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Simulation of a Cantilever Biosensor for various Diseases Detection

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Abstract
Development in the field of Microelectromechanical systems has led to the enormous increase in the field of biomedical applications. In this paper, various diseases are simulated in the cantilever biosensor to detect at an early stage. The designs are modelled and simulated using Comsol multiphysics software to get the displacement value. Displacement refers to the changes in the structure by providing force or pressure on the surface of the cantilever. By the displacement value we can identify the type of disease through this biosensor.

Key-words- Biosensor, Cantilever, Disease, Displacement.

1. 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 [Julian et al 2013]. 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 [Bashir 2004].

A biosensor is commonly defined as an analytical device that uses a biological recognition system to target molecules or macromolecules. Biosensors can be coupled to a physiochemical transducer that converts the recognition into a detectable output signal. Typically biosensors comprises of three components:

1. The detector, which identifies the stimulus;
2. The transducer, which converts the detected stimulus to a useful output;
3. The signal processing system, which involves amplification and display of the output in an appropriate format.

A biosensor is an independently integrated receptor transducer device, which is capable of providing selective quantitative or semi-quantitative analytical information using a biological recognition element by the definition of [Thevenot et al. 1999].

2. Design Constraints of Cantilever Biosensor

Any representation of a cantilever such as rectangular, triangular, trapezoidal, v-shaped, t-shaped has a fixed shape anchored at any one of its end.

The design parameters of the cantilever is generally defined by three formulae in [Arora et al (2012)].

i. Stone's formula
ii. Spring constant formula
iii. Hooke's law

They serve us a key source to understand about the behavior of the cantilevers of MEMS.

The cantilever deflection depends on the dimension and the materials used for the construction of the structure. It also decides the characteristic features such as

1. Stiffness of the material used in construction
2. Amount of target molecules, so as to observe and analyze the significant amount of the deflection. Transduction principles are used in order to detect deflections which are small.

3. Cantilever based Biosensor

Cantilever biosensor [Gulsan et al 2015] 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.

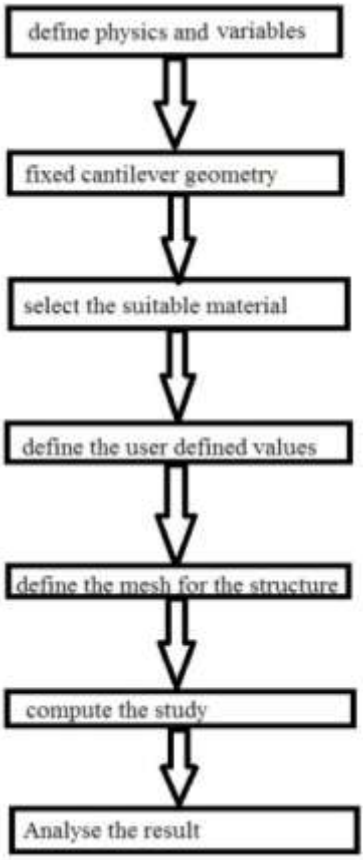
3.1. Fundamental Physics of Cantilever Biosensor

There are three important physics in biosensor. They are:

