

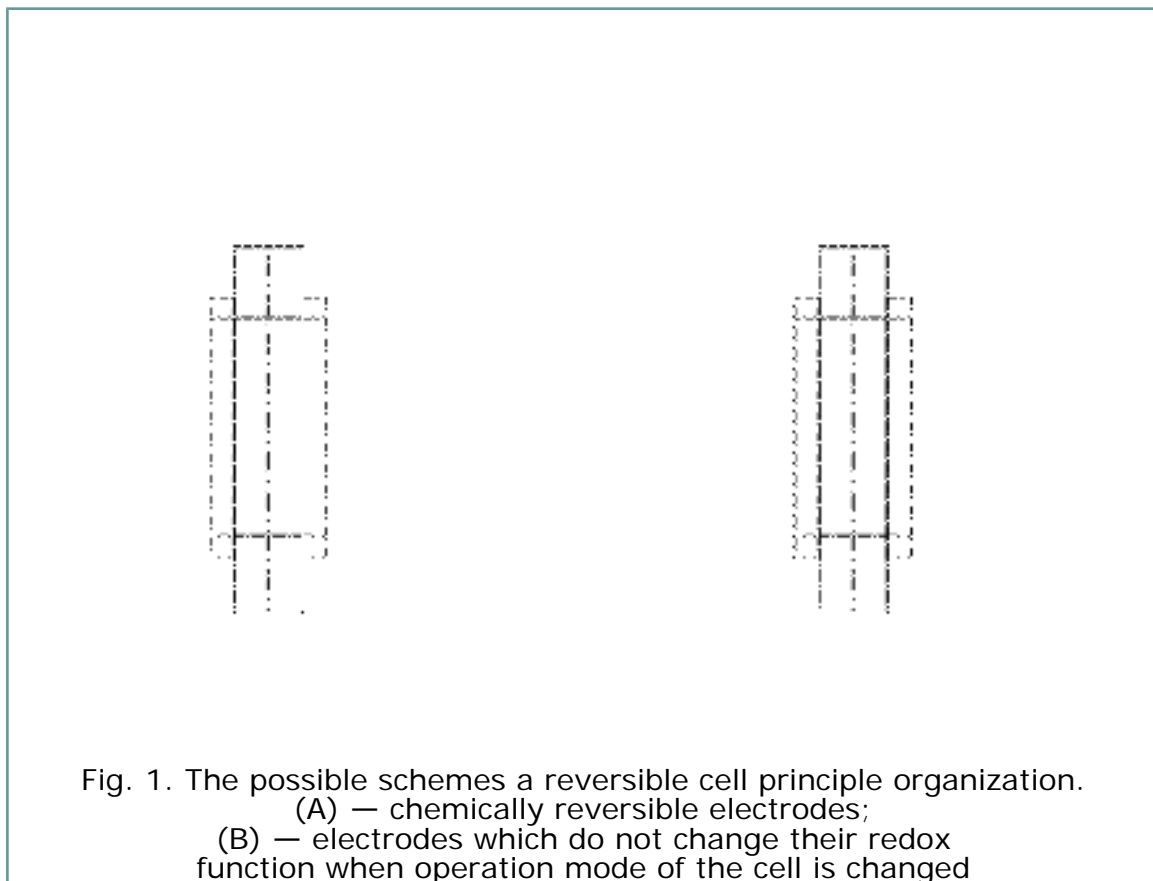
Researches on electrocatalytic compositions for reversible electrochemical cell with proton exchange membrane

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Along with the creation of high effective fuel cells and water electrolyzers there is a necessity of development of the unitized electrochemical system fuel cell – electrolyser, combining the necessary conditions for carrying out of both processes in one device. Among different types of fuel cells and electrolyzers, the technology based on proton exchange membrane (PEM) is a perspective one for creation of reversible systems: PEM-systems are characterized by short response time, high efficiency and specific power, and also by ecological safety. The reversible electrochemical cell which will alternately operate in the electrolyser mode and in the fuel cell mode in systems with cyclic supply of the electric power from renewable sources (for example, the sun or a wind) or from atomic power plants (in "off-load" hours), will reduce the sizes, weight of system and its cost in a considerable degree.

