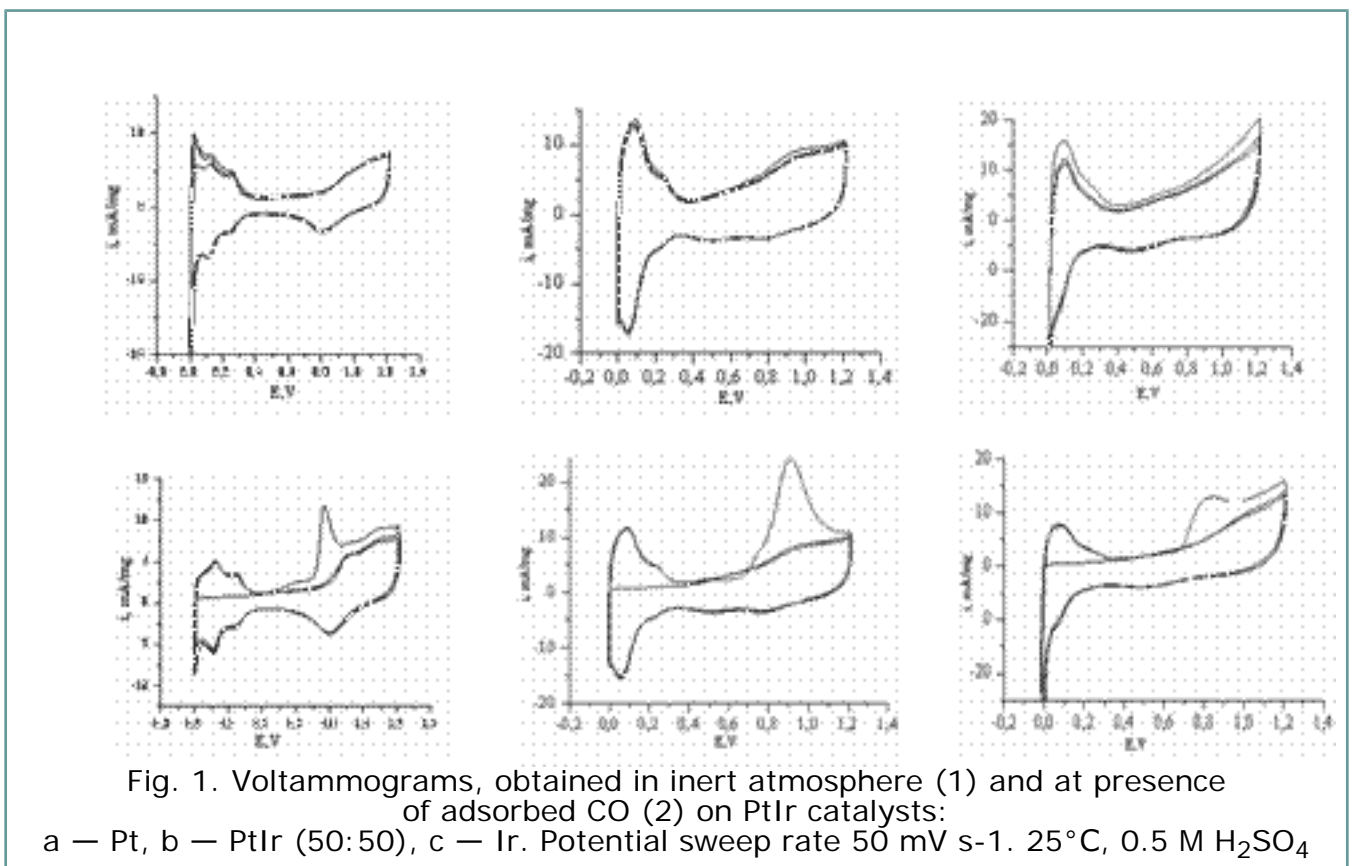
# The research of Pt-Ir electrocatalysts for unitized reversible fuel cell with solid polymer electrolyte

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Recently in connection with development of the renewable energy sources there appeared a need for systems of energy storage which could compensate non-uniformity of its production. One of the solutions of this problem is a unitized reversible polymer electrolyte fuel cell, which can work as an electrolyser, producing hydrogen and oxygen, and as a fuel cell, producing electricity [1]. According to the literature data, the most promising electrocatalysts of both processes are bimetallic systems based on Pt and Ir [2].

