International Journal of Emerging Science and Engineering (IJESE)
ISSN: 2319–6378, Volume-1, Issue-10, August 2013

Application of Nanoelectronics in Medical Science: A Case Study

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***Abstract*— The recent advancements in the field of nanoelectronics have revolutionized the perfomance of electronic devices. Miniaturization of electronic components and as a result devices has reached the new world of single particle which is benefiting the human being in almost every walk of life.**

In this paper we present the brief introduction to nanoelectronics and majorly its application in the field of medical science.

***Index Terms*—.Nanorobotics, Nanobioelectronic, Quantum Capacitance limit, tunneling transistor.**

I. INTRODUCTION

Although miniaturizing the electronic components has boost up the systems' speed and produce great results that were expected by the researchers but it also offers some problems alongwith as the interconnect scaling after some limit produces RC delays because small cross section area increase the resistance and small distance between conductors increases parasitic capacitances. Furthermore, as the operating frequencies are increased, parasitic inductance also shows its appearance.

Today electronic industry see toward nano-scale technology, which is one-dimensional due to layer thickness in nanometer scale.

Further, miniaturization makes it difficult maintain the capacitance due to the interference between neighbouring lines corresponding to other electronic components, which could also affect the current driving capability of the device.

II. SOME ASPECTS OF NANOELECTRONICS

Nanoelectronics refers to process information by considering the properties of matter that are dissimilar with macroscopic properties. Depending upon the phenomena investigated, it is a few nanometers of molecules that acts like transistor, can be 999nm for quantum dot where the spin of electron is considered for information processing. Some of the considerable achievements of nanoelectronics are as follows:

A. Speedy Transport:

In high speed electronics, scattering free electronic transport is necessary, which confirms the ballistic transformation, and to achieve it Carbon Nano Tubes (CNTs) are the best materials at room-temperature[Wind, Appenzeller, and Avouris 2003, Javey et al. 2003, Durkop et al. 2004, Franklin et al. 2009] because of reduced phase space present for backscattering events.

Manuscript received August, 2013.

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Also, ultra-thin body channels-associated property of CNTs is another important source for high speed systems.

B. Band-to-band tunneling transistor:

In electronic systems, the best way to reduce the power consumption without compromising the on-state efficiency is to minimize the supply voltage. Aaccording to the research work band-to-band tunneling transistor (T-FET) is found to be the device best suitable for the task and the CNTs were the materials who firstly shown that T-FET are able to operate with an inverse subthreshold slope quite below 60mV/dec [Appenzeller, .2004]

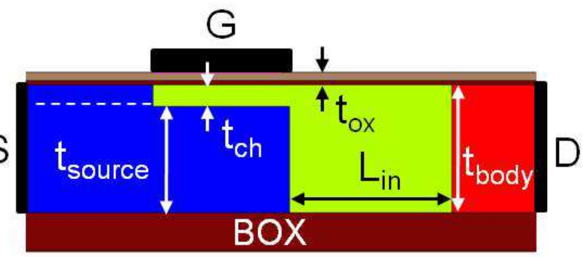

Fig 1. Schematic of the hybrid TFET.

C. Operation in the Quantum Capacitance Limit:

CNTs are an ideal implementation of a one dimensional system at room temperature which ensures its operation in quantum capacitance limit. Its advantage over conventional FETs is the fact that it allows controlling the band movement instead of the charge with the help of gate voltage [Knock and Appenzeller 2006)]for thin gate dielectrics.

Since, the quantum capacitance scales with the channel length but is independent of gate oxide thickness, so shorter channel length translate into a smaller total capacitance.

As a result 1D CNTFETs supports reduced consumption as compared to its counterparts.

III. APPLICATIONS IN MEDICAL SCIENCE

A. Diabetes Control:

The developments in nanoelectronics, biochemistry and information technology are the source of such nano-scaled systems which could help a lot in curing the diseases, diabetes is one of them.

As a current routine a diabetic patient take small blood sample daily or in other cases many times a day in order to maintain sugar level in the blood. This method is painful and hectic and can be avoided by continuous glucose monitoring by the help of medical nanorobots as shown in Fig 2.

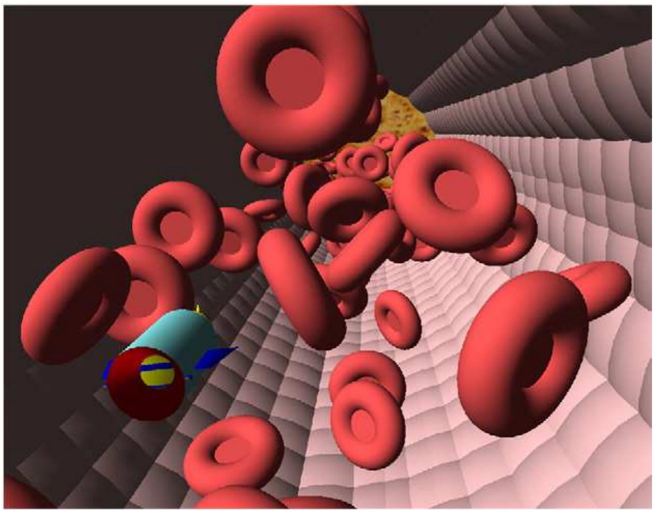

Fig 2. Universal monitoring for a patient with diabetes.

