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Performance Characteristics of Carbon Nanotube Field Effect Transistor based Immunosensor

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***Abstract*—** Carbon nanotube biosensors are used to detect DNA and Proteins. Transistor with array of Carbon nanotubes has proved to enhance in their performance compared to that of conventional Si based. A device with array of Carbon nanotube to respond the Osteopontin (OPN) is a potential new biomarker of prostate cancer has been developed and proposed in this paper. The simulation of the biosensor is simulated using biosensor lab version-2 online through nanohub.org. The performance of the device is checked with a) settling time b) settling time and sensitivity. It is observed that the device reacts with change in time, molecule concentration, buffer-ion concentration. The settling time of the device is found to be 1 second.

***Index Terms*—** *Carbon nanotube, biosensor, biomarker, settling time, sensitivity.*

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I. INTRODUCTION

Prostate cancer is the second most life threatening cancer in the world after lung cancer. The identification of the disease is not possible in the initial stages. It is needed to diagnose at the initial stages itself to protect the life. Enzyme-linked immunosorbent assay (ELISA) is a commonly used method. But it requires pure samples, long processing time, special equipment and trained personnel. So, it is needed to design simple, speed, high sensitivity , high selectivity and Cost effective bio sensor.

Nanomaterials, particularly carbon nanotubes (CNTs) has exclusive feature for acting as support for immobilization of biomolecules at their surface. Carmen-Mihaela Tîlmaciu and May C. Morris[1] in their review on Carbon Nanotube Biosensors discussed the structures, properties and functionalization of carbon nanotubes. The cellular uptake, bio compatibility with toxicity issues of the CNTs were also included. The importance of biosensor has been discussed along with design of biosensors, their application and types. The significance of biosensors towards their resolutions and sensitive were emphasized in the literature [2] & [3].

Osteopontin (OPN) is a potential new biomarker of prostate cancer [4]-[6]. Carbon nanotube (CNT) - and nanowire-based field effect transistor (FET) biosensors have proved to possess good sensitivity and selectivity with the detection of PSA for prostate cancer [7]–[9]. A CNT based biosensor shows an improved detection of prostate specific antigen prostate cancer and shows a detection limit of 30fM of Osteopontin (OPN) for prostate cancer [9]–[11].

Fabrication carbon nanotube field effect transistor (CNTFET) as nano scaled immunosensor will enable to reach the objective of the paper.[13]-[15]. The array of CNTs helps to improve the performance of the device [13], [14] & [15]. Fabrication of highly sensitive and electrical immunosensor for detection of a potential biomarker using single walled array carbon nanotubes (SWCNTs) is proposed.

II. STRUCTURE OF THE DEVICE

A thought of miniaturization leads to Nanomechanics and nanoelectromechanical systems (NEMS). This technology outspreads its hands wide open with its large potential of process technology. By the recent past, scientists investigate the properties of various nanostructures for different applications. Among all, carbon nanotubes shows its promising performance with their extraordinary electrical, mechanical and electromechanical properties for sensing elements in nano systems. The stability nature of carbon nanotubes add advantage to accuracy[13]-[16].

A sheet of graphene is rolled to form hollow cylinders of Single-walled CNTs (SWNTs) with a single layer of carbon atoms with diameters on the order of nm, whereas the length can be several micrometers, due to very high aspect ratios. SWNTs possesses ballistic conductance carrying very high current densities (up to A/cm). Figure 1 shows the structure of the proposed CNTFET nano immunosensor.

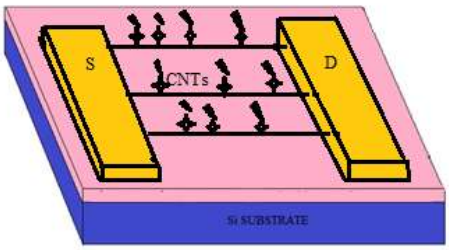

Figure 1: Structure of the proposed CNTFET nano immunosensor

III. RESULTS AND DISCUSSIONS

The proposed biosensor is simulated using Biosensor Lab Version2[17]. Type of the Sensor is cylindrical nanowire Bio sensor with following values of the physical parameters.

Radius = 0.3nm
Length = 5μm
Oxide thickness = 10nm

Two cases are taken for study. Case:1 the settling time alone is enabled while in Case:2, the sensitivity is also enabled.

Case :1 Settling time-Enabled

Table1.1 Provides the details of parameters and their value taken for simulation.

