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A REVIEW ON HIGH SENSITIVE BIOSENSOR USING MEMS

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Abstract— Biosensor using MEMS i.e. BIOMEMS is a device which is used for various biomedical applications. This paper presents a cantilever based biosensor which converts biological recognition analysis into measurable mechanical displacement which is highly sensitive in nature. As the sensitivity of a device is the most important factor regarding to biomedical equipments, this paper deals with the sensitivity of a device. Sensitivity of a cantilever based biosensor decreases with decrease in the concentration of analytes . The sensitivity depends on its deflection of a cantilever based Bio-MEMS due to interaction between the analyte and its complementary bio-receptor molecules. Therefore, designing a cantilever based biosensor which can assay analytes in low concentration is important. The design and development of the cantilever based biosensor to make a device high sensitive either by using different shapes and sizes or a different material for a cantilever structure. This paper proposed to review on an improvement of the sensitivity of a conventional cantilever structure.

Keywords— Micro-Cantilever, Bio-MEMS, MEMS, Bio-receptors, Biosensor.

I. INTRODUCTION

MEMS i.e. Micro-electromechanical system is a process technology which is used to create very small integrated devices or systems that combines an electrical and mechanical component. It ranges from micro to few millimeters and having an ability to sense, control as well as actuate on the micro scale, and generate effect on the macro scale [1]. Bio-MEMS are a micro technology of operating for biological and biomedical applications, which may or may not be contain electronics and mechanical function. It is an integral combination of Electronics engineering, mechanical Engineering, chemical engineering and biomedical engineering. It includes various kinds if applications like proteomics, genomics, diagnostics etc.

Biosensor is the device which is used to convert bio-recognition analysis event into measurable signal [2]. In biomedical equipments, bio-receptor plays vital role which is nothing but bio-molecules combines with and detect a target molecules. The interaction of analyte and antibodies, proteins, nucleic acids are the most common used bio-receptors. Labeling of molecules is a basic requirement for detecting and analyzing bio-molecules and bio-reaction. As it is very expensive, lengthy, and time consuming process, we use a label free detection. For label free detection of bio-molecules, the cantilever biosensor is one of the most significant options as a sensing device due to high throughput [2].

On a cantilever beam structure, the anchor surface is made bio-sensitive by using sensing layer deposited onto it. It contains bio-receptors which are covalently bonded with it [2]. The unique reaction can take place in between analytic solution and its bio-receptor molecules. Fig. 1 shows that when analyte molecules are absorbed by the bio-receptor which is present on the anchor surface of a cantilever structure. The surface stress i.e. force exerted on the surface per unit area is generated that causes to bend the cantilever beam. The deflection is depends on the concentration of the analytic solution. The stress induced on the beam is converted into its equivalent concentrated load that means the surface stress induced by the absorption of bio-molecules on the cantilever surface is equivalent to the concentrated load at free end of a cantilever [2],[3].

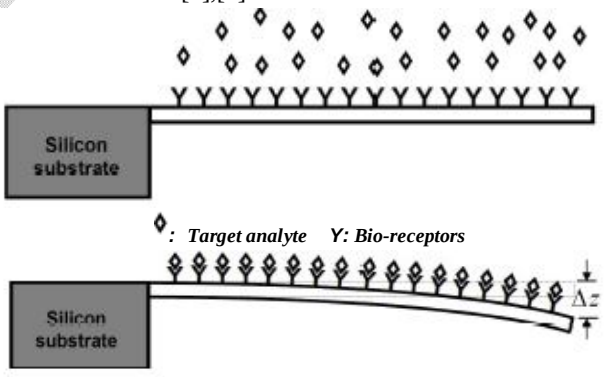

Fig 1 : Working Principle of cantilever based biosensor.

II. LITERATURE REVIEW AND DISCUSSION

In 2004, sandeep Kumar, Ram P. Bajpai and Lalit M. Bharadwaj worked on "Lab-on-a-chip Based On BioMEMS" ,*IEEE*[4], this paper presents The all laboratorial process can be implemented on a single chip; it's called as Lab-on –chip. Micro fabrication of silicon chip will lead to Lab-on-chip for large scale diagnosis of diseases. Lab-on-chip would be made

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from array of few hundred micro cantilevers with each one of them immobilized with probe DNA/antibodies/receptor specific for their complementary bio-molecules.the sensitivity of the Lab-on-chip is directly proportional to the length by thickness ratio of the component micro cantilever. The number of cantilever structure having different analyte molecules increases the sensitivity of a device.

