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Nanostructured bimetallic PtNi catalyst for electrochemical systems with solid polymer electrolyte

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Abstract. A method for forming a nanostructured bimetallic PtNi catalyst on the surface of a solid polymer electrolyte is presented. Nickel particles, on which the bulk of the platinum catalyst is grown by chemical deposition, are obtained by magnetron sputtering. The resulting system has high catalytic activity and temporary stability.

Keywords: bimetallic catalyst, solid polymer electrolyte, catalytic layer, magnetron sputtering, chemical deposition

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Материалы конференции
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Наноструктурированный биметаллический катализатор PtNi электрохимических систем с твердополимерным электролитом

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Аннотация. Представлен метод формирования наноструктурированного биметаллического катализатора PtNi на поверхности твердополимерного электролита. Частицы никеля получены методом магнетронного распыления, на которых химическим осаждением выращивается основной объем платинового катализатора. Полученная система имеет высокую каталитическую активность и временную стабильность.

Ключевые слова: биметаллический катализатор, твердополимерный электролит, каталитический слой, магнетронное распыление, химическое осаждение

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Introduction

Modern hydrogen-oxygen fuel cells typically consist of two electrodes, an anode and a cathode, separated by a polymer electrolytic membrane (PEM) [1]. The PEM use in its original form in fuel cells shows low productivity, which requires the introduction of a catalyst into the reaction area [2]. The most active in the hydrogen oxidation are catalysts based on highly dispersed platinum clusters, the properties and structure of which significantly determine the degree of the electrolytic process intensification [3, 4]. Therefore, the development of methods for the formation of nanostructured platinum-based catalysts with the required functional properties is an urgent task.

Materials and Methods

The PtNi bimetallic catalysts synthesis was carried out in two stages. At the first stage, adsorption centers were obtained on the surface of a solid polymer electrolyte (Nafion) using magnetron sputtering of a nickel target. Before sputtering, the pressure in the chamber was set to 5×10^{-5} Pa, after which the working gas – argon was supplied and a magnetron discharge with a power of 200 Watts was ignited.

Next, by chemical precipitation from a solution of H_2PtCl_6 – 2 g/l, N_2H_4 – 1.0 g/l, NH_4OH (conc.) – 200 ml/l, the main catalyst volume was formed to form a shell-core structure of platinum on nickel on the PEM surface. A membrane electrode block with an electrode area of 7 cm² was made on the basis of a membrane with the resulting catalyst, which was installed in a test bench (Fig. 1) for testing as part of a water electrolyzer and a fuel cell.

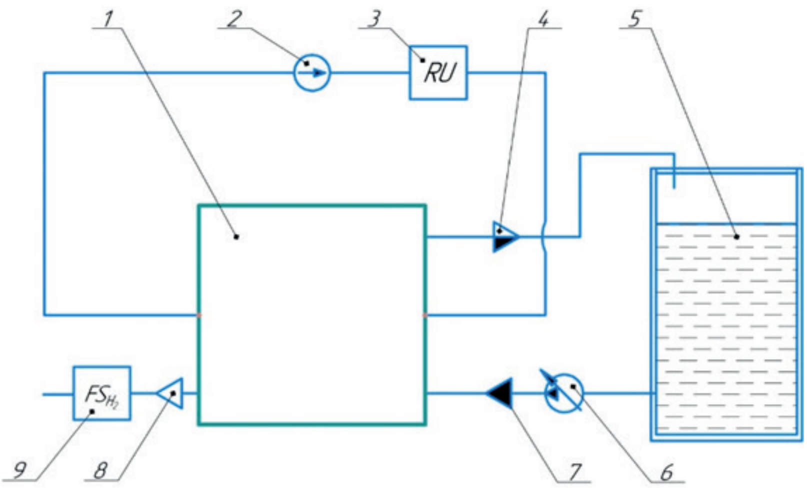

Fig .1. Scheme of the test bench. *1* – electrolytic cell; *2* – current source; *3* – registration block (including ammeter); *4* – tube output of the water-oxygen mixture; *5* –container with water; *6* – pump; *7* – tube for supplying water to the EC; *8* – output channel H_2; *9* – flow measurement sensor H_2

Results and Discussion

The study of membranes obtained by the combined method showed that the catalytic layer has a porous structure that does not interfere with proton transport to the membrane surface. The surface area of the membrane manufactured using a combined technology, fixed on the SEM, is shown in Fig. 2.

