# PERFORMANCE ANALYSIS OF BIOSENSOR FOR CANCER DETECTION

[1]Bhenesha Shree R P, [2]Shanmugaraja P, [3]Kavitha K
[1]Research Scholar, [2]Associate Professor, [3]Research Scholar
[13]Department of ECE, Annamalai University, Annamalainagar,608 002, Tamilnadu, India
[2]Department of E&I, Annamalai University, Annamalainagar,608 002, Tamilnadu, India

***Abstract :*** In this paper, Mathematical models of Nanodevices are reviewed to describe the functionality of the biosensors. The Biosensor lab tool is used to analyze the performance metrics of the Planar, Cylindrical Nanowire and Nanosphere biosensors. The performance metrics such as Settling time, Selectivity and Sensitivity are useful in obtaining the transient response with respect to the analyte concentration. Sensitivity plays an important role in detecting cancer with high accuracy.

***Index Terms*** **–Settling Time, Biosensor, Sensitivity, Analyte, Nanowire, ISFET**

## I. INTRODUCTION

Cancer diagnosis and treatment are becoming an area of great interest due to its widespread occurrence and high mortality rate. Existing screening tests are less powerful when it comes to detect cancer at an very early stage. Hence there is an need for specific and reliable technology to detect cancer. Nanotechnology plays a vital role in the disease diagnosis and different Nanomaterials have been utilized to detect cancer at early stages. The hypothesis is based on the self consistent solution of diffusion capture model and Poisson Boltzmann equation that illustrates the magnitude of screening limited kinetic reaction of Nano biosensors. Section II discusses the structure of biosensors. Section III discusses the diffusion capture model that is used for modeling nanosensors, section IV presents the experimental setup for simulation and design of biosensors[1].

## II. STRUCTURE OF THE SENSOR

Sensors consist of source and drain regions placed above the gate. Gate consists of the receptors that capture the unknown molecules diffusing across the target molecules.

Current flows between source and drain .The molecules that are bound to the sensor determines the source-drain current. The sensitivity of such sensor is found to be between molar and few micro molar ($10^{-6}$M). Thus for any disease detection, sensors should have higher sensitivity.

To improve the sensitivity of a sensor for bio applications, CNT[2] was introduced. The sensitivity of the CNT sensors when compared with nanosensor[3] was increased by several orders of magnitude (femto molar). In order to further improve sensitivity, nanodots[4] are used. Fig [1], [2], [3] below shows the different types of biosensors.

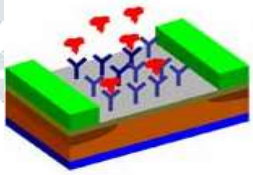

Fig 1 Planar Biosensor

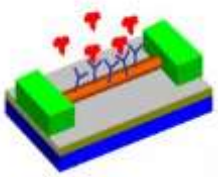

Fig 2 Cylindrical Nanowire Sensor

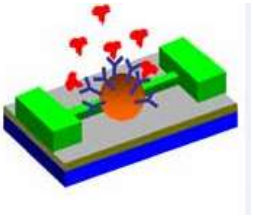

Fig 3 Nanodot sensor

## III. DIFFUSION CAPTURE MODEL

There are two equations that explain the diffusion-capture[5] activity in the Nanobiosensor. The capture equation is defined as

$$dN/dt = [(N_0 - N)_s - k_R N] \qquad (1)$$

Where,
N is the number of conjugated molecule
N0 is the initial number of molecules

The number of conjugated molecule (N) is proportional to number of unconjugated molecules and is determined by ($N_0$-N), where $k_F$ is reaction constant. The second term $k_R$N represents the number of deconjugated molecules and $k_R$ is reverse reaction constant. Deconjugation is very weak in Nanobiosensors, and hence the diffusion equation can be approximated to the equation as

$$dN/dt = k_F N_0 \rho_s \qquad (2)$$

Where,
$\rho_s$ is the surface concentration of the captured molecules.
As the molecules present in the electrolyte diffuse across the receptors, the diffusion equation is given as

$$d\rho/dt = D\nabla^2\rho \qquad (3)$$

Where D is the diffusion coefficient and $\rho$ is the concentration of molecules.

The number of molecules captured[6] are defined as

$$N(t) = \rho_0 t\,[A/C_0 + 1/k_F N_0]^{-1} \qquad (4)$$

The above equation is used to compute the number of molecules that have been captured for a certain period of time. The capacitance Co is chosen based on different kind of sensors used. Thus it can be seen that the dimensionality of sensor influences the number of molecules captured, thus affecting the sensitivity of the sensor.

The analysis is carried out assuming steady state analysis, i.e. the concentration of diffusion is constant inside the outer boundary. In order to model the sensor behaviour in transient state, figure below[7] shows a sensor at the centre, and the analyte with unknown molecules (blue). The sensor captures the molecules closer to it and thus as the distance increases the analyte concentration increases, as the molecules closer to the sensor are being captured (white).

