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In-House Fabrication and Electrical Characterization of Planner si-Nanogap

Th. S. Dhahi[1], Tijjani Adam [2], Uda Hashim[3]

[1]Department of physics, University of Basra, Basra, Iraq.
[2]Faculty of Technology, Universiti Malaysia Perlis (UniMAP), Kampus Uniciti Alam Sg. Chuchuh, 02100 Padang Besar (U), Perlis, Malaysia.
[3]Institute of Nano Electronic Engineering, University Malaysia Perlis,Perlis, 01000 Kangar, Malaysia.

Abstract. Nanogap is increasingly known to be beneficial, dependable and higher sensing technology. Another possible purpose is to examine a bioactivity and study the reaction of single molecule. It is important to carefully recognize the differences between the sensor surface and electrode in order to incorporate the biological system with nanogap. Also, it crucial to examine the dielectric properties between the planar nanogap with and without a sample. Electrical concentration between the electrodes could be increased due to integrating of microfluidic channel when the sample is being used. This paper is a report on an electrical point of view of planar nanogap capacitor device with comparison of different excitation frequency with and without microfluidic channel. By using 40 nm Si nanogap devices, the sensitivity of nanogap was compared by dropping deionized water and pH 7 onto the target. Experiments were carried out in wide range of frequencies from 1 Hz to 1 MHz at room temperature with 30 mV input signal (0 V, DC, Offset). Both effects of excitation frequency on capacitance sampling with 10 µm microfluidic integration were analysed.

1.0 Introduction

There had been the greater opportunity in the field of healthcare in terms of the ability of manipulating the matters at atomic and molecular level in order to create material with altered and new properties. There had been a rapid area of researches to manipulate the matters at atomic level. Fortunately, today the technology had showed us the way to create matters with varied, new properties as well as the function of it. In the medical field, it is a great achievement which permit us to use it in therapy diagnostics, and many areas of healthcare research and development as well as clinical applications. Again, in the field of medicine, the way we would treat the diseases in the future will be surprisingly change due to the use of nanotechnology. The functionality of the device being use at present time could be improved drastically due to availability of nanotechnologies. As the results, at the present time detecting the diseases before it occurs is possible therefore doctors could be able to control not making the diseasing worst. In past many techniques, had been identified in order to apply it but today it had been in realities[1-5].

The components used in order to produce sensors are nanogap, nanoparticles, nano thin film etc. with various geometries and assembling it direct us into a powerful general platform for the ultrasensitive direct electrical detection of biological and chemical species, a device for detecting disease such as cancer, dengue etc, cells at earliest stage. The sensor renders the electric signal when it had found the particular target[6-10]. It had been design to bind with complementary target in the cell. Furthermore, various devices had been tested to be accurate in detecting the target molecules such as nano fibers, magnetic nanoparticles, gold nanoparticles and carbon nanotubes. It has sensors on it which has ability to detect the proteins and DNA of certain diseases with very less time needed, for instance less than half an hour. Between the devices capacitive devices had been known for most sensitive due to its integral or inbuilt capability to react to minute changes and capacitor is a passive component that depot energy in an electrostatic field but not in form of chemical[11].

Typically, capacitive which is grounded with transducer comprises two parallel metallic or sometime non-metallic plates that unusually divided by the permeable material for instance air, liquid which are normally describe as dielectric polarizer. In a typical capacitor, the space between the two plates non-transferable but transducing it, In the normal capacitor, the distance between the two plates non-movable, but transducing it variable this capability of varying the dielectric with allow to measure noticeable changes [1-3]. The operational mechanism is as follows. When a target molecule sample comes in close contact with the receptor/DNA, negligible but opposing partial charges appear in both plates (electrode) and can be observed by impedance analyser [4].