In 2008,Mohd. Zahid Ansari et. al. had proposed their work on "Design and Analysis of a high sensitive Microcantilever Biosensor for Biomedical Applications" at *IEEE*[5], in This paper proposed a new design of the cantilever based biosensor that can detect and measure analytes in extremely low concentration. By introducing a narrow strip towards the fixed end of the conventional cantilever based biosensor, reduction in cantilever flexural stiffness and hence increases in sensitivity of the cantilever beam. The designed geometry of the cantilever beam bends nearly twice as compare to conventional one. Fig 2.Shows the conventional and proposed cantilever designs. For stress of 0.05N/m, the deflection of the conventional cantilever beam is 0.936µm while the deflection of proposed cantilever beam is 1.802µm which improves the sensitivity of the device nearly about twice to the conventional cantilever beam.

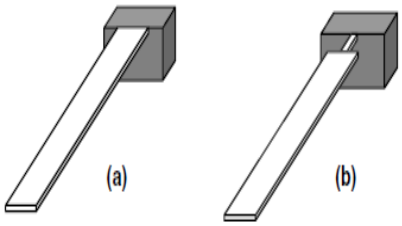

Fig 2: The conventional and proposed cantilever designs;
(a) Conventional model has uniform cross section area
(b) Proposed model has a narrow throat section near base.

In 2013, Yu-Jie Huang et. al. had proposed their work on "A CMOS Cantilever-Based Label-Free DNA SoC With Improved Sensitivity for Hepatitis B Virus Detection" at Ieee transactions on biomedical circuits and systems.[6] This paper presents a highly integrated DNA detection system which is implemented on a single chip is integrated monolithically in 0.35 µm CMOS bio-MEMS process. The cantilever based biosensor with embedded piezoresistor aim to transduce DNA hybridization into variation of resistance by avoiding cumbersome labeling process. To improve the sensitivity for low DNA concentration use, an oscillator based self calibrated circuit with high precision is proposed to convert small resistance variation i.e. 0.02% of original resistance of a sensor into adequate frequency variation. The piezoresistor acts as a physical transducer. After the hybridization process the change of the surface stress induced on the surface of the cantilever which causes a bending movement of the beam, due to that the resistance varies, by using electronic circuits DNA detection can be achieved by extracting the resistance variation of the piezoresistor. The sensitivity differs with different types of the structures of a cantilever beam. The detail specification can be given into table.

Table :1 Details information of cantilever structures.

Cantilever Profile	Width/ Length(µm)	Thickness (µm)	Piezoresistor layout(Rh) (µm)	Sensitivity ΔF/F0@1µm
Rectangular 1	40/150	1.62	12	0.306%
		3.26		0.582%
Rectangular 1	20/300	1.62	12	0.473%
		3.26		0.347%
Split Rectangular	40/150	1.62	5(x2)	0.344%
		3.26		0.034%
Trapezoidal	Top: 75 Bottom: 205 Height :135 Beam Width: 25	1.62	5(x2)	0.289%
		3.26		0.422%

In 2014,Yang Choon Lim et.al. Worked on "A Surface-Stress-Based Micro cantilever Aptasensor"*IEEE* [7]. the work proposed that a design and development of a micro cantilever based aptasensor employing SU-8 polymer as a fabrication material. As the Young's modulus of the SU-8 polymer is low i.e. 4.40 GPa as compare to other polymers like silica, polysilicon, silicon nitride, as a fabrication material, the stiffness is low due to that the sensitivity of the device gets improved automatically. They use an optical method to read out the signal. This method has high resolution and linear response, simple and produces absolute displacement but it is not affordable for low cost diagnosis as it is expensive. The machinery has to be very precise to read out the signal. The SU-8 polymer is poor sensitive in liquid domain. The stability of the device for various applications in pH and temperature are crucial.

III. CONCLUSION

Sensitivity is a precious issue regarding to Bio-medical equipments. MEMS are a best alternative to implement a whole system on single chip. As bio-medical equipments require high sensitivity to get desired results the device should be very much sensible for low concentration of Bio-molecules. From the above discussion this problem can be resolved either by using different polymers as fabrication

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materials or by using different shapes of a cantilever structure. Different methods can be used for detection purpose but stability is also another factor which is to be considered at the time of designing. The optical method gives good results than other methods but it is very costly as well as requires very précised mechanical alignment.

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