1. Transduction Principle.
2. Resonant Behaviour of Cantilever Beams.
3. Bending Behaviour of Cantilever Beams.

3.2. Flow Chart of Modelling of Biosensor

Fig. 1- Flowchart of Modelling of Biosensor



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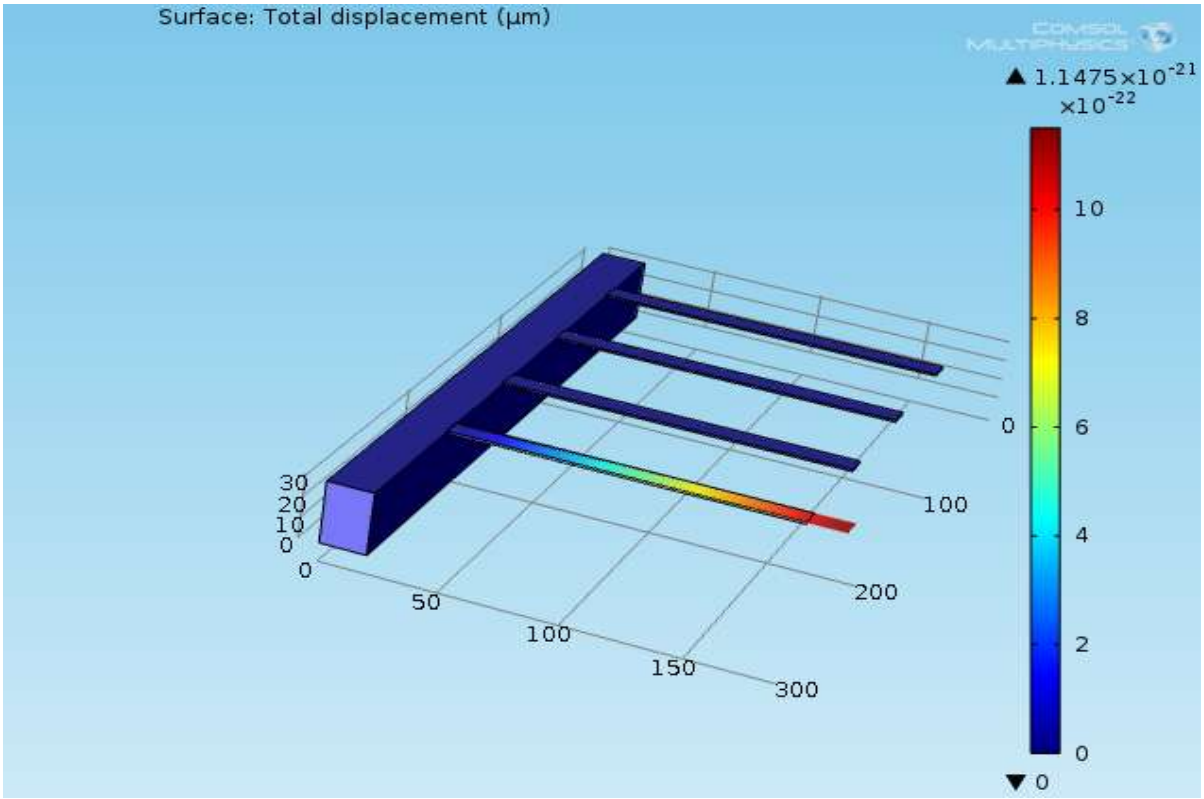
4. Simulation Setup

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 [Bhenesha et al 2021]. These beams are useful for various disease detection in the cantilever structure. A pressure input in the surface is given according to the disease and the deflection is observed. A total pressure including the antibody and antigen binding is applied in the surface of the cantilever again with various values because of the different disease type. 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.

First beam is taken into account for swine flu detection applying Sio_2 as the material and the corresponding pressure.

Fig. 2- Biosensor for Swine Flu Detection



Second beam is taken into account for hepatitis detection applying Si as the material and the corresponding pressure.

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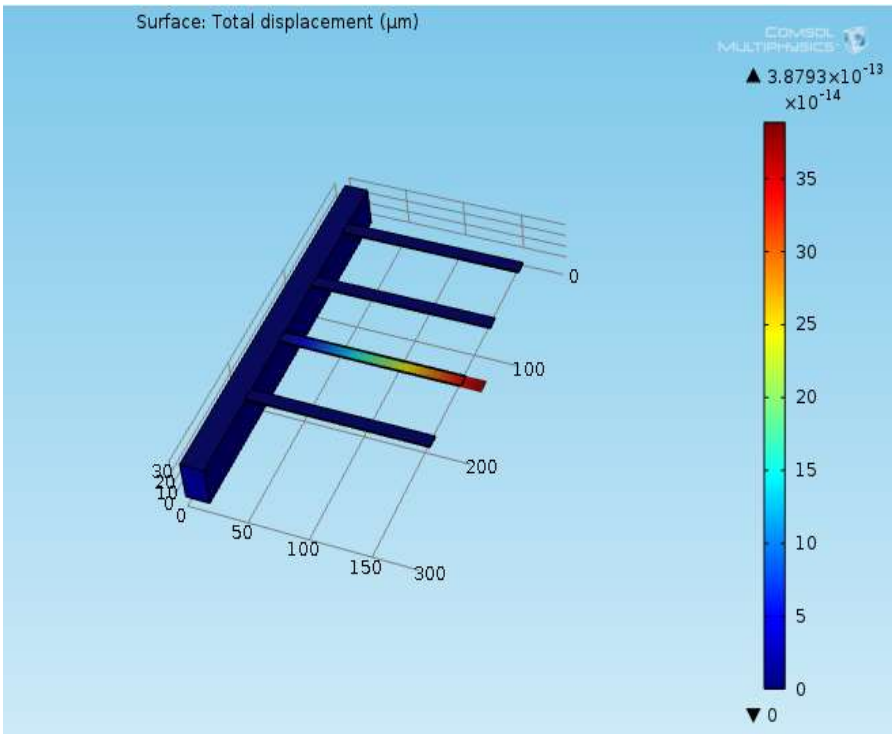
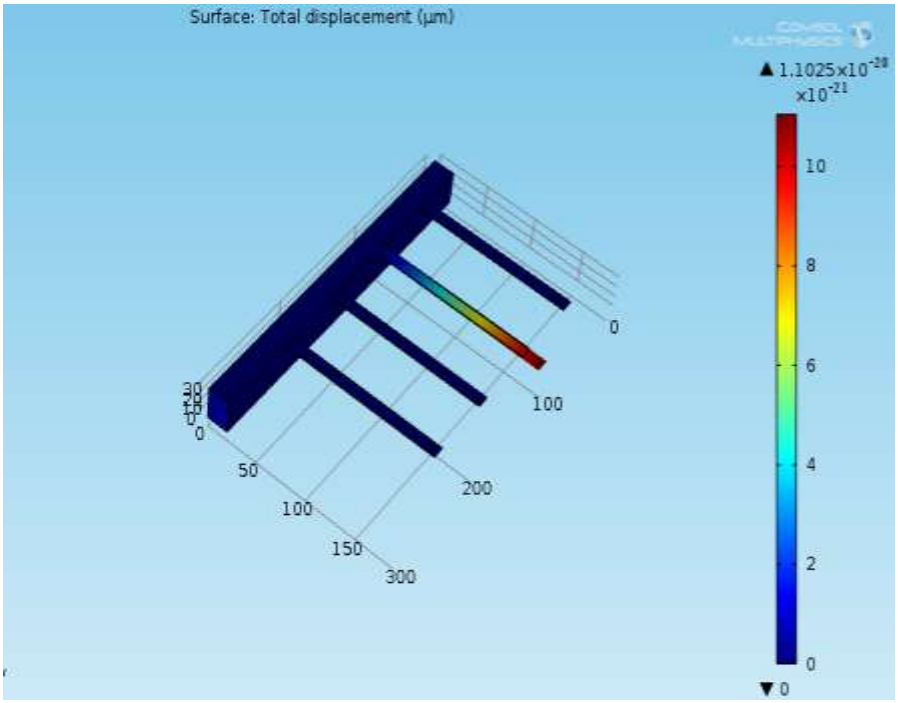
Fig. 3- Biosensor for Hepatitis Detection