The Electrical bio-detection is solely relying on the changing electrical profile such currents fluctuation and voltages to identify the binding. With this complementary, mismatch and non-complementally bimolecular are studied. Due to the inherent capability of electrical detection methods in allowing Interaction with the targeted ssDNA to create a field across the transducer and increase the capacitive effect, the nanogap capacitor is special kind of capacitor that based on electrical double layer (EDL) theory that has been recognised by chemist since the nineteenth century when Von Helmholtz first developed and modelled his colloidal suspension work [5]. Previous designs of planar nanogap are still lack in geometry and structure [6-7]. Yexian Wu and co-worker using ebeam to fabricate heterogeneous metal nanogaps but still the contact surface area is not well defined [8]

The geometry of the nanogap electrode seems to be distorted and far different form AUTOCAD design due to many process and chemical involved during fabrication. This project managed to get a very sharp trench nanogap having wider surface area as designed. Simulation and electrical characterization can be conducted to get better understanding of nanogap at 40 nm gap size. According to the Boltz, the nanogap can be fabricated with gap spacing in the range of 15 to 300 nm, allowing the electrical double layer at each electrode to overlap each other at sufficiently low ionic strength [9]. By closing the air between the nanogap with microfluidic is perhaps to reduce the noise and increase the capability to store electric charge in a highly reversible way. Even though nanogap allows to readily interact with biological or ionic entities, which have smaller dimensions, other component might be integrated to complete the tuning signal process. The advantages of this device are the small time of analysis, the low reagent costs, and the reduced amount of chemical waste. The application of portable, easy to use, and highly sensitive for real time detection could offer significant advantages over current analytical methods[12-17].

Nanogap in lab on chip is very useful in many fields such as chemical analysis, environmental monitoring, medical diagnosis and cellomics, synthetic chemistry (rapid screening and microreactors for pharmaceutics) DNA labyrinths, single cell detection in bioanalytical applications [10].

2.0 Methods

In this project, we developed a simple device containing planar nanogap attached with PDMS microfluidic having micromixer in the middle for fast processing of sample. Two different sample events can be injected at the same time in a second. With well-defined structure and contact surface area of electrode, this device has a very good selectivity and sensitivity as biosensor [18-22].
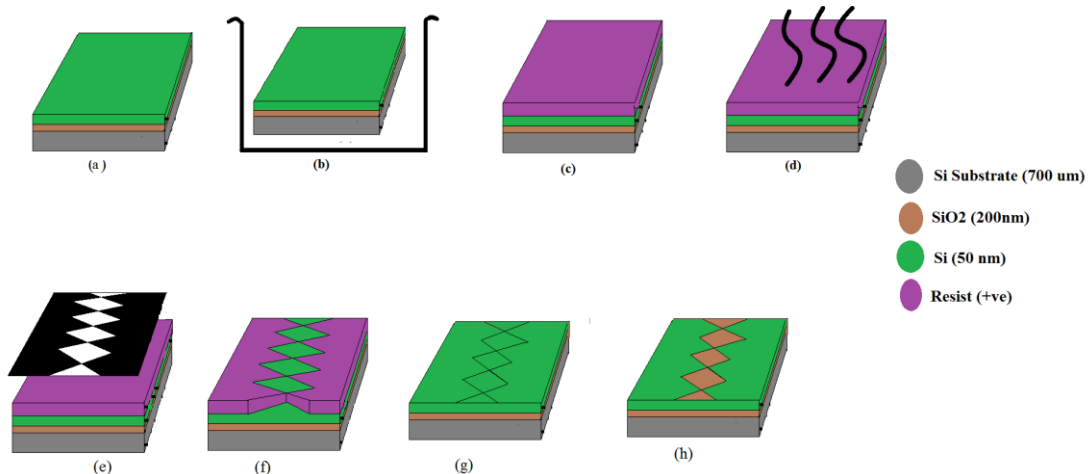