The nanorobot for diabetes monitoring should comprise of an ASIC as shown in Fig 3.

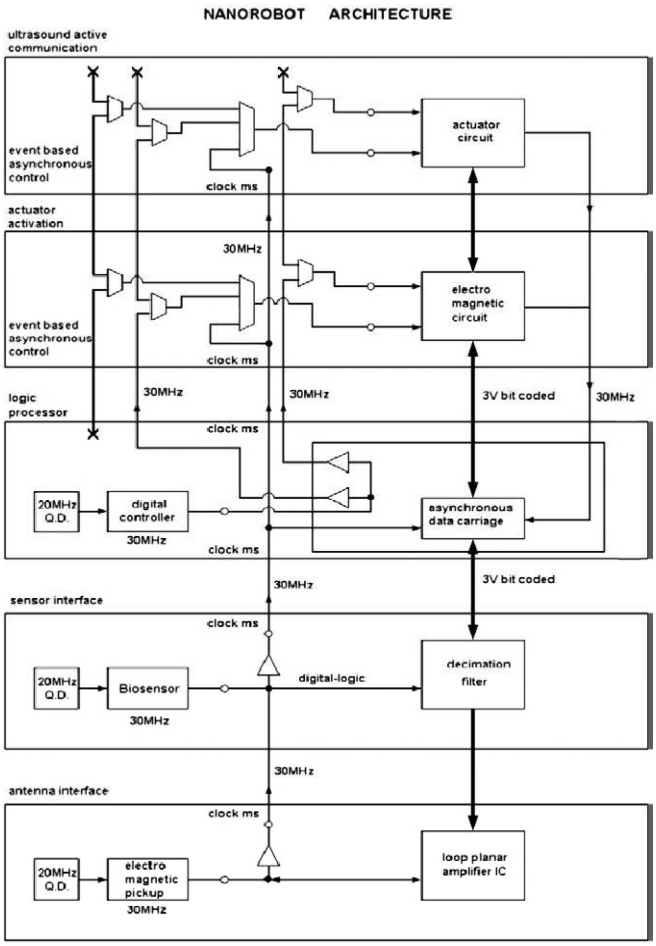

Fig 3. ASIC block diagram

Various nano devices used to integrate a nanorobot should deeply consider the size of hardware keeping in mind its applicability inside the human body.

Due to continuous research it has been possible to achieve great milestones such as lithography has made it possible now tomanufcture compact components composed of several wire layers which facilitate the integration of nano electronic components.

Nanosensors composed of CNTs and DNA were successfully demonstrated for protein detection. The current implementation of a high-K/metal-gate in the 45nm-Silicon technology node should result in positive impact on the advancement of high-K research for InSb and InGaAs, which opens the new path to achieve smaller nano-IC packaging.

According to molecular machine architecture, to successfully set an embedded antenna with 200nm size for the nanorobot RF communication, a small loop planar device is used for electromagnetic pick up, which shows a good matching on Low Noise Amplifier and is based on gold nano crystal with 1.4nm3, CMOS and nanoelectrnic circuit technologies. Frequencies ranging from 1 to 20 MHz can be perfectly utilized for inner body environment, satisfying the safety requirements medically.

At present the normal practice requires several skin punctures. Type 2 patients perform the same on the average of two to three times per day, but due to nanoelectronics similar process would have to be performed one time for the intervals of 90 days!

According to the recent research , nanotechnology enables the nanorobots to flow through the blood stream and measures the glucose levels in blood, whenever glucose level approaches a critical limit the nanorobot sends an alarm throught he mobile phone which alerts the patient to have some medication.

For a normal condition of blood having 36˚C temperature and PH 7.0, the biosensors associated with nano structure may achieve response time which is 90% of steady state signal in less than 90msec as shown in Fig 4. This reduces the time delay and the patient gets aware in few seconds (real time).

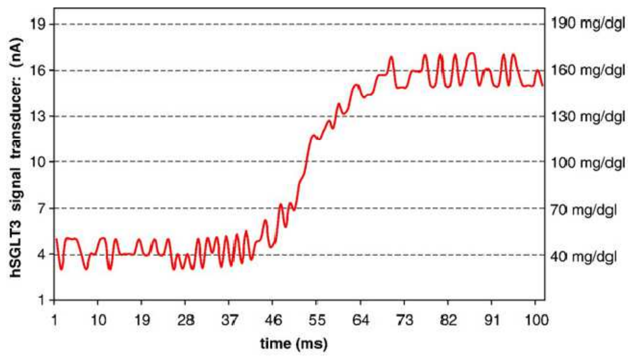

Fig 4. Nanosensor response time.

