Simulation of Cantilever Biosensor for Rapid Detection of Mycobacterium Tuberculosis

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***Abstract*—Mycobacterium tuberculosis is a very dangerous pathogen which causes tuberculosis. Every-year this hazardous syndrome affects to millions of peoples. It is an airborne disease because bacteria of tuberculosis transfer from one person to another via air. There is various traditional methods are available to detect tuberculosis, but every method has some limitations and not get fast and exact result. Thus there is a spacious necessity to develop extremely sensitive tools which gives perfect and prompt throughput. In the present circumstances biosensors plays an important role to detect various diseases at a premature phase. The purpose of the research article is to acquire knowledge and simulate the structure of cantilever biosensor for expeditious sensing the bacteria of tuberculosis. The structure of cantilever biosensor is a layered with the surface made of various materials. The cantilever top plane is varnish with antibodies. The antibodies coated on the surface of cantilever get binds with the antigens when the sample is placed on it. After binding of antigen-antibody it gives the result as displacement of the beam.**

***Index Terms*—Biosensors, Cantilever, Mycobacterium Tuberculosis, Antigen, Antibody.**

I. INTRODUCTION

In the field of medical various technologies were adopted to diagnose and prevent diseases. Most health related issues were sorted with the help of modern technological skills. Biosensor plays a crucial role in medical field due their sensitivity and stability. Using various types of biosensors researchers has done a noticeable work to diagnose the several diseases. But till today some diagnoses process are in developing stage. Tuberculosis is one of them as tuberculosis detection is a very tedious job.

Mycobacterium tuberculosis is a very dangerous pathogen which causes tuberculosis. It is most severe transmissible syndrome that mostly harmed to the lungs. The tuberculosis bacteria are escalated through small droplets via coughs and sneezes [1][2][3]. Since several decades, tuberculosis impact on the fitness of persons mainly in emerging countries such as India and sub-Saharan Africa, it affects to all age groups of peoples [1]. Tuberculosis is of Pulmonary and extra pulmonary types. Lungs organs are infected in pulmonary tuberculosis and in extra pulmonary tuberculosis skin, joints, bones and other part of bodies are infected [4, 5, 6]

Across the world, Tuberculosis is among the top ten diseases, which leads to death ranking above HIV/AIDS [7]. Every year millions of peoples were infected by this deadly disease. In 2015 near about 9.6 million new TB instances were found from these peoples 1.5 million people were departure from their life. Similarly in 2016 near about 10.4 million new TB instances were found from these 1.4 million people were death. As considering the ratio of 2015 and 2016 TB cases it was estimated that it goes in the increasing order [8, 9, 10, 11, 12, 13, 14, 15]. It has been estimated that TB cases are sky-scraping due to the expanding in HIV cases [16]. Bacteria of tuberculosis spread rapidly that becomes a drug resistant, due to disease not get diagnosed within time which led to increased mortality [17]. Thus a quick and inexpensive detection technique is required to reduce or to stop spreading this dangerous disease. In this research article Cantilever-Biosensor were design and simulated for diagnosed the bacteria of tuberculosis because the sensitivity and result generated capacity of cantilever biosensor is much superior then other sensors.

II. ANTIGEN-ANTIBODY

The tuberculosis was causes by the antigen ESAT-6 and CFP-10. The antigen ESAT-6 having the

molecular load as 6KDa and the molecular load of its antibodies is 11KDa. Therefore the combined weights of Antigen-Antibody are 17KDa, where 1.661 x 10^{-24} kg is approximate value of 1KDa. According to this the collective weight is 28.228 x 10^{-24} kg for ESAT-6 antigen and antibody [18, 19].

The surface force range of interactions of antigen-antibody is 10N to 100N. In the process of single antigen-antibody interaction, the intermolecular force produced is 10N [20]. The intermolecular force of 10 such antigen-antibody interactions is estimated which is applied on a cantilever surface for demonstrate the deformation value. Thus 28.228 x 10^{-24} kg is the load of 10 antigens [21].