The purpose of the present work was the search of the optimal catalyst for hydrogen oxidation, oxygen reduction and water oxidation. Both pure Pt and Ir catalysts and binary systems were investigated. Electrochemical activity of electrocatalysts was determined on two types of model electrodes. The pyrographite disk electrode was used to obtain voltammograms and polarization curves. Model gas-diffusion electrode (GDE) was used to obtain polarization curves in the conditions similar to the work of real fuel cell. The GDE represented a square matrix of hydrophobitised carbon Toray paper with the surface area of 1 cm<sup>2</sup>, on which a thin layer of 80 µg of the electrocatalyst with binder was applied.

Determination of a specific metal surface area of the electrocatalysts was performed in two different ways: by measuring the amount of adsorbed hydrogen and by amount of adsorbed CO. Voltammograms of PtIr catalysts, obtained in an inert atmosphere and in the same atmosphere after adsorption of CO, are presented on fig. 1.



The peaks, corresponding to desorption of hydrogen and CO, are observed at 0.15 V and 0.8 V respectively and coincide with literature data. The specific area of metal surface in electrocatalysts is presented in table 1. This values correspond to literature data, according to which the metal surface area of Pt black, determined by BET method, was 27 m<sup>2</sup>/g cat.

Table 1. Kinetic parameters of hydrogen oxidation in 0,5 M H<sub>2</sub>SO<sub>4</sub> at 80°C on PtIr electrocatalysts

Electrocatalyst	dE/dlgi, V		j <sub>st</sub> , mV	S <sub>area</sub> , m <sup>2</sup> g <sup>-1</sup> cat		i, mA mg <sup>-1</sup> at E = 0,2 V	
	0-0.08 V	0.08-0.2 V		by H <sub>2</sub>	by CO	RDE	GDE
Pt 100	0.0716	0.274	22	20.3	7.3	13.4	36.4
PtIr (90:10)	0.0741	0.625	18	20.5	16.8	17.7	249.3
PtIr (70:30)	0.0662	0.530	20	15.6	19.4	17.7	292.3
PtIr (50:50)	0.0615	0.477	18	16.8	16.0	20.9	279.3
PtIr (30:70)	0.0514	0.325	19	16.1	12.1	22.0	231.2
PtIr (20:80)	0.0450	0.549	17	16.5	15.7	21.8	305.9
PtIr (10:90)	0.0747	0.388	15	37.0	26.9	22.0	289.6
Ir 100	0.0764	0.274	17	13.3	11.4	21.8	312

On fig. 2 hydrogen oxidation polarization curves are presented, and in table 1 some electrochemical properties of electrocatalysts obtained on the same electrodes are shown at a various ratio between Pt and Ir. Since the potential range which is of interest to use in fuel cells, is 0,2-0,4 V, hydrogen oxidation current values in table 1 are presented at 0,2 V. The Tafel dependences corresponding to obtained polarization curves are presented on fig. 3. The Tafel slopes values are shown in table 1.

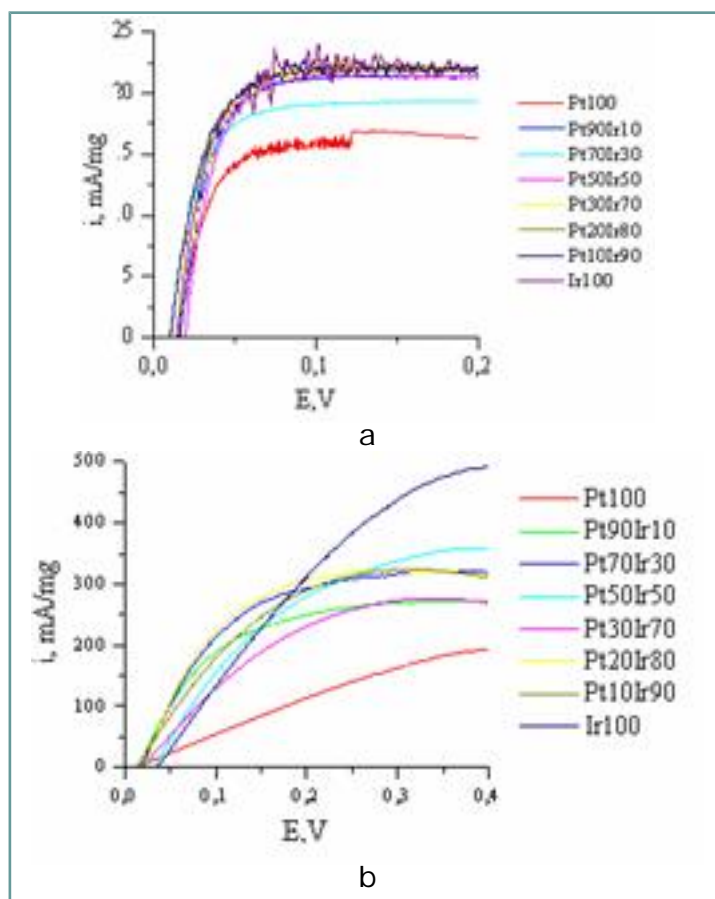


Fig. 2. Hydrogen oxidation polarization curves, obtained on PtIr catalysts:  
 a — on RDE; b — on GDE. 80°C.  
 0.5 M H<sub>2</sub>SO<sub>4</sub>, potential sweep rate – 1 mV·s<sup>-1</sup>,  
 RDE rotation speed 630 rpm

