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Short Communication

Microelectromechanical Systems of the Impulse Betavoltaics Element for Electric Power of Biosensors

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In the paper we carry out the calculation mechanical properties and intracellular pressure of erythrocytes by finite element method and comparison of these data to the experimental data obtained using atomic force microscopy. The paper proposes a model of the erythrocyte representing the erythrocyte as a homogeneous elastic body with the elasticity depending on the distance to the center of the erythrocyte. The model is based on data from atomic force microscopy obtained by various authors, in particular the data on rigidity of the membrane, which depends on the position of the measuring point on the surface. The good agreement between calculated and experimental data confirms the consistency of the model and allows us to conclude that the morphology of the erythrocyte is largely determined by the elastic properties of the membrane and intercellular pressure.

Keywords: Betavoltaics, Pulsed current source, Micro-electromechanical system, The accumulation of charge, Biosensor.

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1. INTRODUCTION

The miniaturization of semiconductor circuits and the development of microelectromechanical systems have led to a decrease in energy consumption. Now the most economical industrial semiconductor chips consume about 1-10 nA in standby mode. Recent work on the study betavoltaics effect on the an isotope of nickel-63 has been achieved in the generation currents of tens and hundreds of nA that close enough for commercial applications [1-4]. The activity of nickel-63 is 1-40 mCi/cm^2, the half-life of 100.1 years is that for 30-50 years provides performance electronic circuits betavoltaics. The most common are the sources of the activity of 10 mCi/cm^2, which is integrating the spectrum of energy, you can get that dissipated power is about 1 μW. Energy conversion efficiency of beta decay is currently high enough and does not exceed 0.3 % [5, 6]. Low efficiency is related to several factors: the inelastic scattering of beta particles, absorption of beta particles in layers, where there is no generation of electron-hole pairs, the recombination of charge carriers, etc. [7, 8]. Assuming that all of the generated electron-hole pairs are separated by the field of the *p-n* junction and contribute to the current and EMF voltage is about 0.35 V, we can find that the theoretical limit of efficiency for silicon structures does not exceed 10-15 %.

In the medical industry, many efforts are focused on the miniaturization of medical devices and implants. At present, this trend is gaining momentum, so that the range of the devices is reduced from cubic centimeter to cubic millimeter. With decreasing scale medical devices acquire a large potential to reduce healthcare costs and mitigation of invasive implantation operations, while simultaneously improving support and reducing post-operative recovery period [9, 10].

Topical is the search for methods of miniaturization of devices and of biosensors pacemaker, which should be small enough to be implanted directly into the right ventricle of the patient's heart. The process of reducing the size of pacemakers and other medical devices is limited essentially by the size of power sources. Batteries for pacemakers usually occupy 80 % of device volume. An understanding of this problem has led to what is now the trend search further significant reduction of medical devices is due to the limited size of power supplies.

The recently developed implantable millimeter-sized device, which measures the intraocular pressure in glaucoma [9]. Such miniature CMOS device comprises a microcontroller, containing a radio transmitter and sensor board. Power consumption during sleep cycles in the tens and hundreds of picowatt, but at the time of signal transmission with the results of measurement of power consumption at the peak of microwatts [9, 10]. Miniaturization of the device allows its implanted directly into the patient's eye, thus there is a measuring / recording the intraocular pressure throughout the day and radio broadcast the processed data at regular intervals to the external device.

As a result for electric power of biosensors and miniaturized medical devices betavoltaics elements can be used, but due to the length of alert time it arises the problem of storing electrical energy and use it for short-term survey and transmission of information over a distance that is the aim of the present work.

2. MEMS OF IMPULSE BETAVOLTAICS ELEMENT FOR BIOSENSORS

As the circuit diagram of such a planar structure we can offer the following (Fig. 1). The betavoltaics elements are connected in series, and at the entrance there

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is a pulsed source of high voltage while charging a capacitor with low leakage currents. While the capacitor is not charged the voltage is less than the threshold on it.

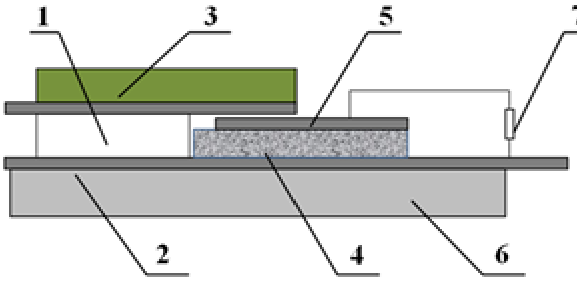

Fig. 1 – Microelectromechanical system with a contact on the reverse piezoelectric effect:
1 – dielectric with inverse piezoelectric effect,
2 – contact "land"
3 – the ceramic with coated bottom of input terminal,
4 – isolating the solid support,
5 – contact platform with a "small" gap between the input terminal,
6 – silicon substrate,
7 – Load Resistance

All voltage of betavoltaics element drops across the resistance through which charging current flows. Since the capacity of the pulsed source is high enough, the charge occurs during the period of interrogation and transmitting a signal.

When reaching the threshold's voltage MEMS is triggered with the terminal on the reverse piezoelectric effect. This creates a situation of short circuit and the output pulse is generated, provided that the load resistance is sufficiently small. Once the capacitor's charge flows down through the load resistance, the voltage drops and MEMS opens contact.

To the left MEMS connected in parallel to the capacitor. On the right there is load resistance, through which it occurs the discharge. The gap between the contacts corresponds to the reverse piezoelectric effect. The principle of MEMS operation can be described as follows. When reaching the threshold voltage the contacts are closed due to the inverse piezoelectric effect (Fig. 1), there is short circuit, which formed the beginning of the electrical impulse through the load resistance. At the piezoelectric the voltage falls below the threshold, but there are the capillary forces between contacts, which keep contact for a short time, while piezoelectric will do not break it. In the process of reducing the voltage across the piezoelectric force tending to break the contact increases, while the capillary forces remain constant. After a certain period of time there is a break contact and charge accumulation resumes. Thus, the system periodically charged and discharged.

Obviously, during the charge – discharge process involved not only electric forces but also the capillary forces, which form an electrical pulse duration. Over exploitation time the surface may fail due to oxidation or exposure to the atmosphere as a result the capillary forces will change, and the pulse duration will change, too. To prevent such situation we need the entire micro electromechanical system to place in a vacuum environment or in an inert gas environment, which would provide stable conditions and to prevent surface oxidation.

The development of systems that would be integrated pulse betavoltaics and microbatteries, for example, based on technology LiPON [11], are highly important issue for modern medicine. The proposed MEMS scheme for pulse charging of the microbattery allows you to create devices with time operation for over 20-30 years.

3. CONCLUSION

We propose a MEMS scheme for impulse charging of microbatteries based betavoltaics element with the source of nickel-63, which allows to accumulate charge under generating current in the *p-n* junction in a thin film capacitor. The developed technologies of micro batteries with low leakage currents allow to accumulate energy in the solid-state batteries by feeding from the pulsed elements of betavoltaics. Thus, to create a breakthrough technology in implantable medical devices, we need to combine several techniques: solid state chemical batteries, betavoltaics elements, as well as the charging system of capacitor and its impulse discharge to restore the charge in the battery. Such a system would be nonvolatile and it will allow miniature devices to receive data and transmit them at a distance for a long period of time.

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