JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 9, No. 8, August 2007, p. 2589 - 2592

A test biodevice with lipophylic and hidrophylic bioliquids

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This paper is starting from a generalization of the SOI "Silicon On Insulator" concept. In a previous paper was mentioned that the meaning must be extended today rather to "Semiconductors On Insulators". Others materials than silicon like diamond, silicon carbide, quartz, placed onto an insulator gave special electrical properties. Placing a drop of Bioliquid On Insulator and contacting him with two electrodes results a test device for the non-linear electrical conduction through two types of solutions. Some experimental curves provide information about the non-linear electrical conduction through these hormonal solutions.

(Received January 7, 2007; accepted July 11, 2007

Keywords: Bioliquids, SOI, Biomaterials

1. Introduction

This paper extends the meaning of Silicon On Insulator concept toward biomedical application. In a previous paper was mentioned that the meaning must be extended today at "Semiconductors On Insulators", [1, 2]. Among "others materials" than silicon placed on an insulator, are the organic semiconductors and electrolytes.

Now some Biomaterials, like lipophylic hormones (a testosterone propionate) and a hidrophylic neurohormone (epinephrine) are tested. The biomaterials are placed on a plexiglass support and provided the Biomaterials On Insulators structures.

The oily testosterone propionate solution from pharmaceutical usage belong to the lipophylic hormon class. In the human body this kind of steroid has nuclear receptors. The physic explanation comes from the hidrophobic property of steroids molecules that penetrate the cellular lipidic membrane, [3]. The electrical conduction was investigated in paralel with another lipophylic biosubstance – α-tocopherol – for comparison.

Epinephrine (the greek name) or adrenaline (the latin name), $C_9H_{13}NO_3$ being a neurohormone, catecholamine type, is released into the bloodstream as response to a physical or mental stress. Electrical properties of the epinephrine experimentally demonstrated a high resistivity among naturals electrolytes, [4]. This is intuitive correctly because the nature selected this substance for the nervous impulse transmission in synapses. The non-linear dependence current-overvoltage in the test device investigated for comparison two types of aqueous solutions: epinephrine and physiologic serum, both from pharmaceutical usage.

These kinds of bio-liquids could be possible candidates for organic semiconductors, if they present non-linear electrical conduction. In this case, some new applications versus p-n junctions, could be offered by these bio-devices, like: n-logic functions, memory function, oscillators, molecular power supply.

2. The experimental set-up

Fig. 1 briefly present the device set-up that comprise two gold electrodes that allow some polarography experiments. An ampoule of α-tocopherol is placed between electrodes, performing a Bioliquid On Insulator device architecture with two electrodes. Its dual device in Silicon is the pseudo-MOS transistor with points contact, [5].

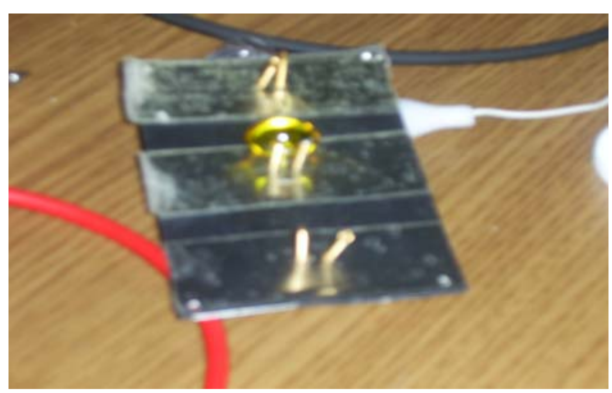


Fig.1. A drop of α-tocopherol placed on a plexiglass support between Au electrodes.

Fig. 2 present the electrical circuit used for the current-overvoltage I-U characteristics measurements. All lypophilic substances gave a similar and reproductible curve. In turn, the aquous neurotransmitter solution (epinephrine hcl, 1mg/1ml) provides unstable characteristics, despite of the non-reactive electrodes composed by Au. Additionally, the neurotransmitter solution present hysteresys, that proves the memory property of this kind of biomaterial, while the oily testosterone propionate solution didn't presents hysteresis not at all; hence the last material doesn't remind the trace of the voltage (increasing or decreasing).

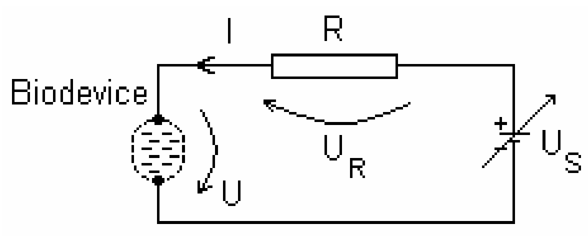


Fig. 2. The experimental circuit.

The biodevices, in series with a high value resistance, R=110kΩ…1,7MΩ was connected to a DC power supply Hameg HM 8012. The current, I, was extracted in a classical manner: by measuring the U_S, U_R voltages with a Hameg HM 8001-2 milivoltmeter. The current value results from the Ohm's law: I= U_R/R and the potential drop over the biodevice is: U=U_S-U_R.

