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Design of MEMS Biosensor for Pathogenic Bacterial Disease Detection.

Ms. K. R. Katole[1], Mrs. S.P Balwir[2], Mr P. P Manekar[3]

[1,2]Department of ECE, Assistant Professor, Dr. Babasaheb Ambedkar College of Engineering & Research, Nagpur, India
[3]WWT Divisoin, Scientist, CSIR, National Environmental Engineering & Research Institute ,Nagpur, India.

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***Abstract*— *In situations of a critical disease outbreak, any time delay in identifying the pathogen can prove to be risky and has its far-reaching effects on public health systems. There is a need for pathogenic bacteria detection at the point-of-care (POC) using a fast, sensitive, inexpensive, and easy-to-use method that does not require complex infrastructure and well-trained technicians. For instance, detection of pneumonia, tuberculosis at acute infection stage has been challenging, since current antibody-based POC technologies are not effective due to low concentration of antibodies. In this study, we demonstrated for the first time a label-free electrical sensing method that can detect pathogenic bacteria, through MEMS cantilever technology. The presented method offers a rapid and portable tool that is MEMS biosensor, can be used as a bacteria detection technology at the hospital and primary care settings.*

***Keywords*— Biosensor, Micro-cantilever, pathogen, MEMS.**

I. INTRODUCTION

A Micro-cantilever is a device that can be used as physical, chemical or biological sensor by detecting the changes in cantilever bending or vibrational frequency. It is the miniaturized duplicate of a diving board that moves up and down at regular intervals. This deflection of micro cantilever changes when a specific mass of an analyte is specifically adsorbed on its surface similar to change when a person steps onto the diving board.

The development of electrochemical micro-sensors in micro-scale is a revolutionary advancement for non-destructive and in situ measurements of both absolute levels and changes in chemical and biological species in engineered and natural aquatic systems. A needle-type electrochemical micro-sensor represents one of the most prominent methods for better understanding fundamental mechanisms contributing to the rates and magnitude of liquid-solid (e.g., corrosion and biofilm) interfacial chemical and biological reactions.

II. PATHOGENIC BACTERIA

The human body is continually exposed to many species of bacteria but Pathogenic bacteria are those bacteria that can cause disease. Pathogenic bacteria may cause different disease like pneumonia, tuberculosis, cholera, anthrax, leprosy, the bubonic plague and many more. Pneumonia is a lung disease, caused by infections. The many causes of pneumonia include bacteria, viruses, fungi, and parasites. We are concentrating on bacterial pneumonia in this paper.

Also in this paper, we are going to study about the Bacteria a microorganism made of a single cell, having a variety of shapes and features, and can live in just about any environment, including in and on human body. Most species of bacteria are harmless and are often beneficial but others can cause infectious diseases.

Streptococcus pneumoniae bacteria are lancet-shaped, Gram-positive cocci, that are typically observed in pairs (diplococci) but which may also be found as individual bacteria or in short chains. Most S. pneumoniae serotypes can cause disease, but only a minority of serotypes produce the majority of pneumococcal infections [16].

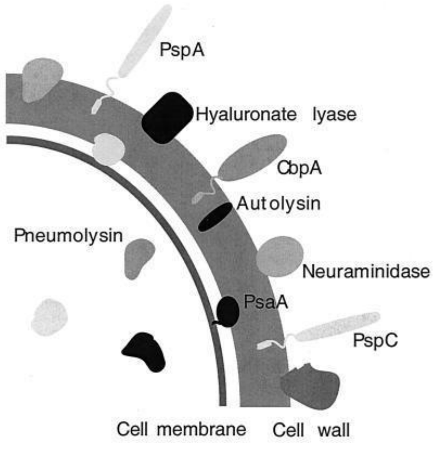

Fig.1 Schematic diagram of the virulence factors of S. pneumoniae [14].

III. OBJECTIVE FRAMING

Objectives of this Research is, to explore the challenges of existing biosensor and their operation.

1. To expose the recent trends and advancement in the field of MEMS.
2. To study the different pathogenic bacteria.
3. To study the different micro-cantilevers.
4. Design and simulation of micro-cantilevers with different specifications using COMSOL software.
5. To implement the designed micro sensor for pathogen detection.
6. To reduce the time and cost of micro sensor as compare to the existing one.

