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"OPTICAL BIOSENSORS"

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SIR M. VISVESVARAYA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

CERTIFICATE

Certified that the Technical Seminar (18ECS86) on **"OPTICAL BIOSENSORS"** prepared by **N.B. VIDHYASHREE (1MV19EC068)**, a bonafide student of **SIR M. VISVESVARAYA INSTITUTE OF TECHNOLOGY.** The report is in partial fulfillment of the requirements for the award of the degree of "**Bachelor of Engineering**" in **Electronics and Communication Engineering.** From the **Visvesvaraya Technological University**, Belagavi, Karnataka, India, during the academic year 2022-2023. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report submitted to the Department. The Seminar report has been approved as it satisfies the academic requirement in respect to the work prescribed for the said Degree.

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DECLARATION

I hereby declare the Seminar Report on **“OPTICAL BIOSENSORS”** undertaken has been presented under the guidance of Dr. Sasmita Mahopatra, Associate Professor, Department of Electronicsand Communication Engineering, Sir MVIT, Bengaluru. This topic has not been submitted previously in the Dept. of ECE and any other Departments of Sir MVIT.

Place: Bengaluru	N.B. VIDHYASHREE
Date:	1MV19EC068

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A technical seminar is incomplete if it fails to thank all those instrumental in the successful completion of the report.

I welcome this opportunity to convey my regards, gratitude, respect, decorations, and a lot of thanks to them who inspired me to complete this report in the stipulated period of time provided.

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ABSTRACT

Biology has played an important role for engineers in developing increasingly powerful machines. Biosensors are the combination of bio receptor and transducer. The bio receptor is a biomolecule that identifies the target whereas transducer converts the identified target into the measurable signal. Biosensors are analytical devices that combine a biological component with a physicochemical detector to detect, identify, and measure the concentration of specific biomolecules or analytes in a sample. The biological component of a biosensor can be an enzyme, antibody, nucleic acid, or other biological molecule that can interact specifically with the target analyte. The physicochemical detector converts the biological signal into a measurable output signal, such as an electrical or optical signal.

Optical Biosensors generate output depending on the light transmitted or emitted in the presence of analyte or group of analytes in biological systems. The output of the optical biosensor is measured by analyzing the changes in frequency, amplitude, polarization, and phase of the output light excited by the recognition element due to the presence of a chemical or biological element.

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CHAPTER – 1

INTRODUCTION

Biosensors are analytical devices that convert a biological response into an electrical signal. Quintessentially biosensors must be highly specific, independent of physical parameters such as pH and temperature and should be reusable. The materials used in biosensors are categorized into three groups based on their mechanisms: biocatalytic group comprising enzymes, bio affinity group including antibodies and nucleic acids, and microbe based containing microorganisms.

Two important components of biosensing:

1. Bio recognition element to detect chemical or biological species.
2. Transduction mechanism which converts physical or chemical response of biorecognition into another signal.

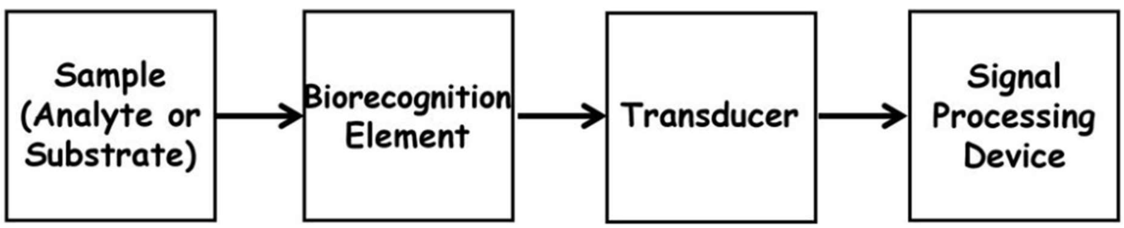

Figure 1 : Block diagram of a Biosensor

Biosensor is broadly classified into two classes:

1. **On the basis of biological element**
    - Enzyme Biosensor.
    - Microbial Biosensor.
    - Antibody Biosensor.
2. **On the basis of Transducing element**
    - Calorimetric/Thermal detection Biosensor.
    - Optical Biosensor.
    - Resonant Biosensor.
    - Piezoelectric Biosensor.
    - Ion selection Biosensor.
    - Electrochemical Biosensor.

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Optical biosensors are the most commonly reported class of biosensors. Optical biosensors are a type of biosensor that uses light to detect the presence of biological molecules or other analytes. Optical biosensors are based on the principle of detecting changes in light transmission, absorption, fluorescence, or surface plasmon resonance (SPR) caused by the binding of the target analyte to a biological recognition element. There are several types of optical biosensors, including surface plasmon resonance biosensors, fluorescence biosensors, and colorimetric biosensors. Surface plasmon resonance biosensors use the interaction of light with a metal surface to detect the binding of the target analyte to a biological recognition element immobilized on the surface. Fluorescence biosensors use the emission of light by fluorescent molecules to detect the binding of the target analyte to a biological recognition element. Colorimetric biosensors use the change in color caused by the binding of the target analyte to a biological recognition element.

Optical biosensors have several advantages over other types of biosensors, including high sensitivity, selectivity, and real-time monitoring capabilities. They are also non-invasive, non-destructive, and can be used for high-throughput screening. Optical biosensors have many applications in various fields, including medical diagnosis, environmental monitoring, and food safety.

Optical biosensors offer a promising approach for the development of sensitive and selective biosensors, and ongoing research is exploring new ways to improve their performance and expand their applications.

