

# A Survey approach: Device for Biosensing Application

Shradhya Singh<sup>1</sup>, Krishnakant Chaubey<sup>2</sup>, Nandini Kumari<sup>3</sup>

<sup>1,2</sup>Assistant Professor, Dept of Electrical and Electronics Engineering

<sup>3</sup>Assistant Professor, Dept of Civil Engineering

<sup>1,2,3</sup>Lok Nayak Jai Prakash Institute of Technology, Chapra, Bihar

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**Abstract** - Field-effect transistors have emerged in the field of biosensors over the last few years, due to their attractive simplicity and high sensitivity to interfacial changes, both on the gate and Si body interface, where a target-specific bio receptor can be immobilized, which can be treated as a cavity. This article reviews the recent literature concerning biosensing with such type of field effect transistors, gives clues to understanding the basic principles under which field-effect transistors work, and details the transduction mechanisms that were investigated to convert a receptor/target association into a change in threshold voltage, which is treated as biosensing metric.

**Key Words:** Junctionless, biomolecules, dielectric modulation

## 1. INTRODUCTION

Biosensor has been defined by the International Union of Pure and Applied Chemistry (IUPAC), is that “a device which uses specific biochemical reactions mediated by isolated enzymes, immune systems, tissues, organelles or whole cells to detect chemical or biological compounds, usually by use of electrical, thermal or optical signals” [1,2]. Biosensors are capable analytical tools for monitoring food toxins and pathogens, and environmental screening due to their unique characteristics of affordability, portability, disposability, and simple construction [3].

Biosensors are not able to just sense basic parameters such as humidity or pH, but also numerous types of non-biological compounds such as heavy metals or small organic pollutant molecules such as bisphenol A. However till now biosensors are not spread out in the market So transistor can be a great alternative to interface the biomolecule with it for sensing application.

Nowadays, the most popular transistor used is the field-effect transistor (FET) [4], past research study shows that field-effect transistors have been highly appreciated for biosensing applications, because of their nano level scaling make the sensing device portable and also because the field effect is capacitance-related, and this capacitance shows high sensitivity towards surface changes, as it effects the overall characteristic of the transistor.

It is very difficult to create ultra sharp doping profile between source/drain (S/D) regions with body region at nanoscale level. Several novel MOSFET designs have been developed to defeat the fabrication issue. Colinge et. al. [5]

[6], reported Junction Less Transistor, having lower Drain Induced Barrier Lowering and enhanced on-state and transfer characteristics than that of the usual MOSFETs [7], [8].

Therefore, junctionless transistors are widely used for biosensing application.

## 2. Biosensors with FETs

The use of the concept of dielectric modulation of a vertical nanogap in the FET’s gate due to the presence of biomolecules has enabled the application of FET biosensors for detecting the presence of charge-free biomolecules as well [9-10].

The reported dielectric-modulated FET (DMFET) based biosensors show high responsiveness to both dielectric modulation and charge of the biomolecules, with the two effects often affecting the device parameters in opposite directions leading to reduced sensitivity [11].

The proposed structure demonstrates high sensitivity for biomolecule detection and retains dielectric-modulation as the dominant effect, as opposed to the conventional DMFETs where the impact of biomolecule charges on the device sensitivity is significant. The proposed sensor device shows good scalability across process technology nodes and can be an exciting alternative to FET biosensors for both advanced technology nodes as well as the older technology nodes where low-cost is the driving factor.

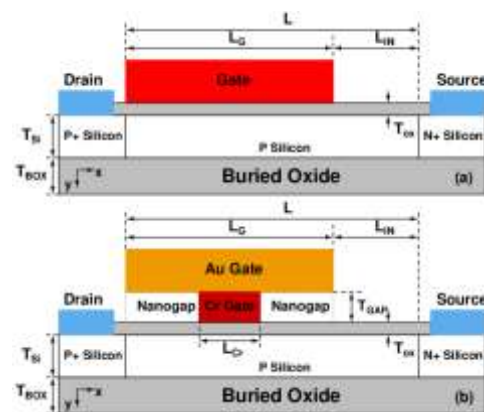


Fig.1 cross sectional view of device of reference paper [12]

In this series, one more device has been introduced that is Dielectric Modulated junctionless Double Gate MOSFET based biosensors. This junctionless MOSFET structure detects target biomolecules that are confined in the nanogap cavity according to changes in electrical parameters, such as the threshold voltage. A shift in the threshold voltage has been used as the biomolecules sensing parameter [13]. Nanogap cavity is formed by etching some part of the gate

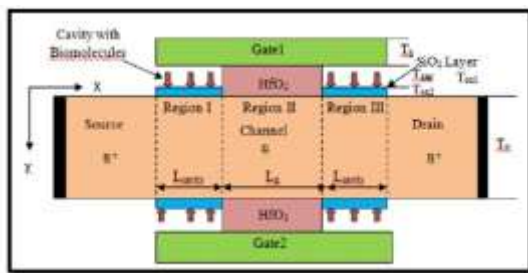


Fig.2 cross sectional view of device of reference paper [14]

The proposed DM-DG-junctionless MOSFET shows the good sensitivity for the shorter channel length. For the charged biomolecules, it shows the greater change in the surface potential, energy bands, and electric field for negatively charged biomolecules as compare to the positively charged biomolecules. It has been observed that for negatively charged biomolecules n-type DM-DG-junctionless MOSFET shows greater change as compared to the positively charged biomolecules. Therefore, it can be concluded that n-type device is suitable for detection of negatively charged and p-type device suitable for detection of positively charged biomolecules.