IV. METHODOLOGY

Detection of pathogens in liquid medium has significant applications in medicine (for the monitoring of biomarkers in body fluids) and in public health (for the monitoring of disease agents in water). For point-of-care (POC) diagnostics applications, compact and label-free sensors that can operate directly with body fluids without requiring expertise are desired. There are many methods for bio sensing.

In this study, we proposed to develop a biosensor for pathogenic bacteria detection.

In the first stage, various pathogenic bacteria will be analyzed with the help of microbiologist after collecting various samples.

A micro cantilever will be virtually fabricated and simulated by using software like Coventor or COMSOL

Here the surface stress-based sensors as bio-chemical sensors will be developed.

The antibody-antigen interaction on the surface of the microcantilever generates a quasi-static deflection which was detected by analyzing the motion of the scanning laser along the entire length of the cantilever. By analyzing the intensity of the reflected signal and integrating the derivative of the topography, one can obtain the profile of the entire micro-cantilever surface.

The MEMS fabrication needs many techniques which are used to construct other semiconductor circuits like oxidation process, diffusion process, ion implantation process, low-pressure chemical vapor deposition process, sputtering, etc. Additionally, these sensors use a process like micromachining.

MEMS cantilever gives quick and exact response based on bio molecular activities as compare to the conventional cantilever design [8]. First the Clinical Samples of streptococcus bacteria to Be Collected. Next proposed approach is to coat a microcantilever with antibodies that bind the streptococcus bacteria. When bacteria bind to the microcantilever, its effective mass changes resulting in changes in the resonant frequency of the cantilever vibration [3].

In such cantilever, the settling time of biomolecule, which is mainly taken by the analyte molecule to settle down on the sensor surface, decreases and provides rapid detection of biomolecules. There are two operating mode of cantilever: static and dynamic. In former, the deflection is measured by the pressure produced by the biomolecules on the cantilever surface. In later, the concentration of biomolecules is measured by detecting the change in oscillating frequency with respect to the change in mass, where applied sinusoidal voltage is kept constant. The deflection at the micro cantilever beam can be monitored by various methods namely, optical reflection, capacitive and electron tunneling, interferometric and piezoelectric based detection. The optical reflection is most effective method for deflection detection. [8]

There has been increased utilization of nucleic acid-based biosensors for pathogen detection. Hybridization of deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) on the sensor surface causes signal change; and detection of gene identification sequences using that signal change can reveal analyte identity [10].

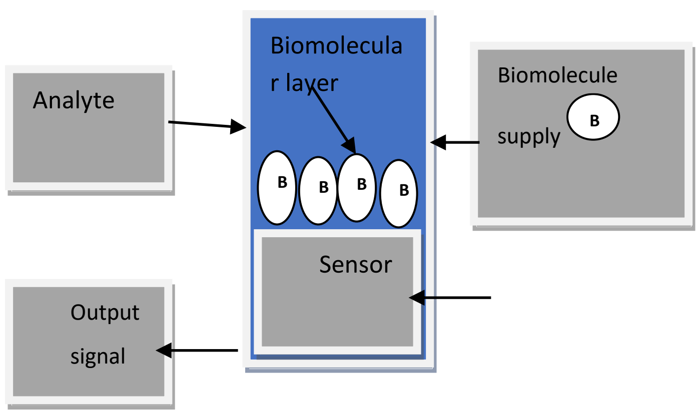

Fig 2: Schematic of Biosensors. [15]

V. TECHNICAL NOVELTY

Diagnosis and monitoring of complex diseases require quantitative detection of multiple pathogens. Recent study has shown that when specific biomolecular binding occurs on one surface of a microcantilever beam, intermolecular Nano-mechanics bend the cantilever, which can be detected.

VI. CONCLUSION

Microbial identification of pathogens causing pneumonia is an important issue for optimum clinical management of pneumonia and is a major challenge globally, given the expanding rate of multidrug-resistant pathogens and the emergence of new pathogens.

This concludes the study of MEMS microcantilever as a bio sensor which is applicable for sensing pathogenic bacteria. The overall goal of this device is to become a portable platform for pathogenic bacteria detection, detecting various bio analytes for the disease pneumonia identification. These MEMS sensors hold advantages such as low cost of productional due to lesser materials, easy integration, greater portability, robustness and low power consumption.

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