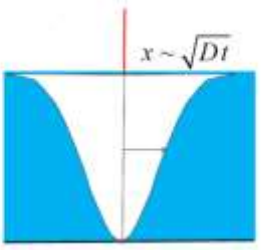


Fig 4 Diffusion Changes

The factor $W^8$ is time dependent and changes with geometry of the biosensor.

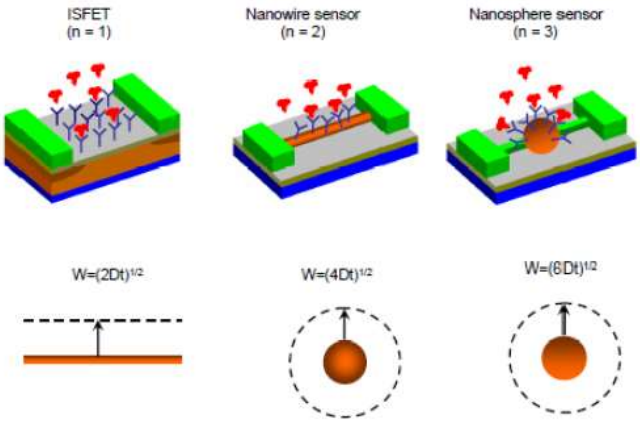


Fig 5 Different types of sensors with change in W

**IV SIMULATION RESULTS AND DISCUSSIONS**

*4.1 ISFET*

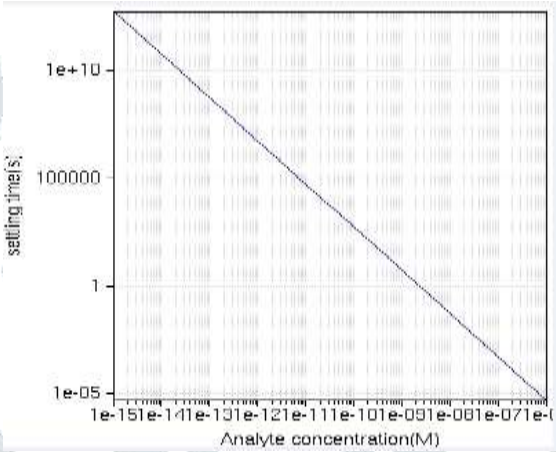


Fig 6 Settling Time of Planar Biosensor

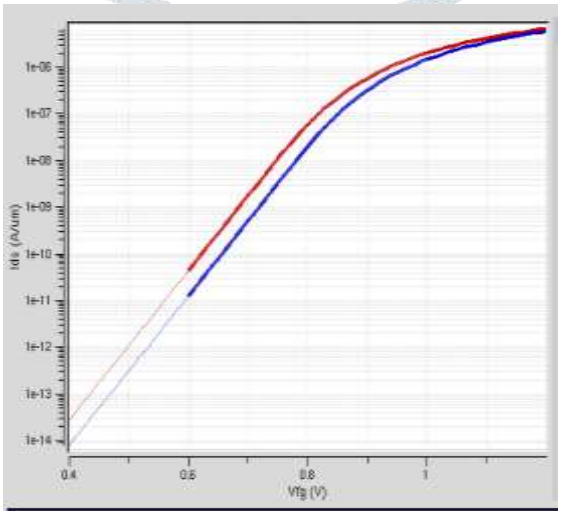


Fig 7 Sensitivity of Planar Biosensor

Fig[6][7] show the settling time and sensitivity of the planar biosensor. Planar sensor is less sensitive when compared with other sensors.