Figure 1. Fabrication flow of nanogap

First, the design of device was accomplished by using AUTOCAD as shown in Figure 1(a). Alignment marks were placed to ease the Ti/Au pad fabrication while red line indicates an oxide trench where Si nanogap electrode stands to tune the signal. Figure 1 (b) highlights the nanogap fabrication steps. Fabrication process of nanogap was realized by using Boron doped SOI substrate. After cleaning the substrate using ultrasonic machine, EZP520-87 resist is diluted in anisole is spin coated at Speed (rpm):4000 (10s), 500 (5s), 0 (5s) to get approximately 100 nm thickness of resist. The resist was baked at 180 ˚C for 2 minutes as shown in Figure 1 (d). The trench pad and gap line are then patterned using EBL with the same dose of 600 µC/cm^2 at 100 kV. But there were fabricated at different area step size; dose area performed for trench pad is 6.4µs-320s and 4.2µs-210s for gap. Then, the device was developed by using MIBK: IPA (+) ve developer for 30 s. The trench pad was etched separately by using RIE followed by gap line was etched by using DRIE. As a result, a sharp and higher aspect ratio of nanogap was achieved. In this paper, 40 nm nanogap having thickness of 50 nm were characterized. Finally, Ti/Au pad were simply fabricated on top of electrode by using conventional