The primary tasks in the development of reversible cells are researches and optimization of the electrocatalytic layers which will effectively work both in the fuel cell mode, and in the electrolyser mode. Chemically reversible oxygen and hydrogen electrodes [1] changing their reductive-oxidative functions at switching of operating modes of a cell (fig. 1A) can be used for creation of convertible system. In the present work other approach is offered: not "truly reversible electrodes" are used, but hydrogen and oxygen electrodes are swapped over at change of an operating mode of the cell (fig. 1B).



As the cathode catalyst operating in the fuel cell mode, platinum on the carbon carrier with the additive of the hydrophobisator (polytetrafluorethylene) has been

used; carbon-graphite paper Sigracet 10 bb with a hydrophobic micro-porous sub-layer was used as the gas diffusion electrode. The same electrode serves as the cathode (hydrogen regeneration) in the electrolyser mode. In these conditions carbon materials possess sufficient chemical stability, and the hydrophobicity necessary for the fuel cell electrode, is not so critical for the electrolyser's hydrogen electrode.

Pt and Ir mixes in various ratio (see Table 1) were used as bifunctional electrocatalysts on the anode, thus layers Pt and Ir have been put in various sequence: first Pt, then Ir, and on the contrary. Porous titanium, which has a hydrophobicity optimum for the electrolyser mode, and does not create essential difficulties at start in the fuel cell mode, was used as the gas diffusion electrode on the anode.

Table 1. Values of voltage of reversible cell in the electrolyser U_E and the fuel cell U_{FC} mode at $i=0,5 \text{ A/cm}^2$ for various catalytic compositions

| Structure of the catalytic composition | Pt | Pt _{0,5} Ir _{0,5} * | Ir _{0,5} Pt _{0,5} ** | Ir |
|--|-------|---------------------------------------|--|-------|
| $U_E, \text{ V}$ | 2,721 | 1,747 | 1,591 | 1,699 |
| $U_{FC}, \text{ V}$ | 0,270 | 0,593 | 0,673 | 0,619 |

1. operating conditions in the electrolyser mode: $t=90 \text{ }^\circ\text{C}$, $P_{O_2}=P_{H_2}=0$;
2. operating conditions in the fuel cell mode: $t=85 \text{ }^\circ\text{C}$, $P_{O_2}=3,0 \text{ bar}$; $P_{H_2}=2,0 \text{ bar}$;
3. overall Pt and Ir loading on the anode: $2,0 \text{ mg/cm}^2$, 5 wt. % of ion-exchange polymer;
4. Pt loading on the cathode: $0,8 \text{ mg/cm}^2$; 15 wt. % of ion-exchange polymer;
5. membrane — Nafion 115;
6. * Pt-Ir mix, where 0,5 – mass fraction of the given metal, Pt layer is arranged near the membrane;
7. ** in a similar way to *, but Ir layer is arranged near the membrane.

One can see from Table 1, among various catalytic compositions the best characteristics of the reversible cell both in the electrolyser mode, and in the fuel cell mode are realized with Ir_{0,5}Pt_{0,5} on the anode. In this case the arrangement of Ir layer near the membrane allows to conduct the electrolysis process effectively (oxygen generation) on the iridium catalyst, and oxidation of hydrogen basically on the platinum catalyst. So, for example, in the electrolyser mode at a current density of $0,5 \text{ A/cm}^2$ the typical voltage on a cell was 1,591 V in a case when Ir layer is arranged near the membrane and 1,747 V in a case when Pt layer was is arranged near the membrane; in the fuel cell mode at the specified current density the voltage was ca. 0,673 V in a case when Ir layer was is arranged near the membrane, and 0,593 V in a case when Pt layer was is arranged near the membrane (see Table 1).

Thus, the reversible cell with PEM on the basis of electrocatalytic compositions optimized within the framework of the given work shows rather high performances.

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References

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