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Design of a Cantilever Biosensor for Tuberculosis Detection

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Abstract

In this paper, various materials are used in the cantilever biosensor to review the characteristics of the structure and analyse the better material to be used up for the functionality of the biosensor. The biosensor is simulated using Comsol multiphysics 4.3b. This structure is responsible for the detection of tuberculosis with its displacement value. This type of device provides better accuracy. Sensitivity is the main parameter used in biosensor to detect the tuberculosis. Sensitivity of a cantilever based biosensor is measured using the defection in the cantilever occuring as a result of interaction of analyte with bioreceptor molecules.

Keywords: Cantilever, biosensor, displacement, Bioreceptor

I. INTRODUCTION

MEMS i.e. Micro-electromechanical system is a process technology that is used to create very small integrated devices or systems combining an electrical and mechanical component. Its range is usually from micro to few millimeters.

It has an ability of sensing, controlling as well as actuating on the micro scale, also generating the effect on macro scale [1]. Bio-MEMS are a micro technology of operating in the field of biological and biomedical applications that may or may not contain electronics and mechanical function. It is an integral combination of many fields of engineering. It includes applications like proteomics, genomics, diagnostics etc.

Biosensor is the device which is used to convert biorecognition analysis event into measurable signal [2]. In biomedical equipments, bio-receptor plays a vital role in the detection of target molecules**.**

II. CANTILEVER BASED BIOSENSOR

Cantilever biosensor is used as a sensing device because of high throughput. In the cantilever structure, the surface is made sensitive by depositing sensing layer that contains bioreceptors covalently bonded together onto the surface.The reaction exist between analyte and bioreceptor molecules.

Fig. 1 shows that bioreceptor absorb the analyte molecules in the surface of the cantilever creating stress in the surface to bend the cantilever beam. The deflection depends on the concentration of the analyte. The induced stress on the beam gets converted as concentrated load[9] that can provide the surface stress induced by the absorption of bio-molecules on the cantilever surface.It can be equivalent to the concentrated load at free end of a cantilever [2][3].

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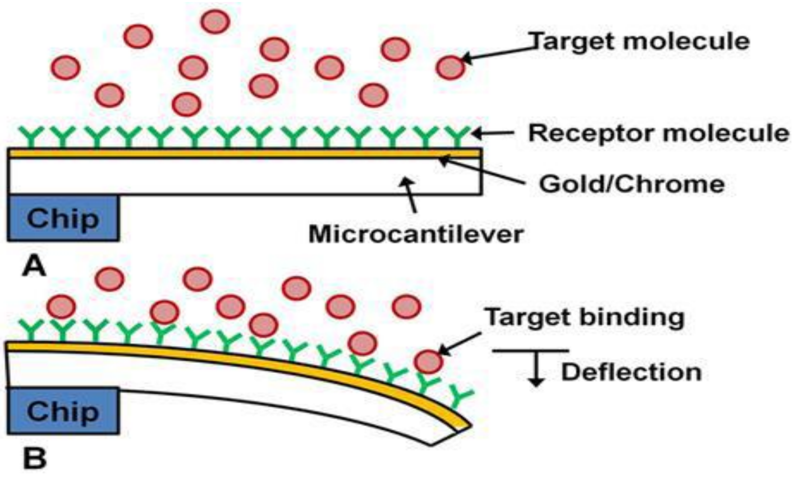

Fig. 1. Cantilever before and after binding[4]

III. CANTILEVER STRUCTURE

An array of four beams in the cantilever are constructed by fixed dimensions with length 150 µm, width 10 µm and thickness 1000 nm in all the cases. A pressure of $3.146167743*10^{-12}$ Pa as input in the surface is given and the deflection is observed. A total pressure of $5.749892771*10^{-12}$ Pa including the antibody and antigen binding is applied in the surface of the cantilever again. It is assumed that antigens interact with all the antibodies of the cantilever. Therefore the displacement of the cantilever will be equal to the deflection caused by the pressure of the antigen antibody binding of the cantilever.

