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Study of electric properties of self-assembled films of albumin during their dehydration

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Abstract. In this paper conductivity of biomolecular films are considered. Experimental results on study of electric response of albumin solution under the influence of external magnetic field and without the field are presented. The influence of magnetic field on electrical characteristics of protein films is discussed.

1. Introduction
Development of microelectronics is concerned with search of new principles, substances and materials, study of new scientific technical ideas. Significant research trends are as follows: realization of methods of diagnostics of processes of self-organization of molecular systems, study of the structure and properties of new materials, self-organization processes, special of organic materials of biomolecular electronics. Using of organic components, in particular biomacromolecules, is a basis of the new promising technology – molecular electronics and its component – bionanoelectronics [1]. There are a number of publications on creation of biomolecular computers [2, 3].

Integration of modern electronic devices with biological and biomolecular elements is an important issue. Protein films can be considered as one of the basic elements of new electronics. Study of the processes of formation of biomolecular films is a separate task. Various structures, which determine the properties of the film, can be formed under the influence of various factors during the dehydration of the solution. This process can be controlled by these parameters.

It should be noted, that elements of any electronics are impacted by various electromagnetic fields, both natural and artificial origin [4]. Therefore, effects of electromagnetic field on biological systems, proteins, and biological solutions should be studied [5, 6].

Magnetic properties of proteins are insufficiently studied [7, 8]. Thus, the aim of this work is research of the electric response of the protein albumin solution under the influence of external magnetic field and without it.

2. Methods of investigation
In this work electric properties, in particular, conductivity of albumin solution during it’s dehydration and dry albumin films were studied.

Experiments were done on water solutions of albumin during their dehydration. Water solution of albumin was prepared from concentrated protein albumin solution with pH = 9.3 and distilled water with pH = 7.0. in the ratio of 1:1. A pH shift of studied solution to an acidic side to pH = 4.8 was provided with vinegar acid CH₃COOH 99%. This value of pH corresponds to isoelectric point of albumin.

The second part of this work is devoted to studies of electric response of the albumin solution under the influence of an external magnetic field.

Based on the literature analysis [6, 7], it was decided to use fields comparable with the Earth’s magnetic fields (the magnetic field equals about 0.34 Oe).
In our experiments, DC magnetic fields were created by an inductive coil around the sample, and a generator supplying a voltage to the coil. The coil 4 mm in thickness and 40 turns in number, was made of copper wire of 0.1 mm cross section. The experimental setup is presented in Fig. 1.

The investigated solution (4) in volume of 5 μl was placed on the dielectric substrate (3) in the interelectrode gap (2). The signal in volume 5 V from generator (1) with various frequencies was applied to the interelectrode gap. Fig. 2 shows electric scheme of experimental setup.

The voltage \( V_{out} \) at the interelectrode gap was measured by voltmeter (5) as a function of time and frequency. In accordance with the equation (1) the output voltage is proportional to sum of samples resistance and voltmeter input resistance.

\[
V_{out} \sim \frac{R_v}{R_{v}+R_{mes}}
\]  

(1)

It is known that conductivity of an object is in reverse proportion to resistance and, thus, proportional to the output voltage in our measurements. So the described experimental setup allowed us to compare and analyze the conductivity of the samples.
3. Experimental Results

Experimental results on studies of conductivity of albumin solution during dehydration were obtained. Distilled water was measured as a control sample. Fig. 3 – 5 illustrate the transfer characteristic of distilled water, water albumin solution pH = 4.8 and pH = 9.3.

![Figure 3](image-url)

**Figure 3.** Dependence of voltage on time in distilled water.

Also a study of conductivity of albumin was performed on pure albumin samples (pH = 9.3) and on native albumin samples (pH = 4.8).

![Figure 4](image-url)

**Figure 4.** Dependence of voltage on time in pure albumin solution with pH = 9.3.
Fig. 3 – 5 show that the voltage on protein solution exceeds the voltage on distilled water at about 3 times. However, the voltage measured on samples of albumin in isoelectric point (pH = 4.8) is higher than voltage on pure albumin (pH = 9.3). This effect may be caused by differences in electric resistances of the samples of albumin at different acidity.

Conductivity of solutions under the influence of external magnetic filed has been studied. Experimental results are presented in Figures 6, 7.

**Figure 5.** Dependence of voltage on time in water albumin solution with pH = 4.8.

**Figure 6.** Dependence of voltage on time in water albumin solution with pH = 4.8 at external magnetic field 3 Oe, co-directional with the drying front of the sample.
Fig. 6, 7 show, that external magnetic field affects on electrical response of protein solution. The voltage in the interelectrode gap for albumin solution (pH = 4.8) in external magnetic field which was applied in direction “up” exceeds the voltage for albumin solution in external magnetic field which was applied in direction “down”. This effect may be caused by conformation of molecules. In our opinion, a change of biomolecules conformation occurs under an external magnetic field. But a character of this effect has not been established. This is task for further research.

4. Conclusion
In our studies, the experimental results on conductivity of albumin protein films and solutions in external magnetic fields and without it, were obtained. It was shown that the amplitude of output signal is higher in protein solution in comparison with distilled water. We revealed that such electrical properties as conductivity of the protein film is significantly influenced by the value of intensity of magnetic field. And amplitude of the output signal depends on the direction of the applied magnetic field. It was shown, that biological systems are sensitive to weak external influences and can be controlled by them. The experimental results obtained in this work allowed us to conclude that solutions of proteins have nonlinear magnetic properties.

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