The above figure. 2 shows the variation of the settling time and analyte concentration. The curve is negative linear showing that the settling time decreases with the analyte concentration. The range of analyte concentration is between $1x10^{-15}$M and $1x10^{-6}$M. The settling time is 32.3467s with the analyte concentration of $1.26896x10^{-12}$M.

Case: 2 Settling time &, Sensitivity Enabled

The simualtion is carried out after enabling the settling time and sensitivity.

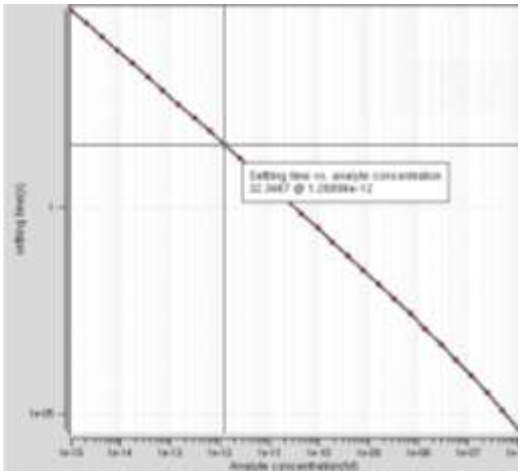

Figure.2: illustrates the graph between settling time and Analyte concentration

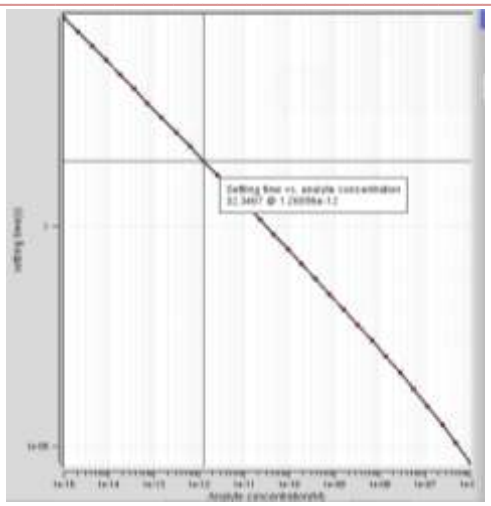

Figure.3: illustrates the graph between settling time and Analyte concentration

The above figure.3 shows the variation of the settling time and analyte concentration with settling time and sensitivity enabled . This curve is also shows a negative, but slightly exponential as it reaches the bottom. The settling time decreases with the analyte concentration. The range of analyte concentration is between $1x10^{-15}$M and $1x10^{-6}$M. The settling time is 32.3467s with the analyte concentration of $1.26896x10^{-12}$M.

The figure.4 illustrates the pattern of change in density of capture target molecules with respect to time with settling time and sensitivity enabled. This curve is positive linear till it reaches 1.14976s from where it maintains $2.99103x10^{9}$ N per cm^2. Thus the capturing of molecules gets saturated after 1.14s approximately. From the graph, at the sample time 849.753μs, the density of the capture time is found to be $2.439x10^{6}$ N per cm^2.

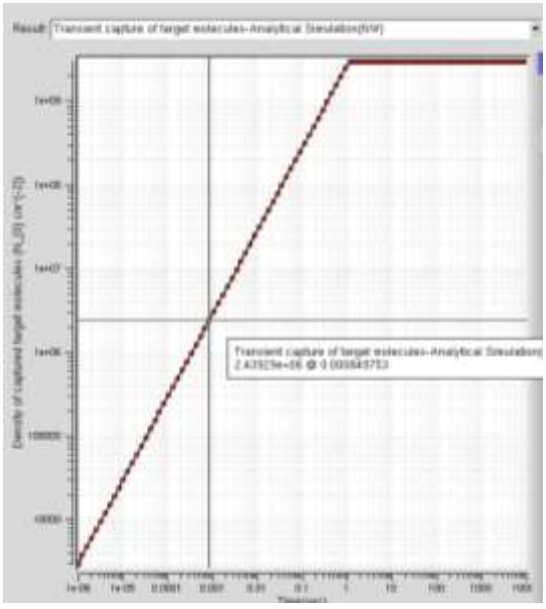

Figure.4: illustrates the graph between Density of captured target molecules and Time.

