

# Catalase-Biomimetic Sensor on Base of Electrochemical Electrode TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb and TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Si

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**Abstract:** It was developed biomimetic electrodes catalase type based on Pb and Si, which for a long time do not lose their activity. Prepared biomimetic sensors compared with their biological counterparts have a number of technological advantages—availability, low cost and ease of process design. With the help of electrode there have been determined low concentrations of  $H_2O_2$  in the water solution and pH-changes of the investigated solutions have been shown.

Key words: Biomimetic, sensor, tetraphenylporphyrin of iron, catalase, semiconductors.

# **1. Introduction**

In recent years, there have been carrying out the large scale investigations for elaborations of biomimetic sensors, which combine specificity and selectivity of the biochemical methods of analysis with the qualities of chemical sensors (steadiness and multipleness of application and soon). The achievements in the field of biomimetic catalysis [1, 2] permit to work out the biomimetic electrodes in which biomimetic analogs of catalase are used. The application of such electrochemical electrodes in sensors enables to get rid of a number of essential drawbacks inherent in the biosensors.

Penetration of biosensors and their mimetic analogs on analytical market is determined by their price and ease of use. The implementation of touch technology will enhance the quality and quantity of medical tests and, therefore, diagnosis, monitoring food, environment.

# 2. Experiments

For the purpose of creating high-sensitive catalase-biomimetic sensor, as transducer electrodes there were used Pb-electrode, on which biomimetic

selectors-derivatives of TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub> for determining rather low H<sub>2</sub>O<sub>2</sub> concentrations in aqueous solution were drawn. The biomimetic electrode was made by wag of sticking (silver paste was used as sticking material) biomimetic catalyst of tetraphenylporphyrin of iron (TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>) on the Pb-electrode. Catalase activity of biomimetic electrodes has been determined by potentiometric method. Experimental mounting for making these investigations consisted of an electrode part, a cell and a volt-meter (Fig. 1). The electrode part of the mounting consists electrode reference of (Ag/AgCl/Cl<sup>-</sup>) and biomimetic electrode.

The investigations have been carried out by potentiometric method in the cell, filled with the certain amount of bidistillated water (supporting solution) it has been determined ( $\Delta E$ ) of the element and then different amounts of hydrogen peroxide (catalase reaction) have been added and changes of ( $\Delta E$ ) in solution have been fixed.

In all the experiments there has been used a magnet mixer in order to reduce the influence of diffusion factor on the motion of catalase reaction.

# 3. Results and Discussion

The results of potentiometric investigation of

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catalase activity of the biomimetic electrode prepared by us are cited in (Fig. 2) which shows that: potential of the background aqueous solution for H<sub>2</sub>O<sub>2</sub> concentration  $1.0 \times 10^{-6}$  mass% and  $1.0 \times 10^{-8}$  mass% make up respectively E =- 0.30 mV and  $\Delta E =$  - 0.33 mV. As well, it is seen from the curves that when adding H<sub>2</sub>O<sub>2</sub> into the electrochemical cell, containing redistilled water in both cases a sharp change of the electrode potential of the system to  $\Delta E =$  - 0.15 mV is observed. To decrease an influence of the diffusive factor on the course of catalase reaction the magnetic mixer bioselector biomimetic was used.



Fig. 1 Electrochemical cell.



Fig. 2 Change of e.m.f. of the system depending on time for TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb  $H_2O_2$  concentration in the aqueous solution: 1:  $1.0 \times 10^{-6}$  mass%; 2:  $1.0 \times 10^{-8}$  mass%.

Tetraphenylporphyrin of iron (TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>) deposited (by gluing) using silver paste onto an Pb-electrode exhibits the highest catalase activity at the beginning of experience with maximum value  $\Delta E$  = -0.15 mV at *t* = 2 min.

While looking through Figs. 3 and 4, one can notice, that the presence of hydrogen peroxide in the system in all cases at first leads to the sharp change in the system potential. From Figs. 3 and 4, it also shows that for Pb-electrode (without imitator) since the 10<sup>th</sup>



Fig. 3 Change of e.m.f. of the system depending on time at low concentrations of  $H_2O_2$  for TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb electrodes: 1: Pb without imitator, 2:  $1.0 \times 10^{-4}$  mass%.



Fig. 4 Change of e.m.f. of the system depending on time at low concentrations of  $H_2O_2$  for TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb electrodes: 1–Pb without imitator, 2–0.5 mass%; 3–1 mass%.