*4.2 CYLINDRICAL NANOWIRE BIOSENSOR*

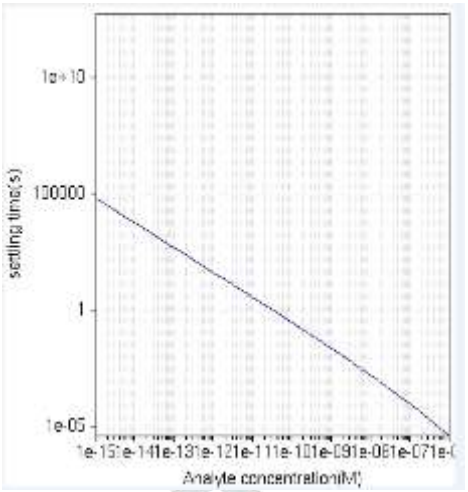


Fig 8 Settling Time of Cylindrical Nanowire Biosensor

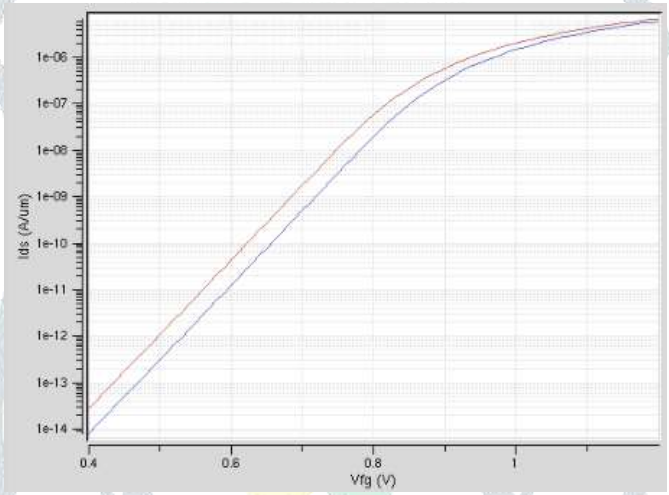


Fig 9 Sensitivity of Cylindrical Nanowire Biosensor

Fig[8][9] show the settling time and sensitivity of the cylindrical nanowire biosensor.

*4.3 NANOSPHERE BIOSENSOR*

From the Fig below, it is found that the analyte concentration dips largely for Nanosphere at 1E0 time, thus indicating the detection of targets by the receptors in a given analyte. Thus, Nanosphere has good sensitivity compared with Nanowire and ISFET.

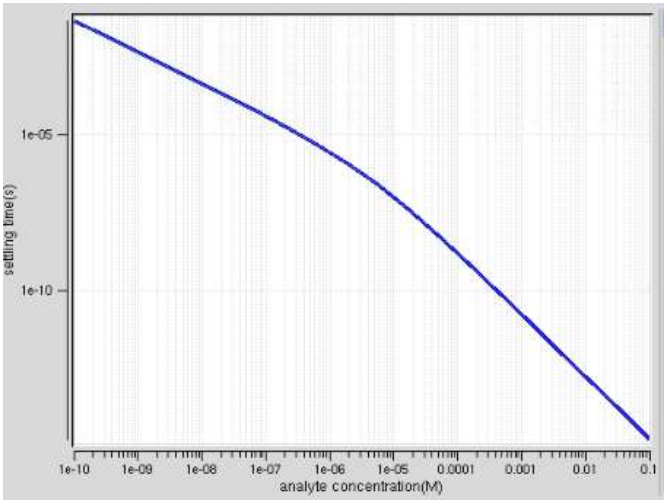


Fig 10 Settling Time of Nanosphere Biosensor

As the concentration increases, settling time has large variation for Nanosphere when compared with Nanowire and ISFET and hence we can conclude that Nanosphere is more sensitive to concentration of target ions.

From the results obtained, Nanosphere is found to be highly sensitive to analyte concentration. This detect the diseases with higher accuracy.

## V.CONCLUSION

In this paper, analysis is done on the mathematical models for Nanowire sensors, variation in sensor properties with respect to geometrical parameters . Experimental setup is developed to simulate three different nanosensors. Sensitivity of Nanosphere is found to be better than Nanowire and ISFET. However, it is practically difficult to realize the Nanosphere sensor. Thus Nanowire sensor is used for system level design particularly in disease detection. Nanowire sensor is simulated and its response to variations in analyte concentration is identified.

## REFERENCES

[1] Friederike J. Gruhl, Bastian E. Rapp, Kerstin Länge,"Biosensors for Diagnostic Applications" in Advances in biochemical engineering/biotechnology-January 2012.

[2] Irina V. Zaporotskovaa , Natalia P. Borozninaa , Yuri N. Parkhomenkob , Lev V. Kozhitovb, "Carbon nanotubes: Sensor properties. A review" in Modern Electronic Materials 2 (2016) 95–105 ,Elsevier Publication.

[3] Sang-Joon Kim, Seon-Jin Choi, Ji-Soo Jang, Hee-Jin Cho, and Il-Doo Kim," Innovative Nanosensor for Disease Diagnosis" in ACS Publication 2017.

[4] Sozaraj Rasappa , Tandra Ghoshal, Dipu Borah, Ramsankar Senthamaraikannan , Justin D Holmes & Michael A Morris," A Highly Efficient Sensor Platform Using Simply Manufactured Nanodot Patterned Substrates" in Scientific reports 2015.

[5] P. Vipeesh and N.J.R. Muniraj ," Development and Validation of Matlab Models for Nanowire Sensors" in International Conference on Advances in Computing and Communication in 2011 . .

[6] Landman J, Chang Y, Kavaler E, Droller, MJ, Liu B.( 1998) "Sensitivity and specificity of nmp-22,telomerase, and bta in the detection of human bladder cancer"Urology 1998, 52, 398-402.

[7] P. E. Sheehan and L. W. Whitman, "Detection limits for nanoscale biosensors",‖ Nano Lett., vol. 5, no. 4, pp. 803–806,2005.

[8] S.M. Ushaa, Vivek Eswaran," Modeling and simulation of nanosensors arrays for automated disease detection and drug delivery unit" in International Journal of Advances in Engineering & Technology, Jan 2012.