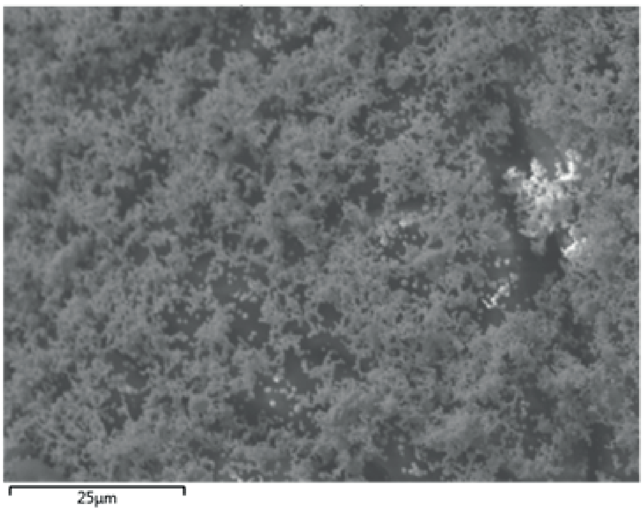

Fig. 2. SEM image of an ion exchange membrane with a nanostructured catalyst layer obtained by magnetron sputtering followed by chemical deposition

The study of the current-voltage characteristics of the obtained MEUs was carried out in comparison with MEUs based on a membrane with a catalyst synthesized only by a chemical method (Fig. 3).

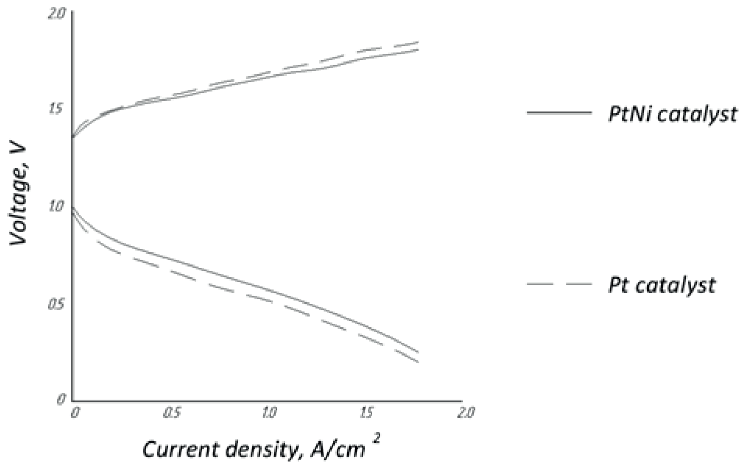

Fig. 3. Current-voltage characteristics of the MEU

The characteristics of bimetallic catalysts are higher, which is explained by electronic effects (lowering the energy of vacant d orbitals). Thus, the water electrolysis voltage is 0.03 V less at a current density of 1 A/cm^2, while the fuel cell voltage at the same current density is 0.05 V higher than the value for a MEU with a catalyst obtained by a chemical method.

It is also worth noting that the high energy of deposited particles during magnetron sputtering (10–20 eV) leads to energetic activation of the condensation process of particles on the substrate and, as a consequence, high coupling between the catalyst and the substrate [5], thereby having a positive effect on the MEU characteristics stability.

Conclusion

The use of a combination of magnetron sputtering and chemical deposition to form nickel and platinum layers, respectively, makes it possible to obtain bimetallic catalysts on the surface of solid polymer electrolytes characterized by high functional characteristics and their stability. The resulting catalyst is characterized by corrosion and morphological stability due to its strong bond with the substrate, as well as high catalytic activity, which is explained by electronic effects (lowering the energy of vacant d-orbitals).

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