III. BIOSENSORS

A biosensor is a device which used to detect the bio-molecules and convert the response into an electrical signal for analysis purpose. Biosensors recognize the biological elements based on antigen and antibodies. When antigen-antibody binds together the sensing layer of biosensor converts the biological response into a quantifiable electrical signal. An antibody, nucleic acid, cell structure can be used as a bio-component. These antibodies interact with the targeted analyst that generates the biochemical reaction which converted into measurable signal through transducer. The transducer can be classified in optical, electrochemical, piezoelectric, and magnetic [21]. Figure 1 shows the flow of biosensor.

Considering the traditional and bio-sensing techniques, it has been observe that bio-sensing methods are quick and responsive for detecting the various diseases.

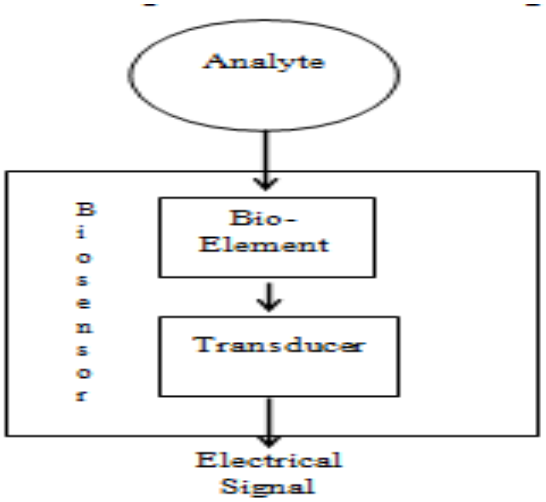


Fig. 1. Biosensor

IV. CANTILEVER BIOSENSORS

The structure follow by micro cantilevers are based on Micromechanical and Electromechanical sensors. One end of this cantilever is restricted and another end is unrestricted for displacement. The cantilever structures are extensively used due to their performance to detect the bio-molecular elements was superior and highly sensitive [19, 22]. The deflection of the cantilever sensor is affected by the tension on the sensitive surface of the cantilever which is created due to the adsorption of bio-molecules. Deflection illustrates that the precise substances are available in the sample when antigen-antibody get binds together. Mass on cantilever surface gets increase when antigen interacts with bio receptor and then it bends on free end of cantilever sensor. Cantilever biosensors are specially used for detection of biological elements. It has the functionality of quick and easy detection and perfect measurement of molecules which were attached to their surface. Now days various fields used micro cantilever beams, including pathogenic labs for different molecules detection for-instance tuberculosis, HIV etc [22]. In the field of medical cantilever biosensors are eye-catching tools through which various diseases can be detected. Detection through cantilever sensor, ablution of sample not required this is the main advantage over the traditional methods [23].

The surface of cantilever is design as bio-sensitive through binding precise antibody on the top layer of beam. In figure 2 the antibody is shown as Y shaped protein which works as immune system to detect foreign objects such as microorganism and viruses. The foreign object means antigens are recognize by the antibody [24].

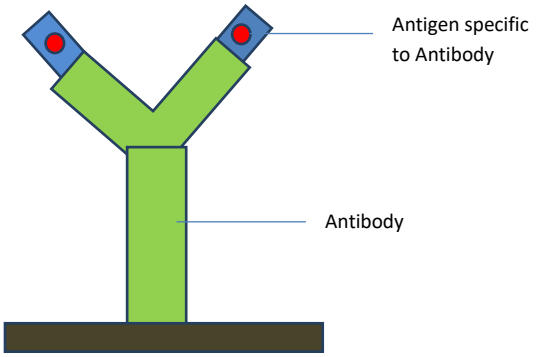


Fig. 2. Antibody Binding to Specific Antigen

This Cantilever is accessible in a various shapes, dimensions and force sensitivities and they are made of various materials such as silicon substrate.