In a typical FET device, electric current flows between the source and drain electrodes when the voltage applied to the gate exceeds a threshold voltage ( $V_T$ ).  $V_T$  depends on the gate capacitance, and hence we can modulate  $V_T$  by changing the dielectric material of the gate. When the chromium layer is etched to form an air gap, the dielectric constant of the gate and the total gate capacitance are decreased. As a result,  $V_T$  for the transistor shifts to a more positive value. In contrast, when biomolecules are introduced into the nanogap, they increase the gate capacitance relative to the air gap, and  $V_T$  shifts in the negative direction. Thus, by monitoring the change in  $V_T$ , it is possible to detect the specific binding of streptavidin to biotin.

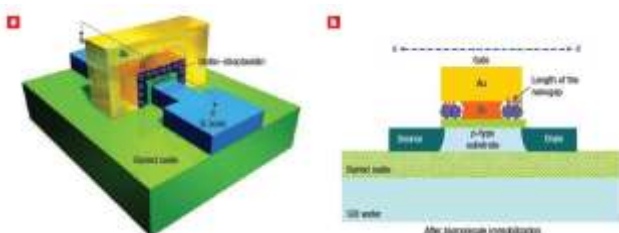


Fig.3 cross sectional view of device of reference paper [15]

In summary, they have demonstrated a dielectric-modulated field-effect transistor coupled with a 15-nm vertical nanogap that detects the binding of streptavidin to biotin using an all electrical, CMOS-compatible technique, without the need for a labelling process. The proposed device shows much better sensitivity than several previously reported FET nanogap biosensors for detecting biomolecules, especially protein-ligand binding. Furthermore, by measuring data after breaking the biotin-streptavidin binding and from control group experiments, we verified that biotin-streptavidin binding is the dominant factor in determining the shift in the threshold voltage. In addition, it is expected that such DMFET-type biosensors will have the capability to detect a number of protein molecules, such as DNA, cancer markers and antibodies, and could be used as a part of a lab-on-a-chip for full electronic detection.

Mostly all the devices consider threshold voltage as biosensing metric as the biomolecules immobilized in the cavity shifts the threshold voltage as shown in the graph

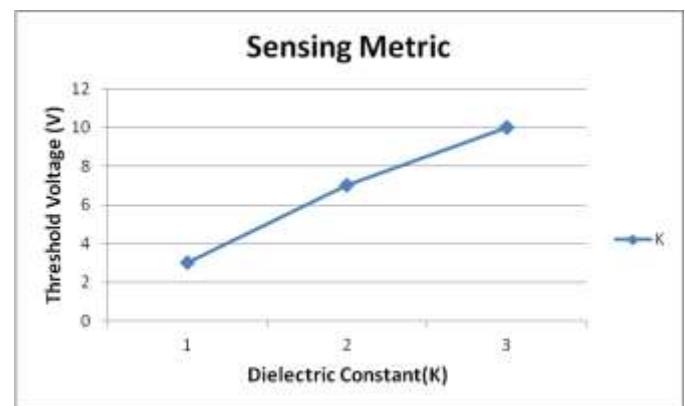


Fig.4. Threshold Vs Dielectric constant

This graph shows the shift in threshold voltage as dielectric constant increases of the biomolecule immobilized in the cavity which can be said that detection of biomolecule.

### 3. CONCLUSIONS

In this review, we presented recent advances in field effect transistor for biosensing application, which is rely on the accumulation of charges at the gate/dielectric and dielectric/semiconductor interfaces. The detection principles based on threshold voltage shift induced by the biological recognition between probe and target molecules. The electrolyte, which replaces the classical dielectric in FET, fits well with biological processes (which generally take place in water). There is still a lot of work to do to improve performances of the devices for biosensing. The most challenging is certainly the stability of the semiconductors in water or neutral buffers, the immobilization of the bio probes whether onto the gate or the semiconductor surface, and a better understanding of the operating principles for the design of more efficient transduction architectures. Concerning OSC, only few were used until now (streptavidin = 2.1, protein = 2.50, biotin = 2.63, and APTES = 3.57) and

many others deserve to be investigated. Concerning immobilization, different methods were used to immobilize the biological probes on the sensing parts of device, whether by covalent or non-covalent methods. Covalent bindings look to be more efficient on the gate, whereas non-covalent immobilizations are more convenient on the semiconductors because it avoids tedious chemical derivatization.

However, an opposite way of thinking, inspired from competitive immunoassays, is also a promising approach, worth trying. At last, nanostructuring of gates or semiconductors should be investigated.

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