Perspective of use of shungite cathode for microbial fuel cell design

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Abstract. The article is devoted to one of the directions of alternative energy – the creation and use of microbial fuel cell (MFC). It is used anode made of plate of macro porous silicon doped with antimony. The cathode is a plate of shungite rock. Shungite is a natural stone containing fullerenes. The possibility of functioning and effective operation of this system is investigated.

1. Introduction
The microbial fuel cell (MFC) is an environmentally friendly alternative source of electrical energy, in which microorganisms are used as biocatalysts to oxidize organic and inorganic matter and generate current [1]. Despite the fact that MFC strongly loses in efficiency to modern energy sources, which are widely used in industry there are able to produce a large amount of electricity. Unique feature of MFC is the ability to generate electricity from organic waste. Increase of MFC efficiency and spread of microbial fuel cell into various spheres of people's lives, will allow recycling into electricity toxic waste that pollute the environment.

In MFC, electrogenic microorganisms oxidize the organic substrate and transfer electrons to the anode. Further, the electrons flow on the electric circuit to the cathode and are connected to protons, oxygen, provided from air, and electrochemically activated catholyte [2].

It is known from the literature [3] that the maximum theoretically achievable potential difference between the anode and the cathode is about 1.1 V. In practice, it was achieved the voltage of 0.7-0.8V on the studied laboratory models of MFC [4]. This demonstrates a close to linear dependence of electrical power on the volume of the anode chamber and the area of the anode current-collecting surface.

2. Experimental equipment
The study of two-chamber MFC were carried out in the Lyceum 1511 with the sample taken from the river Chertanovka, Moscow. The design of the MFC cell is consisted of two interconnected chambers separated by an ion exchange system. A container (15 x 2.5 x 3 m×10⁻²) consisting of 7 cells for the possibility of assembling several MFC at the same time was used as the body (Fig 1.I). One cell is not used.
The working volume of the anode and cathode compartment is $15.75 \times 10^{-6}$ m$^3$. The chambers contain electrodes: the anode is made of a plate of macro porous silicon doped with antimony 1x1 $\times 10^{-2}$, which for our experiment was produced in MEPhI. Of particular interest in the design of MFC is the use of high–tech materials such as silicon plate anode and cathode-macroporous silicon and shungite (Fig 1.II).

Before using the silicon plate as an electrode, it was carried out microscopic study on the microscope OLIMPUS BX51M (Japan) (Fig.2).

Electrodes of macro porous silicon was prepared by electrochemical etching method. Pore size varies in 120-150 nm range. It is observed cracking with crack size 10-20 μm. Single-crystal electron antimony-doped silicon wafers $Si_{por}$, diameter $d=76$mm (silicon grade in Russian specification 76 KES) were used as a starting material. It was carried out etching in a solution of hydrofluoric acid and water at a current value of $120 \times 10^{-4}$ mA/m$^2$. The current source is – AKTAKOM ATN – 2232. Diffusion doping of antimony samples was used to increase electrical conductivity. The shungite plate 2x3x0.2 m$^2$ $^2$ is
used as a cathode. It is selected as an experimental material with a low cost. It was used ion exchange system based on the polymer monopolar heterogeneous ion-selective membrane MK-40, reinforced with nylon fabric (manufacturer OHK "Shchekinoazot"). The membrane was glued between anode and cathode chambers using glue kernel.

The cathode chamber is filled with a solution of 0.8% sodium chloride. The anode chamber is filled with mud (silt) from the Chertanovka river. It was used methylene blue C16H18ClN3S in concentration 0.99 mol/m³ as a mediator in the anode chamber. To prevent oxygen from entering the chamber a float made of extruded polystyrene foam was placed above the liquid of the anode chamber. The top cover of the anode chamber is closed. The electrode was immersed completely in the liquid. The shungite plate was immersed in the cathode chamber by 50% to access oxygen for reducing reaction. The cathode chamber is open for better access of air.

The developed surface of macro porous silicon serves as an adhesive basis for microbial flora, which is part of the river silt. MFC design based on literature data [5]. The wires of the electrode parts of the installation have an output from the top of the structure.

The measurement is made by MASTECH MY-65 multimeter. The measurements were taken when the load was set in the form of a 10 kOhm resistor on the electric circuit.

Interest in the use of silicon is due to its high chemical resistance, manufacturability, the ability to obtain porous structures with a developed surface, to control the electrical conductivity of the volume and hydrophilic behaviour of the surface of such structures, as well as the ability to use basic technologies of microelectronics [6].

3. Experimental results and discussion

The experiment lasted for 9 days. The results are presented in Fig. 3 and 4.

![Graph](image)

**Figure 3.** The dynamics of the system voltage with a load resistor 10K, V

Starting from the first day, the voltage in the system there was a tendency to increase and by the 7th day a was maximum of 1.16 V. Further, the voltage dropped from the maximum value more than to 30%.

The maximum power value was recorded from the 4th to the 7th day of the experiment, amounting to 0.16 mW.
**Figure 4.** Dynamics of changes in the system capacity, mW

In our opinion, the decrease in the power of the MFC is due to a decrease in the concentration of nutrients and the achievement of the maximum density of bacteria in the anode chamber.

4. **Conclusion**

The Design of MFE using as electrodes of porous silicon and shungite not less efficient then counterparts found in the scientific literature [9]. During the experiment, the voltage value equal to 1.16 V was achieved, which corresponds to the maximum theoretically achievable value. It is planned to study the operating temperature range of this MFC.

Summing up we can say that the field of development of microbial fuel cells is actively developing and promising. Creation of new laboratory samples with experimental electrode materials is a promising area of research.

5. **References**

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