V. METHODOLOGY

Fusion 360 software has been used to design and simulate the cantilever sensor. Size of cantilever for simulation is considered as length of beam is 500mm, breadth of beam is 300mm and thickness is 100mm. In fusion 360, cantilever sensors were simulated by giving input as static stress and load force applied to cantilever are 10N and 100N.

Output gets as deflection of cantilever beam at free end as shown in figure 3a to f.

To measure the deflection for cantilever beam of rectangular cross section having a point load on free end is

Deflection = $PL^3/3EI$

Where,

P is load applied,

L is Length,

E is Young's Modulus,

I is Moment of Inertia

and

$$I = BD^3/12$$

Where B and D are Breadth and Thickness.

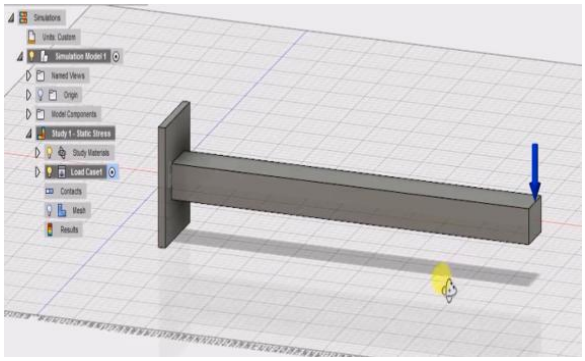


Fig. 3. a.

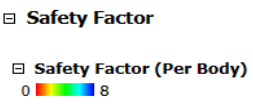
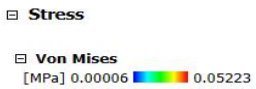


Fig. 3. b.



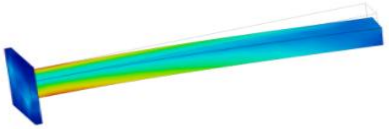


Fig. 3. c.

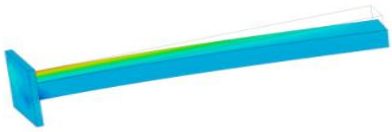


Fig. 3. d.

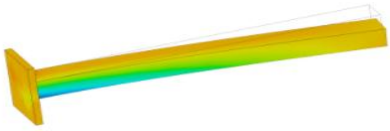
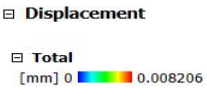


Fig. 3. e.



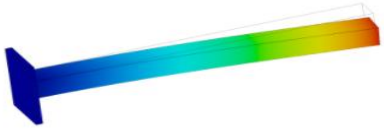


Fig. 3. f.

Fig. 3. a to f Step by Step Displacement Cantilever Model For Load Force of 100N

VI. RESULT AND DISCUSSION

Simulation model of Cantilever biosensor for a surface load of 100N resembles to 28.228 x 10^{-24} kg load of antigen which accomplished 8.206 x 10^{-3} mm as maximum displacement, whereas for 10N it

accomplished 8.206 x 10^{-4} mm displacement. After analyzing both load it has been noted that applying 100N force load cantilever sensor gives maximum displacement. Thus rectangular shape cantilever sensor is a best model for detection of tuberculosis.

VII. FUTURE SCOPE

The rectangular shape cantilever sensor is a perfect model for manufacturing. After manufacturing the model the displacement can be measured using piezoelectric sensor.

VIII. CONCLUSION

Tuberculosis is a hazardous disease which is infected to millions of peoples every year. This disease becomes an unsolved global health issue because of its complex and expensive detection technique. It is necessary to use simple and rapid detection techniques. Cantilever has experienced an exponential growth in medical field for disease detection. In this paper, simulation model of cantilever biosensor has been designed for detection of tuberculosis. ESAT-6 antibodies has been considered for the surface layer of cantilever beam. The fusion 360 software were used and simulation results of displacement are considered and presented the step by step displacement. The cantilever model for 100N load force correlate with 28.228 x 10^{-24} kg weight of ESAT-6 antigen which accomplished 8.206 x 10^{-3} mm as a maximum displacement and this model considered as best model for tuberculosis detection. In future this model can be used for manufacturing the biosensor for detection of tuberculosis.

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