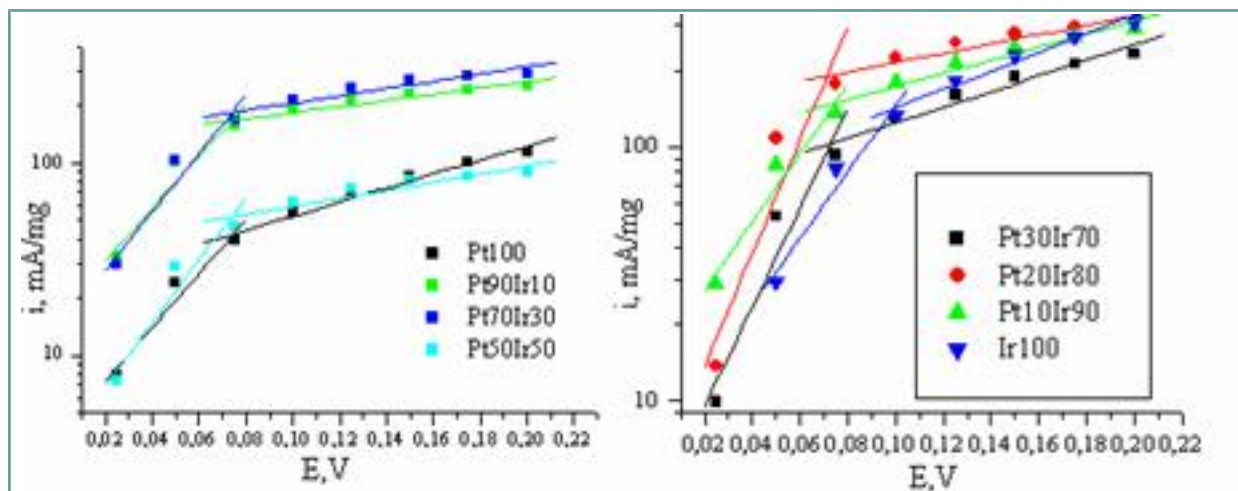
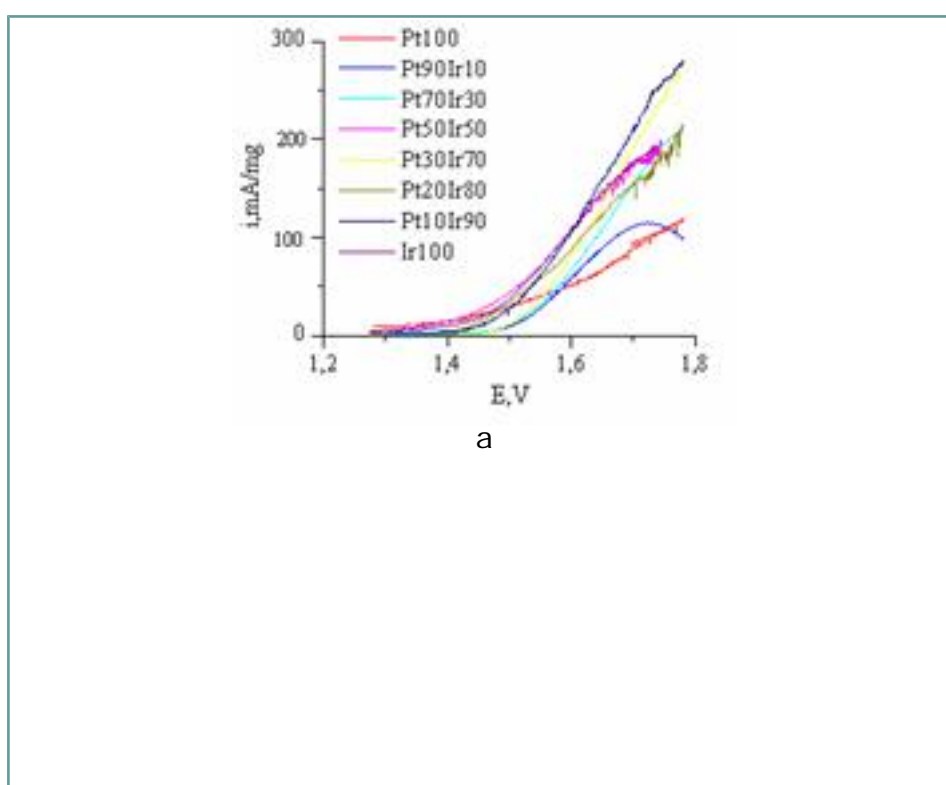