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min  $\Delta E$  does not change (curve 1, Figs. 3 and 4). This indicates that in the case investigate Pb-electrode without imitator (curve 1) catalase reaction, apparently practically almost absent, and in the case biomimetic electrode investigate, containing tetraphenylporphyrin TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb (curve 2 in Fig. 3 and curves 2 and 3 in Fig. 4) observed changes  $\Delta E$  in the direction of increasing and decreasing values  $\Delta E$  up to a certain time, and then it becomes constant, therefore, catalase reaction has ceased to exist. The investigations show that Pb-electrode (without imitator) does not practically decompose low concentrations of H<sub>2</sub>O<sub>2</sub>. But the use of the electrode with imitator TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Pb) affect the curves and as can be seen from the curve 2 in Fig. 3 and curves 2 and 3 in Fig. 4) continues sinusoidally vary almost till complete decomposition of H<sub>2</sub>O<sub>2</sub>. Should be mentioned, that the electrode potential of supporting solution for concentration of H<sub>2</sub>O<sub>2</sub> in water solution  $1.0 \times 10^{-4}$  mass% is  $\Delta E = -$ 0.30 mV; for 0.5 mass% is  $\Delta E = -0.37$  mV; for 1 mass% is  $\Delta E = -0.30$  mV; for Pb-electrode (without imitator) is  $\Delta E = -0.50 \text{ mV} [3, 4].$ 

The change of pH system in studied solutions has been investigated. The results showed that during the contact of biomimetic electrode with  $H_2O_2$  in the water solution pH of different concentrations rises from acid sphere to the neutral one (pH = 6.8 supporting solution). This indicates a complete decomposition of  $H_2O_2$  in the solutions, by the through the catalase reaction.

It was widespread use biosensors to semiconductors, which have a number of technologically attractive qualities before others good reproducibility and high sensitivity, the development of multifunctional chip, the relative cheapness and availability.

The compatibility of silicon with microfabrication makes it an ideal material for biophotonics, bioelectrochemistry and many other purposes. However, for many applications involving aqueous solution, the oxidation of the silicon surface limits the use of this material and alternatives must be found [5].

The article investigates the physical and chemical properties of semiconductors WBG as advanced bioand chemical sensors [6].

In measurement technique found widespread semiconductor pressure sensors based on silicon [7], using the SOI technology (technology of "silicon-on-insulator").

They are executed in the form of a pressure sensor chip on base on which located measuring membrane, but for registration differential pressure in the measured medium.

To this end, we investigated the semiconductor biomimetic of sensor catalase type for determination of trace concentrations of hydrogen peroxide in aqueous solutions. And also to explore their physical and chemical properties.

As semiconductor electrode was used Si (silicon) transducer. The biomimetic electrode was made by wag of sticking (silver paste was used as sticking material) biomimetic catalyst of tetraphenylporphyrin of iron (TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>) adsorbed on alumina.

The experiments revealed a number of features. Firstly, the use of a semiconductor sensor biomimetic has allowed to determine trace concentrations of  $H_2O_2$  in aqueous solution. Second synthesized sensor does not lose its activity for a long time.

Change of e.m.f of the system depending on time at low concentrations of  $H_2O_2$  for Si-electrode (without imitator) are shown in Fig. 5. The investigation showed that Si-electrode (without imitator) does not decompose low concentration of  $H_2O_2$ .

Fig. 6 shows the experimental data obtained in the study of catalase activity of semiconductor electrode containing tetraphenylporphyrin TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Si.

By considering Fig. 6, it can be seen that the semiconductor catalase biomimetic sensor exhibits high sensitivity. Electrode potentials, potential of the background aqueous solution for  $H_2O_2$  concentration



Fig. 5 Change of e.m.f. of the system depending on time for Si-electrodes without imitator.



Fig. 6 Change of e.m.f. of the system depending on time at low concentrations of  $H_2O_2$  for TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub>/Si electrodes: 1–0.1 mass%, 2–0.5 mass%, 3–0.1 mass%, 4–1.0  $\times 10^{-6}$  mass%, 5–1.0  $\times 10^{-4}$  mass%.

1 mass% E = -0.25 mV; for 0.5 mass%  $\Delta E = -0.30$  mV; for 0.1 mass% E = -0.23 mV; for 1.0 ×  $10^{-4}$  mass%  $\Delta E = -0.231$  mV; and  $1.0 \times 10^{-6} \Delta E = -0.305$  mV make up respectively. It should be noted that when adding hydrogen peroxide within a few seconds observed a sharp jump of electrode potential.

## 4. Conclusions

At the investigation biomimetic Pb-electrodes on catalase activity, it was found that the electrodes with TPhPFe(III)/Al<sub>2</sub>O<sub>3</sub> can detect hydrogen peroxide in an aqueous solution in an amount of  $1 \times 10^{-8}$  mass%.

Using semiconductor biomimetic sensor allowed to determine trace concentrations of  $H_2O_2$  in the aqueous solution in an amount of  $1 \times 10^{-6}$  mass%. Synthesized biomimetic sensors do not lose their activity for a long time.

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