The power supply voltage, U_S, is the single independent parameter that varied in the range 0÷21V, firstly increasing and secondly decreasing back to 0V. Either part of the trace represents the polarographic curve. On the other hand, both I-U curves, with U_S increasing and with U_S decreasing, represent the first cycle for a cyclic voltammetry. From electrically point of view a higher hysteresis provided by the first cycle, proves a better memory property of the respective material.

3. The measured curves for epinephrine biodevice

For comparison the bioliquids were: epinephrine solution 5,46×10^{-3}M and physiological serum having a NaCl concentration about 17,1·10^{-3}M. Comparatively to the classical polarography, the biodevice works with fewer molecules (e.g.10^{16}÷10^{18}analyt molecules/drop).

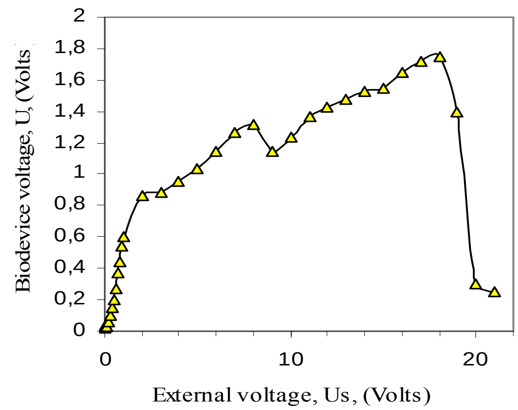


Fig. 3. The fluctuation of the biodevice overvoltage on the power supply bias, in adrenaline case.

The potential drop over the biodevice, usually named overvoltage in electrochemistry, U, depends on the U_S voltage as is shown in Fig. 3. The aqueous solution electrochemically releases new electric charge, in accordance with the epinephrine oxidation, [4].

The polarographic I-U curves measured for epinephrine solution and NaCl (physiological serum), placed between two Au contacts, are available in Fig. 4. The variation rate for U_S was from 0V to 100mV with 10mV/ 5sec, from 100mV to 1V with 0.1V/5sec, from 1V to 14V with 1V/5sec. The I-U curves present negative differential resistance region only for epinephrine.

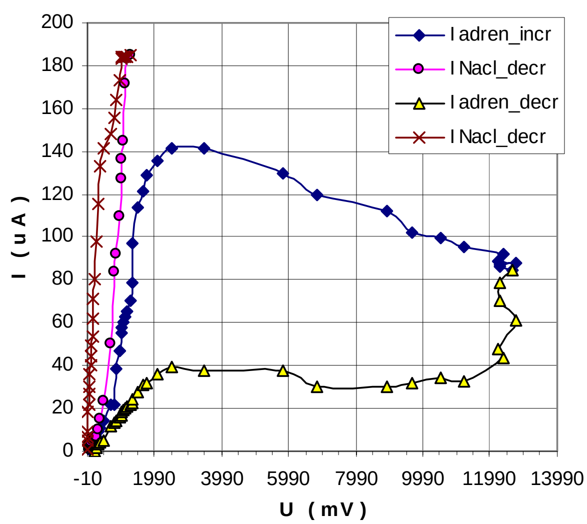


Fig. 4. The hysteresis presented by the epinephrine / NaCl aqueous solutions.

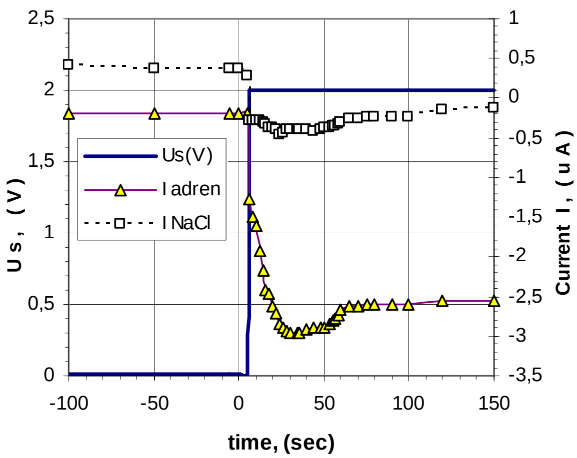


Fig.5. The biodevice behavior in switch regime.

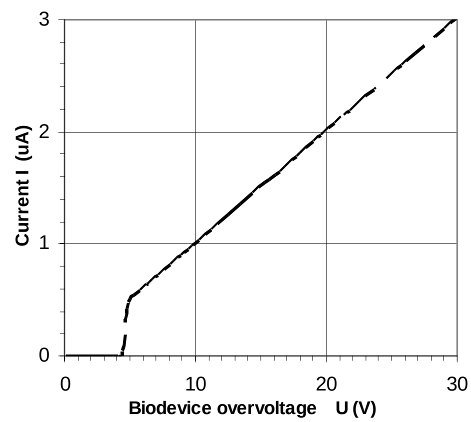
The explanation must be searched in the fluctuation of charges exchanges during the switch regime. A detail regarding the monitorised current versus time, during a switch of the power supply voltage from 0V to +2V, looks like Fig. 5. If the NaCl solution suffered a relatively sharp falling-down and then tends to rest roughly constant, the adrenaline solution has an attipically behaviour. After a high reduction of the current, a decreasing shape with a minimum follows (at t=32sec in Fig. 5) and then an increasing function with a tendence of saturation for t>70sec in Fig. 5.