Fig. 3. Hydrogen oxidation polarization curves in Tafel coordinates for PtIr catalysts

The difference in the catalysts activity values on two different electrodes can be explained by the fact that the RDE worked in a diffusion mode. In case of GDE activity of catalysts was defined only by reaction kinetics.

Since the fuel cell can function in a electrolyser mode also, catalysts have been studied in water electrolysis mode with oxygen evolution. On fig. 4 a the polarization curves obtained on GDE at potential sweep rate 1 mV/s, and on fig. 4 b the same curves in Tafel coordinates are presented. In table 2 some electrochemical properties of catalysts and Tafel slopes are shown. The highest activity was observed at Ir, the least — at pure platinum.



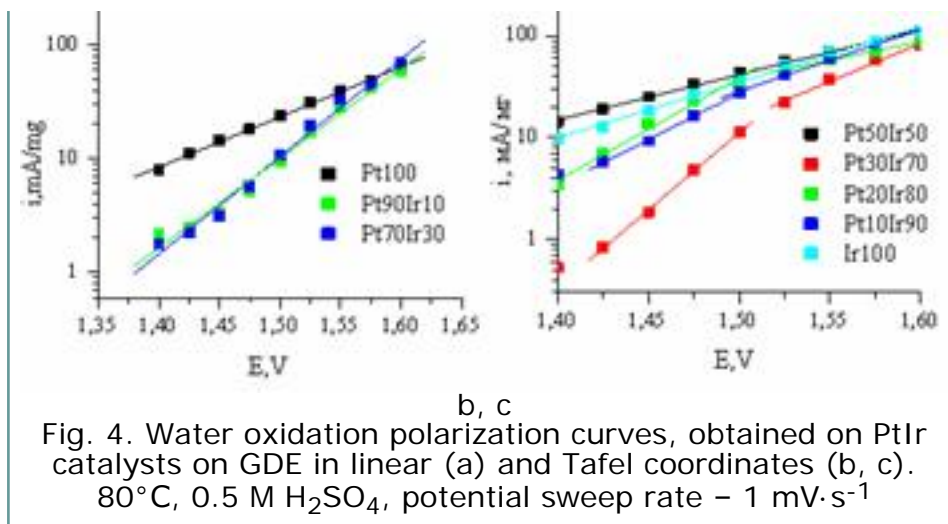
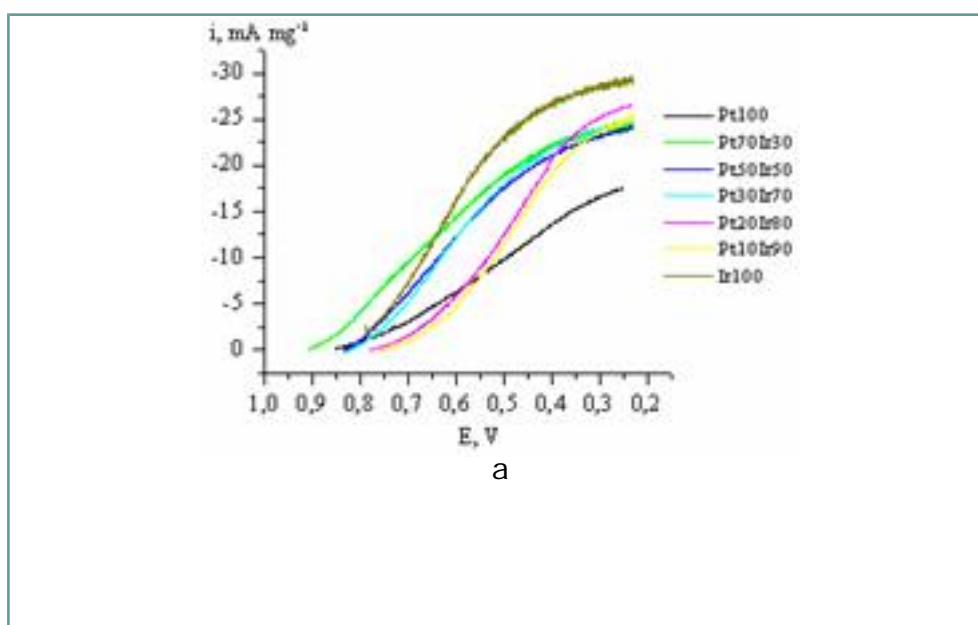