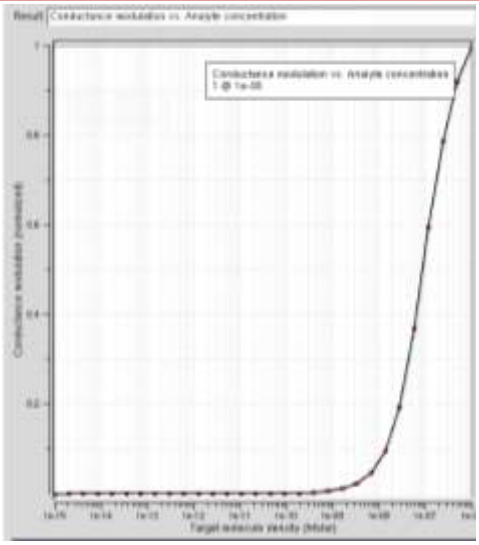

Figure.5: Conductance modulation(normalized) Vs Target molecue density (Molar)

The Figure.5 is the illustration of conduction modulation with repsect to target molecule density in Molar. The conduction is minimum, i.e., 2.77 $x10^{-3}$ at 3.8566$x10^{-10}$ M. There is a steady increase in conductance and reaches 1 with the taget of 1 $x10^{-6}$M. It is inferred from the graph that if the target molecule density is maintained to be greater than 3.8566$x10^{-10}$ M, then the conductance will be appreciable.

Table1.1 Details of parameters and their value taken for simulation

S.No	*Settling time Vs analyte concentration*		*Time dependent Capture of Target Molecules*		*Microfluidic channel parameters*	
1.	Lower value of analyte concentration molar units	$1x10^{-15}$	analyte concentration	$1x10^{-9}$M	Fluid flow	No
2.	Upper value of analyte concentration molar units	$1x10^{-6}$	Start time for transient response	$1x10^{-6}$s	Width	6cm
3.	Number of intermediate concentration steps	30	Final time for transient response	10000s	Length	60cm
4.	Minimum number of molecules	10	Steps	100	Height	6cm

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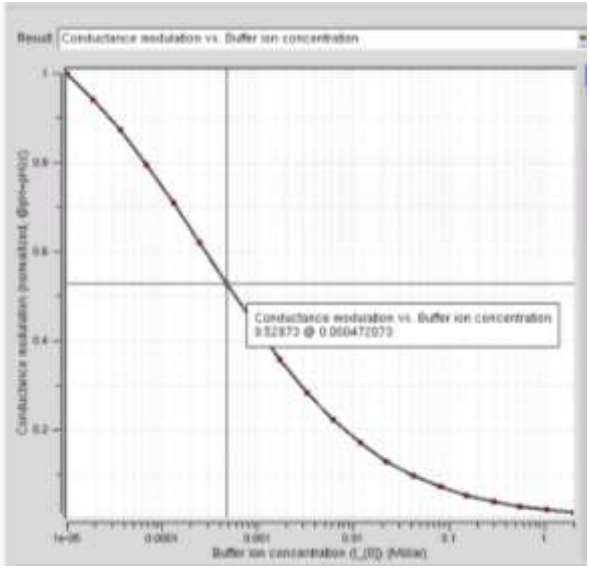

Figure.6: Conductance modulation Vs Buffer ion concentration(I_{0}) (Molar)

The Figure.6 is illustrates the variation of conduction modulation with repsect to Buffer ion concentration in Molar. The conduction decreases exponentially from 1 and tends to reach zero. The sample is taken for 0.52873M at 0.00472073 conductance. Inferrence from the graph is that the conduction gets rolled off with increse in Buffer ion concentration.

The Figure.7 is illustrates the variation of surface potential against the pH value of Buffer. The sample is taken for -0.11304pH at 5.73684V. The surface potential gets rolled off negatively with increse in pH value of Buffer is the Inferrence from the graph.

CONCLUSIONS

The simulation of the biosensor with nanowire is simulated using biosensor lab version-2 online through nanohub.org[17]. The performance of the device is checked with

a) settling time b) settling time and sensitivity. It is observed that the device reacts with change in time, molecule concentration, buffer-ion concentration.

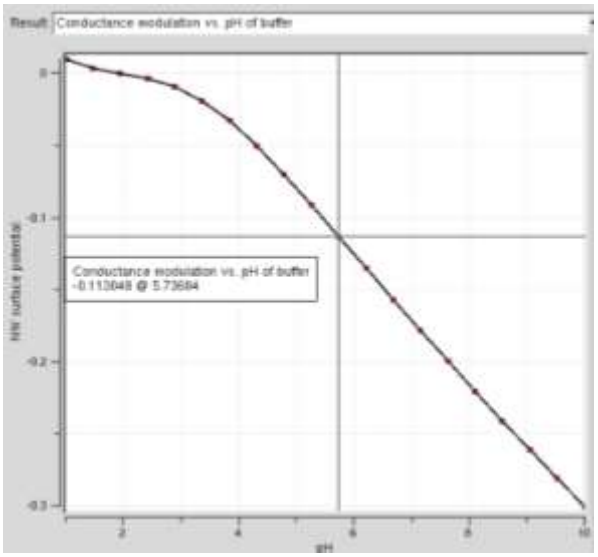

Figure.7: NW surface potential Vs pH

REFERENCES

[1] Carmen-Mihaela Tîlmaciu and May C. Morris, "Review on Carbon nanotube biosensors", Frontiers in Chemistry, Volume3, Article59, pp: 1-21, 2015.