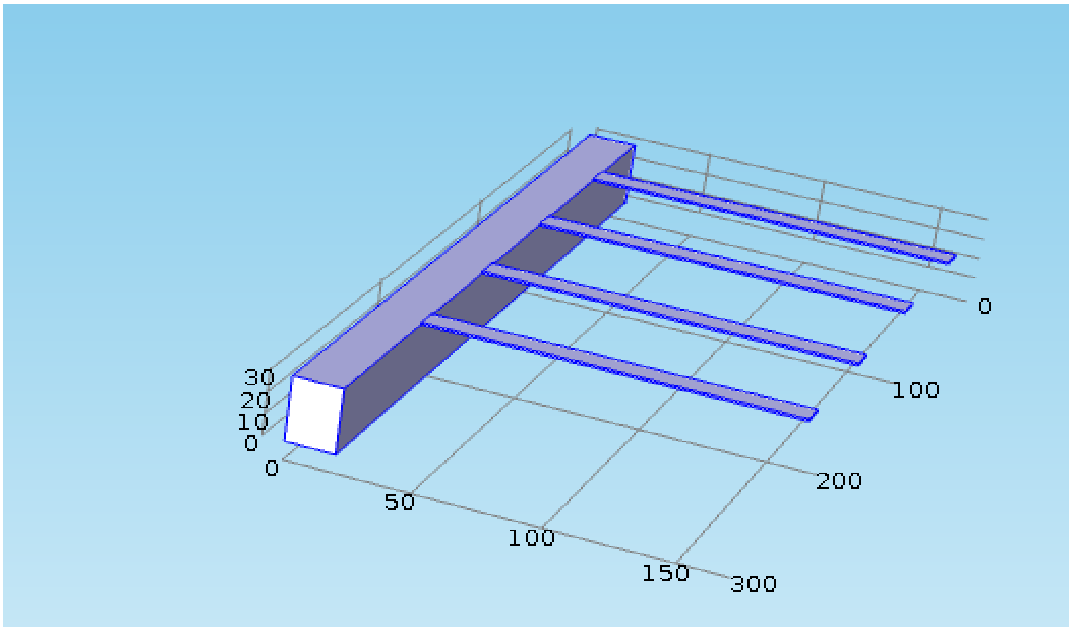

Fig 2 Structure of the Cantilever

By varying the material of the array, performance of the biosensor has been checked for maximum displacement.

The difference in surface stress[6][7] due to molecular adsorption is given by,

$\Delta g = (E.\ \Delta h.t^2)/\ (4(1\text{-}v)\ L^2)$ [7] (1)

Where

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Δg = surface stress change(N/m)
Δh = Cantilever deflection (m)
E = Young's modulus (Pa)
v = Poisson's ratio
t = Thickness of the cantilever (m)
L = Length of the cantilever (m)

The deflection of the cantilever varies with length, width, thickness and various other properties of the material. The cantilever's stiffness is determined by the geometric shape and the material used to build the cantilever.

Sensitivity of the cantilever explained in terms of the spring constant is given by the following equation.

$k = (E.W.t^3)/ (4L^3)$ [8] (2)

Where,

k = Spring constant (N/m)

w = Width of the cantilever (m)