lithographic technique. To complete the function of device, PDMS microfluidic were fabricated on the Si mould. By applying negative resist, microfluidic mould was fabricated on the silicon. PDMS microfluidic could be matched with nanogap by using plasma bombardment at 27˚C. To realize the geometrical aspect of device, nanogap was observed using SEM. Figure 2 has shown a very point that 40 nm nanogap was lie down on the oxide trench.
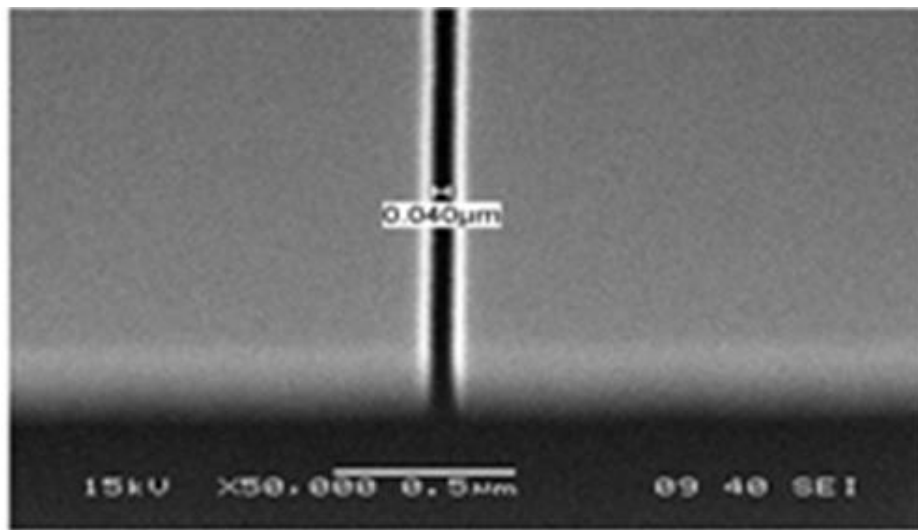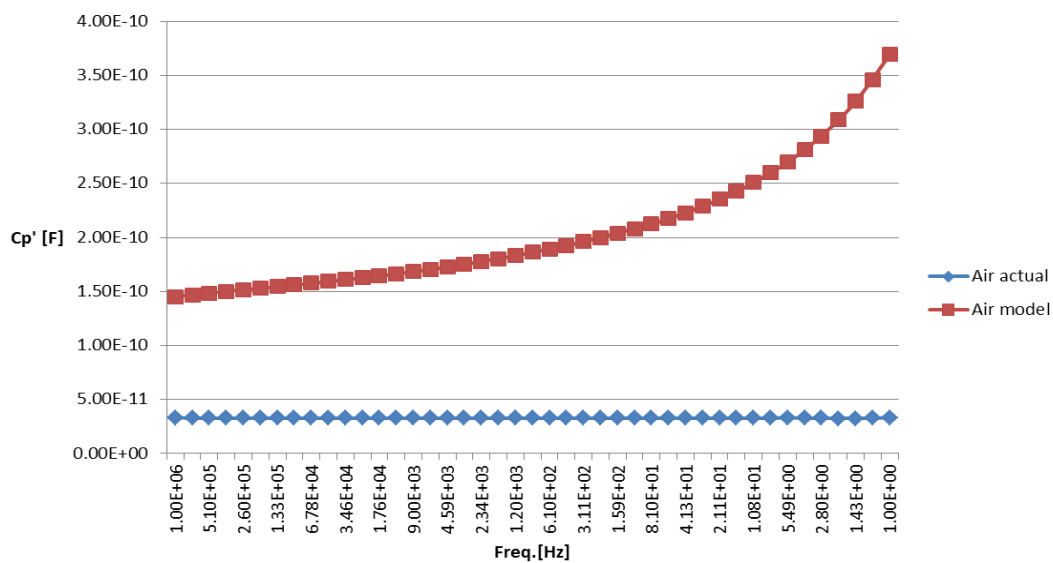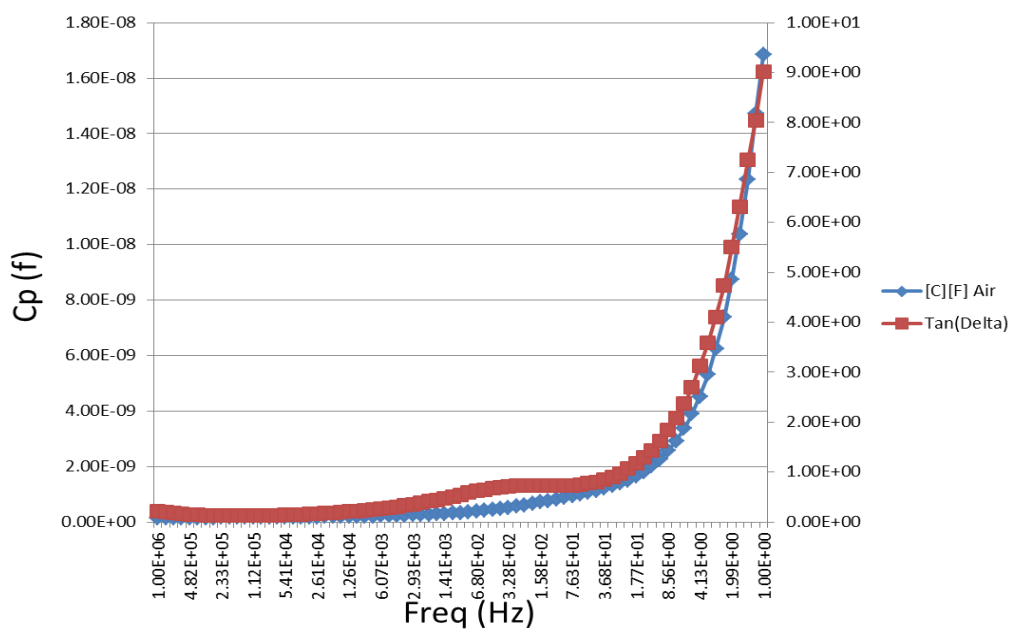
Figure 2. planar nanogap ~40nm
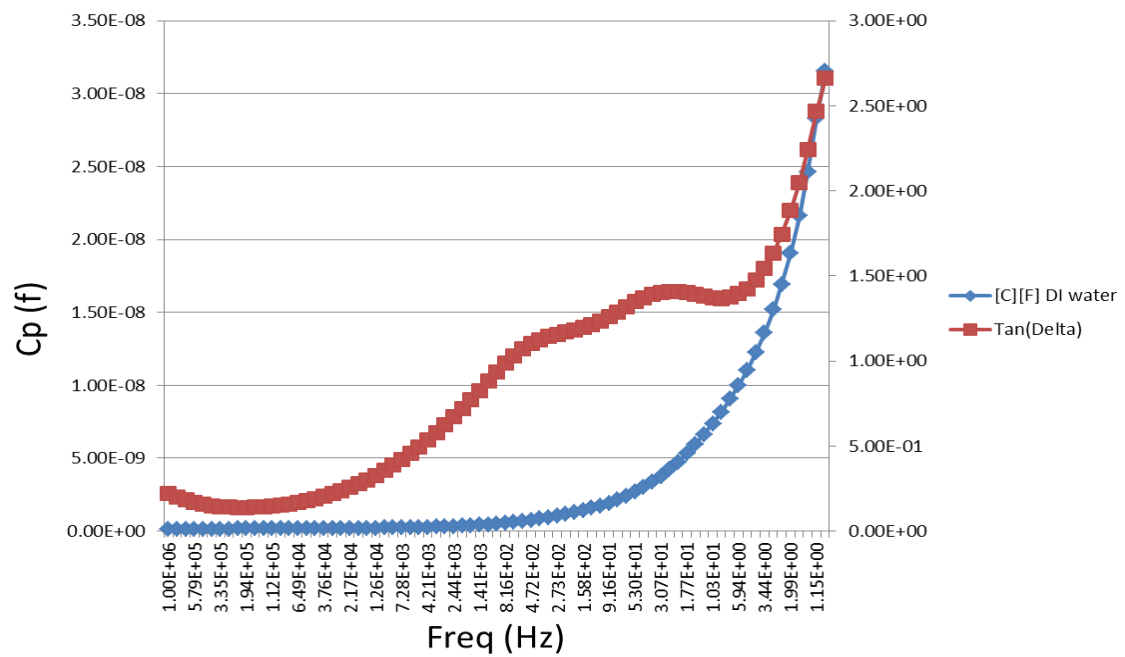
3.0 Results and Discussions