Table 2. Water oxidation kinetic parameters in 0.5 M H<sub>2</sub>SO<sub>4</sub> at 80 °C on PtIr catalysts

Catalyst	dE/dlgi, V		I at E= 1.6 V, mA mg <sup>-1</sup>
	1.4–1.5 V	1.5–1.6 V	
Pt 100	0.300		60.6
PtIr (90:10)	0.111		74.5
PtIr (70:30)	0.117		67.6
PtIr (50:50)	0.259		107.5
PtIr (30:70)	0.066	0.132	80.8
PtIr (20:80)	0.099	0.251	87.3
PtIr (10:90)	0.110	0.164	106.8
Ir 100	0.183		109.5

To determine the catalytic activity of Pt and Ir black and based on Pt and Ir binary catalysts in the cathode process in fuel cell with solid polymer electrolyte the kinetic dependences of oxygen electroreduction reaction were studied. Polarization curves obtained on RDE are presented on fig. 4a. The activity of the catalysts increases with increasing Ir content in binary catalyst. Corresponding to polarization curves Tafel dependences are presented on fig. 4b, c. The values of Tafel slopes are shown in table 2.



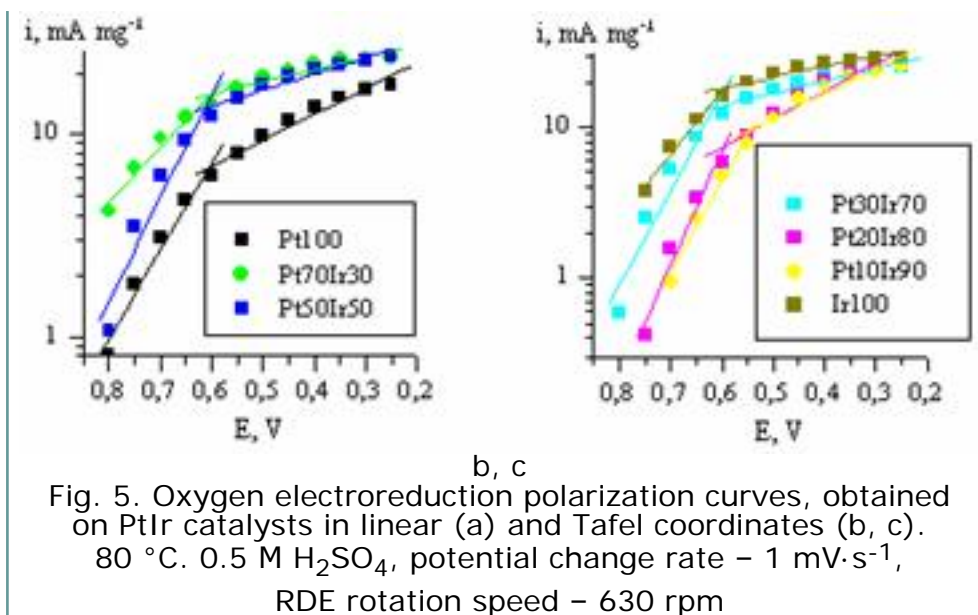


Table 3. Oxygen reduction kinetic parameters in 0.5 M H<sub>2</sub>SO<sub>4</sub> at 80 °C on PtIr catalysts

Catalyst	dE/dlgi, V		I at E= 0.6 V, mA mg <sup>-1</sup>
	0.8–0.6 V	0.8–0.6 V	
Pt 100	0.230	0.783	6.32
PtIr (70:30)	0.378	1.645	14.4
PtIr (50:50)	0.197	1.271	12.2
PtIr (30:70)	0.176	1.217	12.2
PtIr (20:80)	0.133	0.540	5.82
PtIr (10:90)	0.165	0.610	4.74
Ir 100	0.242	1.441	16.0

The analysis of experimental data shows that among the studied catalysts for the anode of unitized reversible fuel cell with solid polymer electrolyte Ir black is the most suitable catalyst.

Further research in this area will be the study of PtIr catalysts activity in water reduction reaction, the determination of their stability in the reactions of hydrogen oxidation, oxygen reduction and water electrolysis.

## References

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2. Ledjeff K., Mahlendorf F., Peinecke V., Heinzl A. Development of electrode/membrane units for the reversible solid polymer fuel cell (RSPFC) // Electrochim. Acta. 1995. V. 40. N.3. P. 315–319.