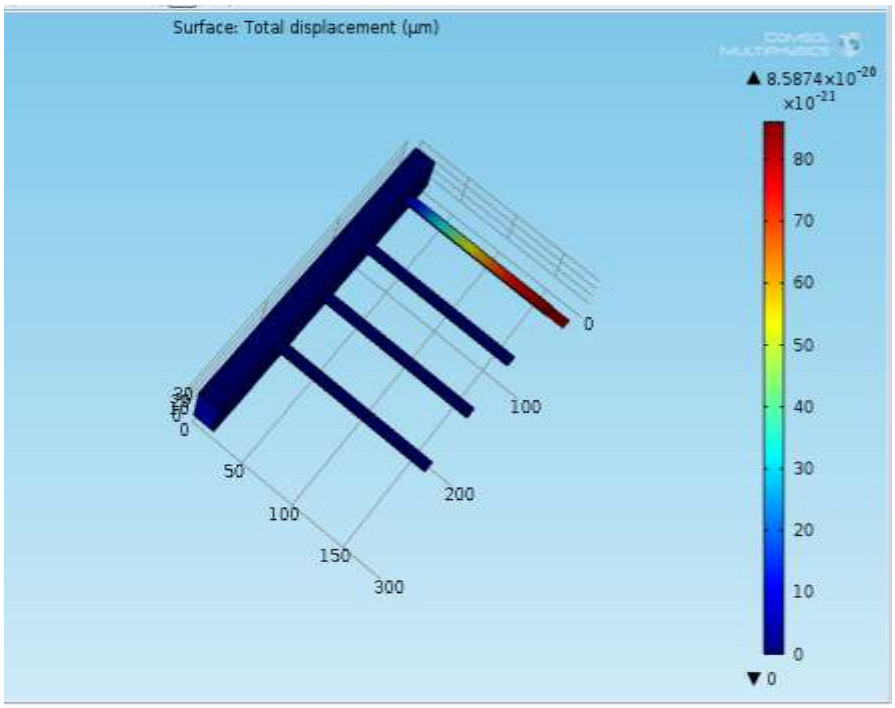
Third beam is taken into account for tuberculosis detection applying gold as the material and the corresponding pressure.

Fig 4- Biosensor for Tuberculosis Detection



Fourth beam is taken into account for dengue detection applying silicon nitride as the material and the corresponding pressure.

Fig. 5- Biosensor for Dengue Detection



5. Results and Discussions

Table 1- Materials and their Displacements for Various Disease Detection

MATERIALS	DISPLACEMENT (μm)	DISEASE TYPE
Sio_2	1.1475E-21	SWINE FLU
Si	3.8793E-13	HEPATITIS
Au	1.1025E-20	TUBERCULOSIS
Si_3N_4	8.5784E-20	DENGUE

From the table, we can analyse the different types of disease detection by the displacement value which occurs as a result of antibody-antigen binding.

6. Conclusion

The cantilever biosensor provides the accurate displacement in each case to identify the disease with better accuracy. The displacement value thereby got has good results when compared to

conventional biosensors. Hence they can be used in the biomedical field for the early detection of various diseases.

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