4. The measured curves for steroid biodevice

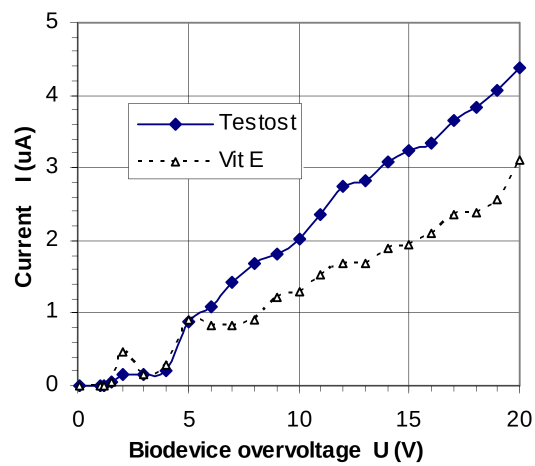
For comparison the bioliquids were: a lipophylic hormone – testosterone propionate (oily solution, The steroid hormone solution presents a completely different I-U curve, without hysteresis, fig.6.a. However, its electrical conduction presents a resistor like behavior at high overvoltages (>4,5 V) and an insulator like behavior at low overvoltages (<4,5 V). Therefore the testosterone biosolution stands for a potential candidate to the controlled resistors.

The DC power supply raised the U_S voltage over 30V in order to catch some possible news deviations. They didn't occur.

What is interesting is that the oily solutions perform very stable I-U curves, with a reproducible shape. This assertion is proved by the results from Fig. 6.b, where the electrical characteristics I-U of a α-tocopherol was raised, but on steel electrodes. However the main shape is preserving. Especially from Fig. 6.a can be observed a threshold voltage,



(a)



(b)

Fig. 6. The electrical characteristics in (a) a lipophylic oily testosterone solution; (b) for oily α-tocopherol (E Vitamin). concentration 25mg/1ml) and oily solution of α-tocopherol (E vitamin oily formula) from pharmaceutical usage.

V_T = +4,5V, that allow the current flow through the biodevice. This oily Bioliquids provided the non-linear characteristics, very close to an ideal pn semiconductor junction. In fig.6.a can be observed I=0 for $U<V_T$ and I increases linearly with U for $U>V_T$. This device would produce the best monoalternance rectifier, without any distortions. On the other hand a logic application would be possible with this device. In series with a load resistance, having the input signal as U_S (see Fig. 2) and output signal as U. When U_S = "high" voltage > V_T on input, then I = high due to $U>V_T$, U_R=high, yield $U=U_S-U_R$ = "low" voltage = 0-logic. When U_S decreases under V_T the current becomes 0 and $U \approx U_S$=high. Hence, an invertors function is fulfilled.

5. Differential resistance extraction

For epinephrine solution can be extracted from the polarographic curves measured in fig.4, the trace "I adren incr", the range of variation for the dynamic resistance: starting from R_{diff} = 12MΩ for U<1,99V, passing through a saturation region with $R_{diff}\rightarrow 0$ for 2V<U<6V, with slow variations till 11V, the differential resistance becomes negative with high fluctuations (e.g. R_{diff} =-40MΩ or R_{diff} =+149MΩ) for U>11,9V. The cause must be searched in the kinetics of the epinephrine redox reaction.

For the testosterone propionate oily solution, there are two distinct zones: I^{-st} zone corresponding to $U<V_T$ where R_{diff}=0 and II^{-nd} zone corresponding to $U>V_T$ where R_{diff}=11MΩ=very constant.

Consequently, these biodevices with a high variation of the differential resistance can be grouped into a special class of the non-linear components.

6. Conclusion

The non – linear conduction through aqueous bioliquids like epinephrine and physiological serum solutions reveals I – U curves with a negative differential resistance. The hysteresis is more obvious for neurotransmitter solution then for NaCl solutions, as is expected, proving in this way the "memory" property of this biomaterial.

The oily Bioliquids On Insulator devices produced I-U curves very close to an ideal diode. Furthermore, the characteristics are very reproducible and haven't any hysteresis. In this case, the most recommended applications in electronics could be signal rectifier and possible two-states logic applications: under the threshold voltage V_T is the blocking state and over V_T is the conduction state.

In the industry fields these studies offer alternative candidats for memory substrate or non-linear characteristics alike to the semiconductor diodes.

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