ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Electrical Study of an Integrated Biomedical Microsensor

Rezki M[1,3*], Belaidi A[2], Benabdallah T[1], and Ayad M[3]

[1] Researcher; Industrial Product and Systems Innovation Laboratory, E.N.P.O (Ex E.N.S.E.T.), University of Oran, 31000, Algeria.
[2] Full Professor; Department of electronic, E.N.P.O (Ex. E.N.S.E.T.), University of Oran, 31000, Algeria.
[3]Assistant Master; Department of technical's sciences, University of Bouira, 10000, Algeria.

ABSTRACT

The silicon-based devices are still in prime position, and are constantly evolving especially in the field of microelectronics and have even touched multidisciplinary fields, Such as bioelectronics and medical electronics (environmental, pharmaceuticals, medical diagnosis). The detection of chemical species present in biological fluids or even in the environment is delicate and often expensive. That's why an alternative was found of designing devices with equivalent reliability, simplicity, speed, selectivity and significant replication to minimize the cost. Among them: microsystems and biosensors. Our study focuses on the development of a numerical characterization to optimize a biomedical sensor such as ion sensitive biosensor, DNA and chemicals for its integration into an embedded system (medical probe, smart card). This is done by using the capacitance measurements technique, so a functional analysis. The biosensor used is a MISFET whose gate is suspended bridge.
Keywords: Biomedical microsensor; MISFET; gap; C (V); blood.

**Corresponding author*

INTRODUCTION

Since the invention of the first biosensor in 1967 which is an enzyme sensor by Updike and Hicks [1]. The technology has evolved with the development of other technologies like bio impedance that exploits dielectric properties of cells and the electromagnetic properties of biological tissues, the techniques of organic electronics using measurements of pH and electrical resistivity of physiological liquid. But the technique most interesting for us is the use of capacitance measurements to detect ions H +, Na + and K + as well as the chemical species. At this moment, we recall that there are three major families of biosensors:

i. The enzymatic sensors.
ii. The immune sensors.
iii. The DNA sensors or microarrays.

The biosensor is composed of a receptor or bioreceptor which is a chemical element, its role is to recognize molecules and a transducer which is a physical element for converting the physico-chemical interactions in most often an electric signal to exploit.

MATERIALS AND METHODS

Classes of transducers (electrodes)

They can be classified into 4 groups:

1. Metal electrodes: as gold and platinum. These electrodes transmit the collision effect of electroactive substance (i.e., enzymes).

2. Semiconductor electrodes: They are the basis of the structures EIS, ENFET, CHEMFET, ISFET, TFT, MISFET and others.

3. Temperature sensitive electrodes (diodes, bipolar transistors): This technique exploits Seebeck effect so the effect detected is the change of temperature.

4. Pressure sensitive electrodes (piezoelectric crystal, piezotransistor, piezoresistor): The effect detected is the change in pressure.

Transducer used

It's an MISFET (Metal- Insulator- Semiconductor- Field- Effect-Transistor) and its structure is the following:

ISSN: 0975-8585

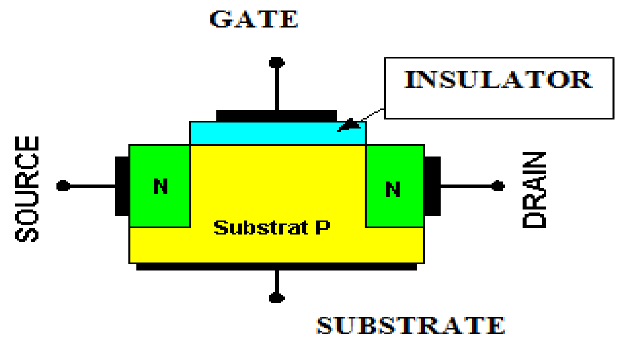

Figure 1 : Structure of the Used Transducer [2].

The insulator is a sandwich of layers (see below) and the method consists of studying the electrical characteristic gate- source.

RESULTS AND DISCUSSION

Study of the Insulation Capacity According to the Relative Permittivity of the gap:

The total capacitance is an MIS –metal insulator semiconductor - capacitance; the insulator used is an insulating compound of SiO2-Si3N4-gap-Si3N4. At the beginning, the gap is the air; than the air is substituted by a chemical substance (blood). We have used the Si3N4 in order to detect the H^+ charges. For example, if you want to detect the charge K^+ we can use glass in place of Si3N4.

The first characteristic studied is the insulation capacity according to the permittivity of the gap regardless of the substance used.

We see that plus the permittivity of the gap is bigger plus we tend to the saturation regime.

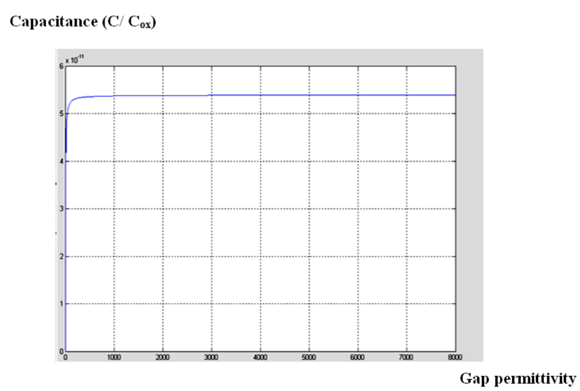

Figure 2 : The Capacitance of Oxide According the Gap Permittivity.