The structure is designed as gap and since the nanogap is designed as capacitor, the dielectric Analyzer was programmed to measure the capacitance and loss tangent. Loss tangent is defined as the ratio of capacitive reactance to resistance. The frequencies were swept from 1Hz to 1 MHz using dielectric analyzer with AC Volt [Vrms]=0.300 or 30 mV input signal (0 V D.C Offset). Reference plane is full calibrated to reference plane and probing station was fully vacuum. Below is typical nanogap measurement at 40 nm showing a near to 33 Pf ceramic capacitor. Air actual is deviates from actual model due to lack of supply vacuum. Primary capacitance model value shown in the graph is 37 nm as shown in Figure 3 (a). Loss tangent for air, deionized water and ph 7 is $<10^{-1}$ and below 10 kHz as shown in Figure 3 (b), (c) and (d). The factors that ultimately determine the best capacitor is the loss lie between these values. Note that the presence of dispersion peaks and the inverse power dependence of the capacitance with the frequency at the whole range [11-12]. First peak indicates the double layer and the second peak surely the probe contact. After dry measured capacitance, deionized water and followed by ph 7 were injected separately to the inlet of sample to see any changes. Moreover, the graph in Figure 3 (c) shows the value of capacitance tunes form the event. After triplicating the data, the final results show very a stable and accurate reading. However, air and deionized water reading is almost similar. 32 nF and 34 nF. Deionized water really has no ions. Of course, it still has about 10^{-7} molar each of H+ and OH- ions similarly to pH 7, at room temperature. In the AC field. Each H_2O dipole changes orientation with the field. If the frequency of the electric field is increased, eventually its becomes so high that the water dipoles cannot turn fast enough to keep up. Then all that happens is that nuclei and the electron cloud of each water molecule move a little response to the field. Measured at a very high frequency for water molecules are not free to rotate. So, this device only valid at low frequency up to 1Mhz.
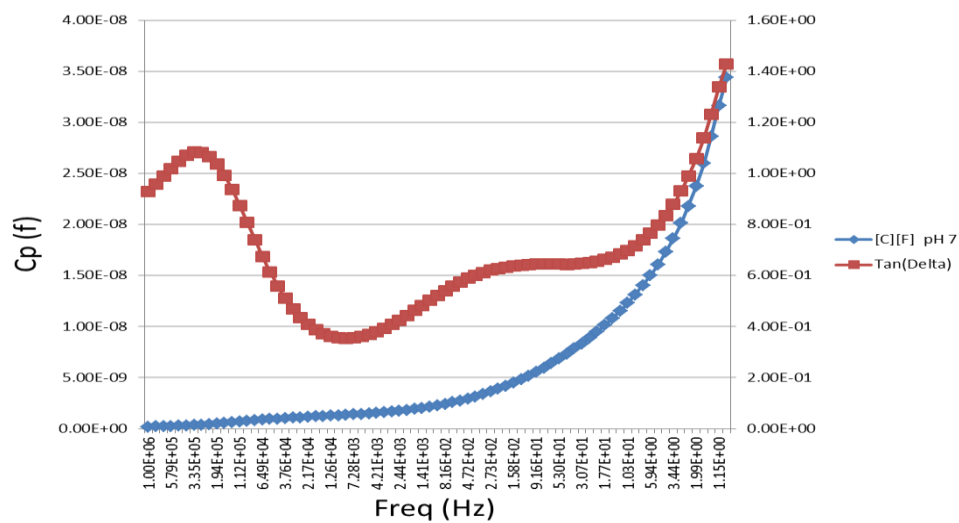
(a)