B. Nanobioelectronic System to Trigger Enzyme Activity:

Advanced research in molecular bioelectronics explores the way which make it possible for biological reactions and biochemical interactions from nature to interact with electronics via electronic signal detection and its processing. As an example we present the researches in US who have designed an integrated nanobioelectronic system exploiting the major properties of nanowires and CNTs for triggering reversibly and on-demand bioelectrocatalytic transformations of alcohols.

According to latest research the embedded nanowire-CNT system depends on nickel-gold nanowires, which consists of an enzyme captured halfway through them and a CNT modified amperometric transducer.

As shown in Fig 5. Changing the orientation of nanowires through magnetic field makes the contact of enzyme with CNT coated electrode, due to which the enzyme , in this case alcohol dehydrogenase (ADH), catalyze the transformation of ethanol to acetaldehyde.

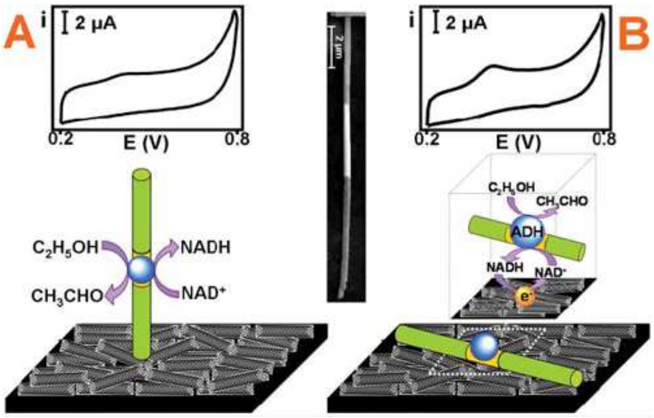

Fig 5. On-demand magnetically-triggered bioelectrocatalytic transformations of ethanol. The nanowire–CNT based activation of ADH involves Ni/ADH–Au/Ni nanowires in connection to a CNT-coated surface and changes in the nanowire orientation between the vertical (A) and horizontal (B) positions for blocking and activating the bioelectrocatalytic process, respectively.

By using nanotube surface regeneration of enzymes's cofactor (NAD^{+}) ensures the catalytic activity, and permits examination by electrochemical method.

C. To Repair the Brain:

For neural prostheses to restore damaged or lost functions of the brain/nervous system, two tasks have to be performed i.e. stimulate the nervous system and secondly, record its activity. See fig 6. For micrograph of a neuron.

In order to achieve them several research work have been done to know the basic mechanism of cell to cell communication through synaptic transmission, further work have been done to make copies of these mechanisms by using artificial devices and then interface them to the nervous system at the cellular level.

For all that work, recent research shows that CNTs may be the ideal material for the recovery of damaged group of cells. Further, CNTs have excellent property of electrical conduction like nerve cells as well as they can make firm mechanical contacts with cellular membranes, thereby providing a communication model for nervous system.

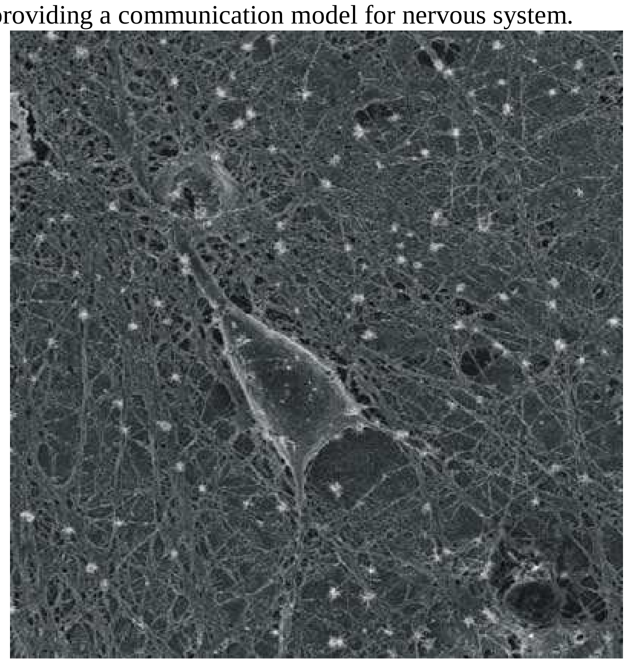

Fig 6. TSEM micrograph of a cultured rat hippocampal neuron grown on a layer of purified carbon nanotubes.

IV. CONCLUSION

In the paper we tried to present some new aspects of nanoelectronics and its application in medical science.

Besides the cases we present there are number of diseases which would better be cured or at least controlled to greater extent by the rapid advancement in nanotechnology.

As conventional electronics have already found several applications in medical science-medical monitoring of vital signals, biophysical studies of excitable tissues, pacemakers and limb stimulation- the application of nanotechnology will explore a new world of implanted electronics in the human body.

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