According to Figure 1 and the above table we see the interest of the study at high frequencies. We have the following table with human blood taken for gap as an example (Table 1).

Table 1: Variation of the Blood Relative Permittivity Depending on Frequency [3].

Frequency [Hz]	Conductivity [S/m]	Relative permittivity
10	0.7	5260
1000	0.7	5258.6
10000	0.70004	5248.2
100000	0.70292	5120
1000000	0.82211	3026.3
100000000	1.233	76.818
1584900000	1.9022	59.766
10000000000	13.131	45.109
63096000000	55.68	11.765
100000000000	63.364	8.2988

Curve C (V) with Metal Electrode:

The frequency used is 1 MHz; the metal electrode selected is gold. With this type of electrode we can detect cholesterol, D-lactate, glutamate and hydrogen peroxide H_2O_2 [4] [5] [6].

The electrolyte is the blood whose relative permittivity is 3026.3 [3]. The relation giving the voltage of the flat strip is [7]:

$$\Delta V_{FB} = -(W_s)_{ref} + \Delta\psi_0 + (W_s)_{sc} \qquad (1)$$

Where $W_{s\ ref}$: the work function of gold electrode (gold). W sc: work function of the semiconductor. ψ0: the potential in the electrolyte "potential surface".

If we know the displacement of the flat strip ΔV_{FB}, we determine the change in potential of the surface $\Delta\psi_0$ and consequently the variation in the concentration so the type of substance selected (ΔCs). With several measures, we can group them in the form of charts, for example, to determine the different species.

With the same parameters and if we take a gap constitued of electrolyte –normal blood- we have the curve below.

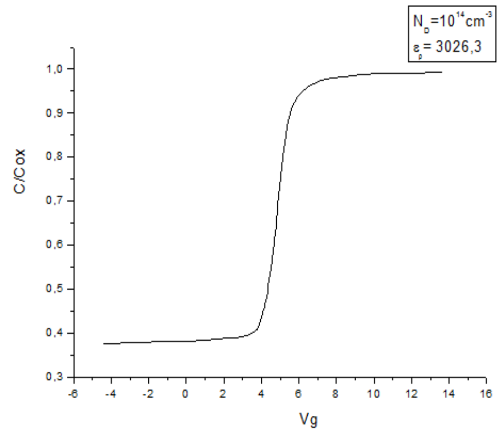

Figure No. 3: Total Capacitance of the Structure with Blood in Place of Airgap.

The semiconctor used is an "N" doped silicon (doping concentration is $N_D= 10^{14}$ cm^{-3}). The introduction of blood into the gap caused the displacement of the characteristic C (V) to positive potentials. This is due to the increase in the relative permittivity. In reality the physic-chemical reactions on the surface of Si3N4 and the absorption of charges can intervene and divert even more moving the capacitive characteristic.

We can explain this phenomenon by the following theoretical model:

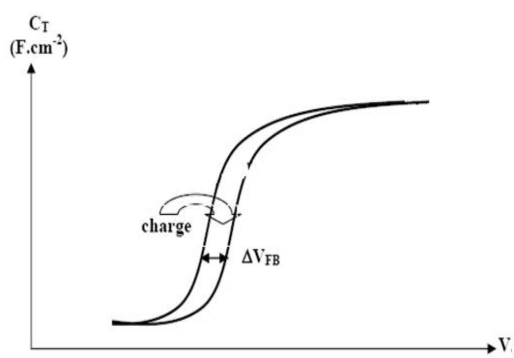

Figure No. 4: Effect of the Absorption of Charges on the Intoerface [7].

This shift may be positive as it can be negative depending on the type of charges.

CONCUSION

Our work is just beginning but already it can tell us from now on the importance of embedded systems with microelectronic components especially in medicine and biotechnology. At that moment the search continues in this line with a basic difficulty grafting or immobilization of chemical species. On this side there is much to do.

ISSN: 0975-8585

REFERENCES

[1] S J Updicke, G Hicks. Nature 1967;214:986.

[2] Website: http://www.polytech-lille.fr/cours-atome-circuit-integre/unip/unip811.htm. (Modified to explanation).

[3] Italian National Research Council. Institute for Applied Physics "Nello Carrara" - Florence (Italy).

[4] S Brahim, D Narinesingh, A Guiseppi-Elie. Analytica Chimica Acta 2001; 448: 27.

[5] AM Gue, H Tap, P Gros, Sensors and Actuators 2000; 68:123-127

[6] E Zilkha, T P Obrenovitch, A Koshy, H Kusakabe, HP Bennetto. Journal of Neuroscience Methods 1995; 60: 1-9.

[7] Houcine Berhoumi ; doctoral Thesis “Elaboration caractérisations de nouvelles membranes enzymatiques pour application « biocapteur » en hémodiazlyse rénale“ 2006; 40- 46.