[2] Ahmed kh. Sabr, Christian Bach, "Biosensors", Journal of Multidisciplinary Engineering Science and Technology (JMEST), Vol. 3 Issue 11, pp: 6098- 6109, November – 2016.

[3] Ahmed Kh. Sabr," Biosensors', American Journal of Biomedical Engineering, Vol.6, No.6, pp: 170-179, 2016.

[4] J.P. Kim, B.Y. Lee, J. Lee, S. Hong, S.J. Sim, Enhancement of sensitivity and specificity by surface modification of carbon nanotubes in diagnosis of prostate cancer based on carbon nanotube field effect transistors, Biosens.Bioelectron. 24 (2009) 3372–3378.

[5] N.S. Fedarko, A. Jain, A. Karadag, M.R.V. Eman, L.W. Fisher, Elevated serum bone sialoprotein and osteopontin in colon breast, prostate, and lung cancer, Clin.Cancer Res. 7 (2001) 4060–4066.

[6] A. Jain, D.A. McKnight, L.W. Fisher, E.B. Humphreys, L.A. Mangold, A.W. Partin, N.S. Fedarko, Small integrin-binding proteins as serum markers for prostate cancer detection, Clin. Cancer Res. 15 (2009) 5199–5207.

[7] X.P.A. Gao, G. Zheng, C.M. Lieber, Subthreshold regime has the optimal sensitivity for nanowire FET biosensors, Nano Lett. 10 (2010) 547–552.

[8] A. Kim, C.S. Ah, H.Y. Yu, J.H. Yang, I.B. Baek, C.G. Ahn, C.W. Park, M.S. Jun, S. Lee, Ultrasensitive label-free, and real-time immunodetection using silicon field-effect transistors, Appl. Phys. Lett. 91 (2007) 103901.

[9] Abhinav Sharma a, Seongkyeol Hong a, Renu Singh a, Jaesung Jang, "Single-walled carbon nanotube based transparent immunosensor for detection of a prostate cancer biomarker osteopontin", Analytica Chimica Acta 869 (2015) pp.68–73.

[10] G. Castellano, G. Malaponte, M.C. Mazzarino, M. Figini, F. Marchese, P. Gangemi, S. Travali, F. Stivala, S. Canevari, M. Libra, Activation of the osteopontin/matrix metalloproteinase-9 pathway correlates with prostate cancer progression, Clin. Cancer Res. 14 (2008) 7470–7480.

[11] A. Bellahcene, V. Castronovo, K.U. Ogbureke, L.W. Fisher, N.S. Fedarko, Small integrin-binding ligand N-linked glycoproteins (SIBLINGs): multifunctional proteins in cancer, Nat. Rev. Cancer 8 (2008) 212–226.

[12] M.B. Lerner, J. D'souza, T. Pazina, J. Dailey, B.R. Goldsmith, M.K. Robinson, A.T.C. Johnson, Hybrids of a genetically engineered antibody and a carbon nanotube transistor for detection of prostate cancer biomarkers, ACS Nano 6 (2012) 5141–5149.

[13] Geetha, P & Wahida Banu, RSD 2014, 'A compact modelling of a double-walled gate wrap around nanotube array field effect transistors', Journal of Computational Electronics, (DOI 10.1007/s10825-014-0607-7) (Impact Factor-1.732). Springer, vol.13, no.4, pp.900-916.

[14] Geetha, P & Wahida Banu, RSD 2014, 'Frequency, delay and velocity Analysis for intrinsic region of CNTFET', Carbon – Science and Technology, vol.6, no.2, pp: 373 – 383.

[15] Geetha, P & Wahida Banu, RSD, 'Capacitance modelling of Single and Double-Walled Gate Wrap Around Carbon Nanotube Array Field Effect Transistor ', International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 10 (2015) pp. 26401-26421.

[16] Geetha, P & Wahida Banu, RSD 2014, 'Performance Characterization of Capacitance modelling for CNT MOSFET'. International Journal of Scientific and Engineering Research, vol. 5, issue.3, pp. 62-67

[17] nanohub.org