(b)

(c)

(d)

Figure 3: (a) Dry measured capacitance for 40 nm nanogap model and 33 Pf ceramic capacitor model,

From Figure 4, the response characteristic indicted by the three curves indicates the double layer and the second peak surely the probe contact. After dry measured capacitance, deionized water and followed by ph 7 were injected separately to the inlet of microfluidic to see any changes. Graph in Figure 4 shows the value of capacitance tunes form the event. After triplicating the data, the final results show very a stable and accurate reading. However, air and deionized water reading is almost similar. 32 nF and 34 nF. Deionized water really has no ions. Of course, it still has about 10^{-7} molar each of H+ and OH- ions similarly to pH 7, at room temperature. In the AC field. Each H_2O dipole changes orientation with the

field. If the frequency of the electric field is increased, eventually its becomes so high that the water dipoles cannot turn fast enough to keep up. Then all that happens is that nuclei and the electron cloud of each water molecule move a little response to the field. Measured at a very high frequency for water molecules are not free to rotate. So, this device only valid at low frequency up to 1Mhz.
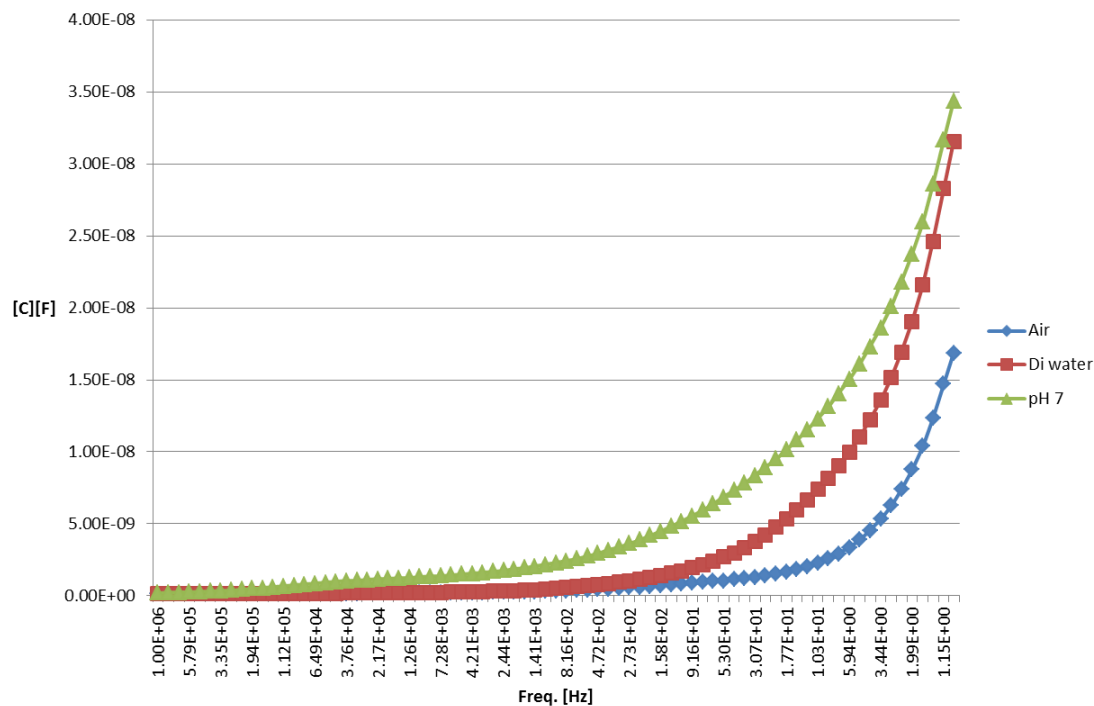 (b,c,d) capacitance and loss tangent of 40 nm device.

Figure 4: Capacitance reading for air= 17 n F , deionized water= 32 nF, and ph 7 =34 nF

4.0 Conclusions

The paper demonstrated the fabrication of Nano gap which is increasingly known to be beneficial, dependable and higher sensing technology. Another possible purpose is to examine a bioactivity and study the reaction of single molecule. It is important to carefully recognize the differences between the sensor surface and electrode in order to incorporate the biological system with nanogap. Also, it crucial to examine the dielectric properties between the planar nanogap with and without a sample. Electrical concentration between the electrodes could be increased due to integrating of microfluidic channel when the sample is being used. This paper is a report on an electrical point of view of planar nanogap capacitor device with comparison of different excitation frequency with and without microfluidic channel. By using 40 nm Si nanogap devices, the sensitivity of nanogap was compared by dropping deionized water and pH 7 onto the target. Experiments were carried out in wide range of frequencies from 1 Hz to 1 MHz at room temperature with 30 mV input signal (0 V, DC, Offset). Both effects of excitation frequency on capacitance sampling with 10 µm microfluidic integration were analyzed.

References

[1.] Tijjani.Adam, U.Hashim, Highly sensitive silicon nanowire biosensor with novel liquid gate Control for detection of specific single-stranded DNA molecules Biosensors and Bioelectronics67 (2015) 656–661.

[2.] Md. Eaqub Ali, Th.S. Dhahi, Rasel Das, U. Hashim, DNA hybridization detection using less than 10-nm gap silicon nanogap structure, Sensors and Actuators A 199 (2013) 304–309.

[3.] Chen, X., Guo, Z., Yang, G.-M., Li, J., Li, M.-Q., Liu, J.-H., & Huang, X.-J. (2010). Electrical nanogap devices for biosensing. Materials Today, 13(11), 28-41. doi

[4.] M Wesam Al-Mufti, U Hashim, M Rahman, Tijjani Adam, M Arshad, Studying Effect Dimensions of Design and Simulation Silicon Nanowire Filed Effect Biosensor, Applied Mechanics and Materials 754, 854-858, 2015.