IV. SIMULATION RESULTS

IV.I. Si

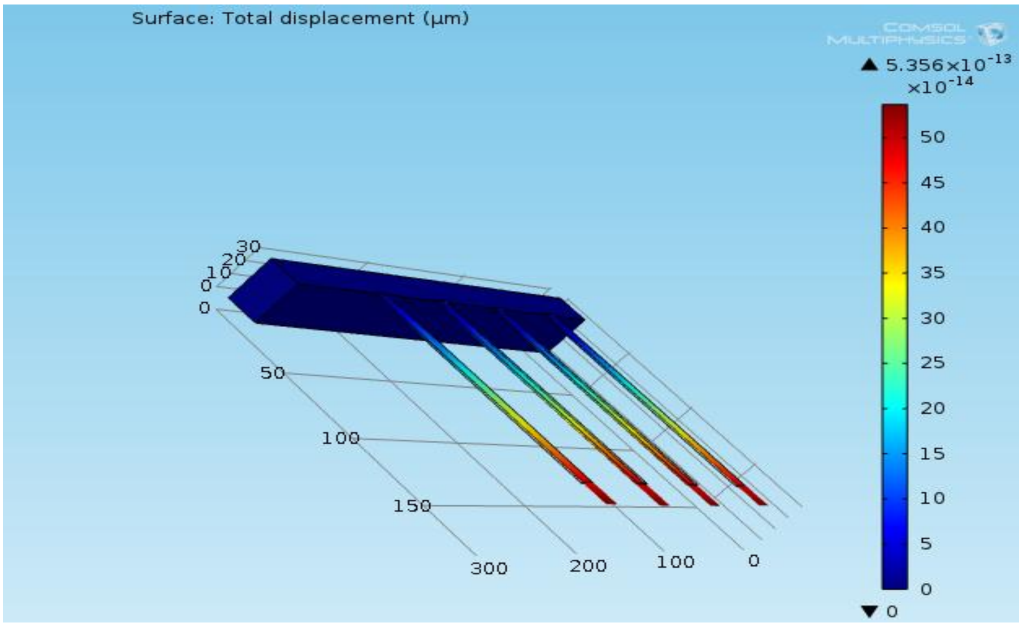

Fig 3 Si Displacement in antigen antibody binding

It displays the displacement of Si in antigen antibody binding.

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IV.II. SiO_2

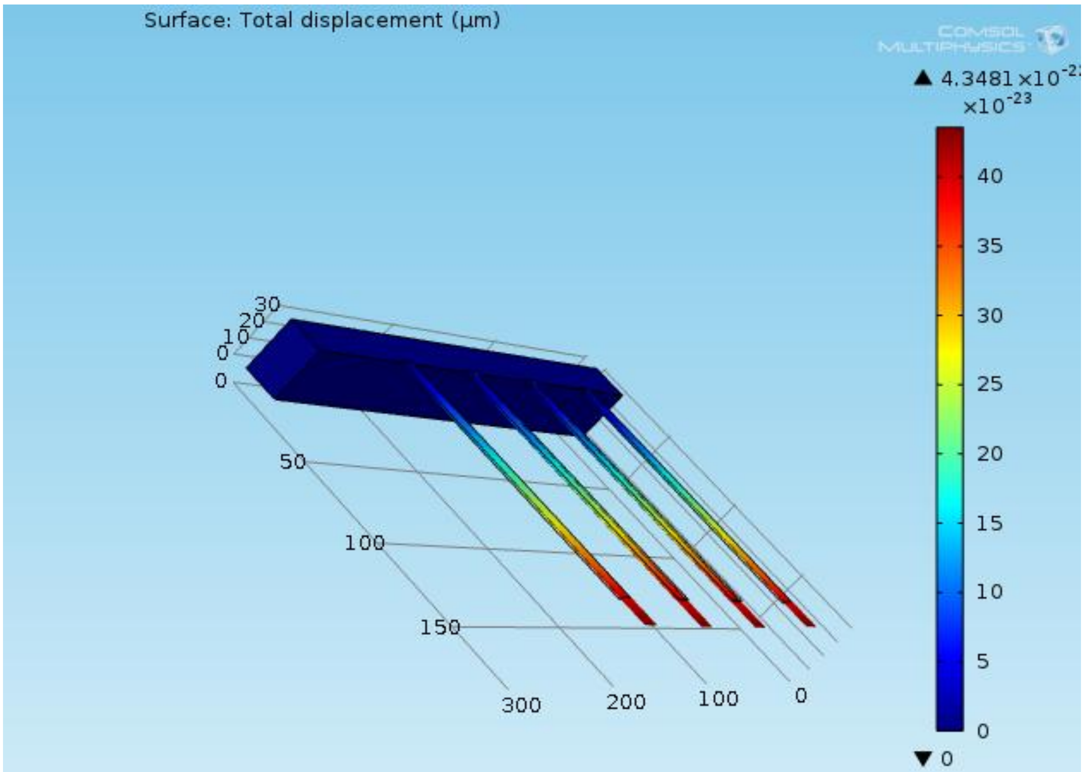

Fig 4 SiO_2 Displacement in antigen antibody binding

It displays the displacement of SiO_2 in antigen antibody binding.

IV.III. SiC

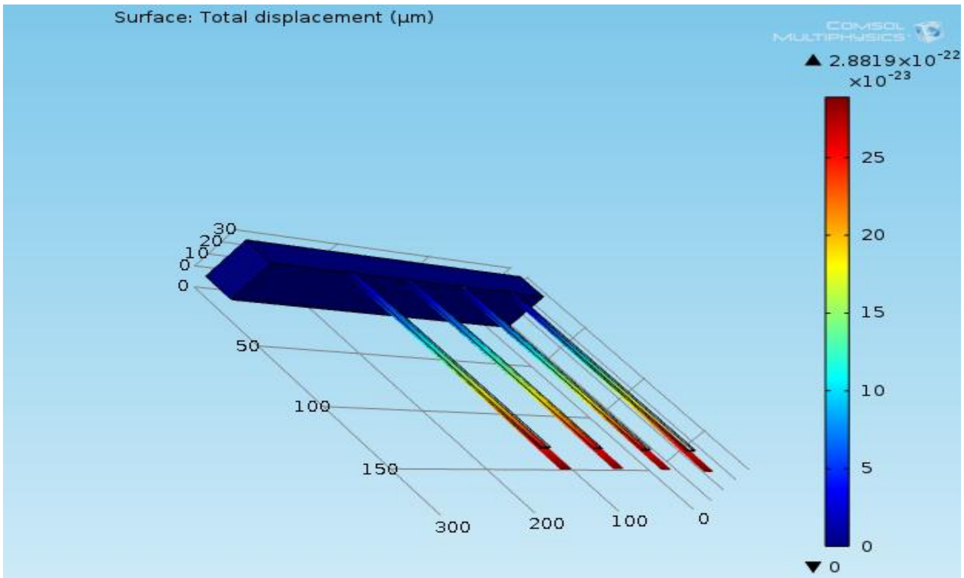

Fig 5 SiC Displacement in antigen antibody binding

It displays the displacement of SiC in antigen antibody binding.

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IV.IV. Si_3N_4

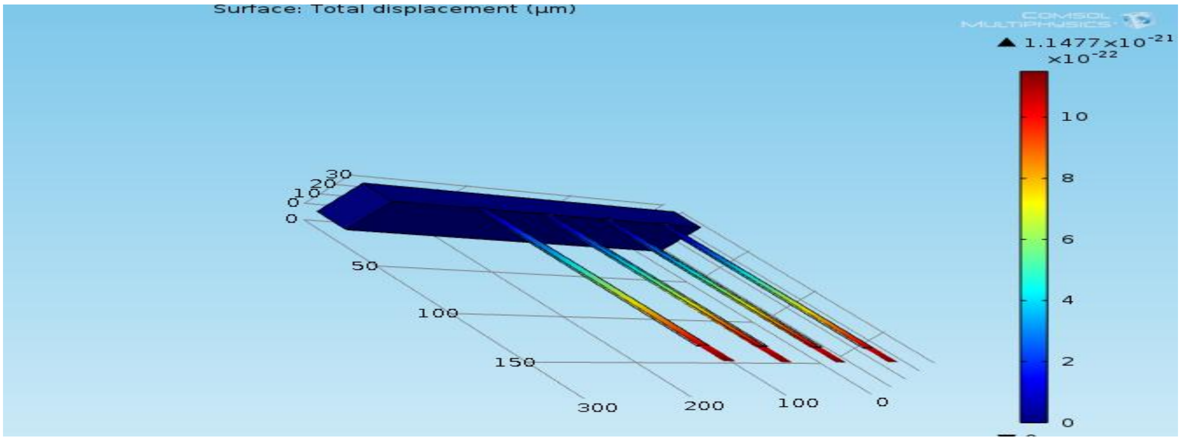

Fig 6 Si_3N_4 Displacement in antigen antibody binding

It displays the displacement of Si_3N_4 in antigen antibody binding.

V. DISCUSSION

From the simulation results, following displacement values have been obtained

MATERIAL	DISPLACEMENT (µm)
Si	5.356 E-13
SiO_2	4.3481E-22
SiC	2.881E-22
Si_3N_4	1.1477E-21

Since SiO_2 has the lowest Young's Modulus of 70GPa among the four materials, the antigen-antibody binding led to a maximum displacement in the surface thus proving the best material for sensitivity. When the length L of the cantilever beam is increased, the spring constant k decreases and the SiO_2 cantilever beam shows increased deflection.

VI. CONCLUSION

The cantilever provides greater displacement which results in higher sensitivity when compared to the conventional devices.Sensitivity is directly proportional to the length of cantilever surface.It is easy to detect tuberculosis with greater accuracy.

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