[5.] Yi, M., Jeong, K.-H., & Lee, L. P. (2005). Theoretical and experimental study towards a nanogap dielectric biosensor. Biosensors and Bioelectronics, 20(7), 1320-1326

[6.] Uda Hashim, N. T., Thikra S. Dhahi, Azizullah Saifullah. (2011). Polysilicon nanogap structure development using size expansion technique. Microelectronics International, 28(3), 24-30

[7.] Wang, C., Huang, J., Wang, J., Gu, C., Wang, J., Zhang, B., & Liu, J. (2009). Fabrication of the nanogapped gold nanoparticles film for direct electrical detection of DNA and EcoRI endonuclease. Colloids and Surfaces B: Biointerfaces, 69(1), 99-104

[8.] Yexian Wu, T. A., Sebastian Gautsch, Nico De Rooij. (2011). Development of passivated Heteregeneous metal nanogaps using E-Beam Overlay Technique. Paper presented at the Proc. Eurosensors XXV, Anthens, Greece.

[9.] Francois Beguin, E. F. (Ed.). (2013). Supercapacitors, Materials,Systems, and Applications (Vol. 4). Germany: Wiley-VCH Verlag GmbH & Co.

[10.] Dimitrios P.Nikolelis, T. V., Arzum Erdem, Georgia-Paraskevi Nikoleli (Ed.). (2014). Portable biosensing of food toxicants and environmental pollutants (Vol. 1). New York: CRC Press.

[11.] Tijjani Adam U. Hashim and Th S. Dhahi, Silicon nanowire formed via shallow anisotropic etching, Si-ash-trimming for specific DNA and electrochemical detection, Chinese Physics B Vol. 24, No. 6 (2015) 06810

[12.] Tijjani Adam, U Hashim, Design and fabrication of micro-mixer with short turns angles for self-generated turbulent structures, Microsystem Technologies, 1-8, 2015

[13.] T Adam, U Hashim, TS Dhahi, KN Khor, PS Chee, PL Leow, Electrochemical Etching: An Ultrasonic Enhance Method of Silicon Nano Porous Fabrication, Wulfenia Journal 20 (1), 45-55, 2013

[14.] Tijjani Adam, H Uda, M Eaqub, PL Leow, The electroosmosis mechanism for fluid delivery in PDMS multi-layer microchannels, American Scientific Publishers All rights reserved.2013

[15.] U Hashim, T Adam, J Lung, P Ling, Fabrication of Microchannel and Micro Chamber for Microfluidic Lab-on-Chip.Australian Journal of Basic & Applied Sciences 7 (1)2013

[16.] T Adam and U. Hashim Light Observation in Polymer: A Study of Silicon-Based Organic Polymer Using Visible Spectroscopy, Australian Journal of Basic and Applied Sciences 7 (1), 76-80, 2013.

[17.] U Hashim, MW Al-Mufti, T Adam, Silicon Nanowire Geometry: Investigation of Interaction Site Potential in Semiconductor-DNA Interaction, Australian Journal of Basic and Applied Sciences 7 (5), 242-245, 2013

[18.] MW Al-Mufti, U Hashim, T Adam, Simulation of Nano lab on chip devices by using COMSOL MultiphysicsJournal of Applied Sciences Research 9 (2), 1056-1061, 2013

[19.] T Adam, U Hashim, KL Foo, TS Dhahi, T Nazwa, Technology development for nano structure formation: Fabrication and characterization, Advanced Science Letters 19 (1), 132-137, 2013

[20.] T Adam, U Hashim, PL Leow, KL Foo, PS Chee, Selection of optimal parameters in fabrication of poly (dimethylsiloxane) microfluidics using taguchi method, Advanced Science Letters 19 (1), 32-36,2013

[21.] T Adam, U Hashim, KL Foo, Microfluidics design and fabrication for life sciences application, Advanced Science Letters 19 (1), 48-53, 2013

[22.] T Adam, U Hashim, ME Ali, PL Leow, The electroosmosis mechanism for fluid delivery in PDMS multi-layer microchannel, Advanced Science Letters 19 (1), 12-15, 2013