CHAPTER – 2

LITERATURE SURVEY

2.1 PAPER 1- J. Joy, M. Zhang, X. Dai, R. Fu, Z. Ghassemloosy and Q. Wu, "Fibre Optics Biosensors for the Detection of Bacteria – a review," 2022 13th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP), Porto, Portugal, 2022

This papers tells about Optical fiber Biosensing for bacteria detection is an emerging technology in the past two decades, which has advantages of high sensitivity, small size, and capability for real time monitoring. In this paper, different types of optical fiber bacteria biosensors were classified and summarized.

Traditional bacteria detection method is the microbiological culturing method, which is the top standard method till the 20th century, due to its exceptional sensitivity and specificity. The microbiological culturing method can analyze a single cell of bacteria in a sample but are very slow (typically 1-2 days, sometimes requires more time to detect bacteria), which might delay the purpose of targeted detection. Also, the microbiological culturing method is expensive, immobile, and need tedious sample preparation and processing of measured values. To solve these problems a wide range of biosensors has been created in recent years. A biosensor is an analytical device that is used to detect and recognize an analyte or group of analytes that combines a biological component with a physicochemical detector . They convert biological changes into electric signals. Based on signal transduction, biosensors are classified into optical, electrochemical, thermal, magnetic, and piezoelectric biosensors

2.2 PAPER 2- Q. Li, L. Ding, Y. Zhang and T. Wu, "A Cholesterol Optical Fiber Sensor Based on CQDs-COD/CA Composite," in *IEEE Sensors Journal*, 1 April, 2022

Cholesterol is a substance that comes from the food we eat and is necessary for our body to function properly. It helps build cell membranes, maintain normal cell activities, and build cell structure. Healthy people typically have cholesterol concentrations ranging from 1.16-2.02 mg/ml. If the concentration is too low, anemia and reduced resistance may occur. However, if the concentration is too high, it can cause obesity and increase the risk of cardiovascular diseases. To maintain good health, it is important to measure cholesterol content and control its concentration within a normal range. This has practical significance for clinical disease diagnosis and prevention.

There are many ways to measure cholesterol levels in the body, including gas-liquid chromatography-mass spectrometry, molecular luminescence, colorimetry, and electrochemical methods. Enzymatic determination is a common and effective method because it is simple, selective, and sensitive. Most enzymatic methods use electrochemical or fluorescence techniques. Electrochemical methods use modified electrodes to convert cholesterol levels into electrical signals, while fluorescence methods use a fluorescent material to detect cholesterol levels. Optical biosensors are a newer but growing field, with carbon quantum dots being used as a fluorescent material to develop a cholesterol biosensor. The CQDs-COD/CA composite sensitive film is fixed onto a quartz fiber by lifting plating method to create a novel cholesterol optical fiber biosensor, which can detect cholesterol levels in a large concentration range.

2.3 PAPER 3- U. Saha, Y. G. Srinivasulu, D. M, R. R. G. Soares, N. Madaboosi and V. V. R. Sai, "Plasmonic Fiber Optic Absorbance Biosensor for MDR-Mtb detection using Padlock Probing," *2022 Workshop on Recent Advances in Photonics (WRAP)*, Mumbai, India, 2022

India is one of the 14 countries with high rates of Multidrug Resistant-Tuberculosis (MDR-TB). To address this problem, a new technology called plasmonic fiber optic absorbance biosensor (P-FAB) has been developed to detect MDR genes of Mycobacterium tuberculosis. The P-FAB uses a method called Rolling Circle Amplification (RCA) to amplify DNA samples for sensitive detection. The P-FAB platform can detect RCA-generated amplicons using a U-bent optical fiber probe sensor with a nanoparticle-labeled DNA assay, allowing for better detection of TB. This new technology can help improve clinical sensitivity towards multiplexed TB detection.

Tuberculosis (TB) is a long-term respiratory infection caused by Mycobacterium tuberculosis (Mtb). Some of these bacteria have become resistant to drugs, making it difficult to treat. This is called multi-drug resistance (MDR) and it's a big problem in India and other countries. A way to detect MDR TB is needed urgently. One method for detecting the bacteria is Polymerase Chain Reaction (PCR), but it's expensive and requires skilled personnel. Rolling Circle Amplification (RCA) is a promising method that can amplify DNA or RNA. It uses padlock probes (PLPs) that circle around the target sequence and are amplified. The amplified product (RCP) can be detected using a U-bent optical fiber sensor probe. This study explores the use of a plasmonic fiber optic absorbance biosensor (P-FAB) for detecting RCPs specific to drug-resistant genes for MDR TB detection. Specifically, the genes rpoB and katG in Mtb are targeted for the assay. This method is potential for efficient monitoring and controlling of infectious disease outbreaks.

CHAPTER-3

BIOSENSORS IN GENERAL

The term biosensor is defined as a sensor incorporating biological elements such as enzymes, antibodies, receptors, proteins, nucleic acid, cells or tissue sections – as the recognition element, coupled to a transducer. Biosensors basically involve the quantitative analysis of various substances by converting their biological actions into measurable signals. Generally the performance of the biosensors is mostly dependent on the specificity and sensitivity of the biological reaction, besides the stability of the enzyme.

3.1 WORKING PRINCIPLE

- Analyte diffuses from the solution to the surface of the Biosensor.
- Analyte reacts specifically & efficiently with the Biological Component of the Biosensor.
- This reaction changes the physicochemical properties of the Transducer surface.
- This leads to a change in the optical/electronic properties of the Transducer Surface.
- The change in the optical/electronic properties is measured/converted into electrical signal, which is detected.

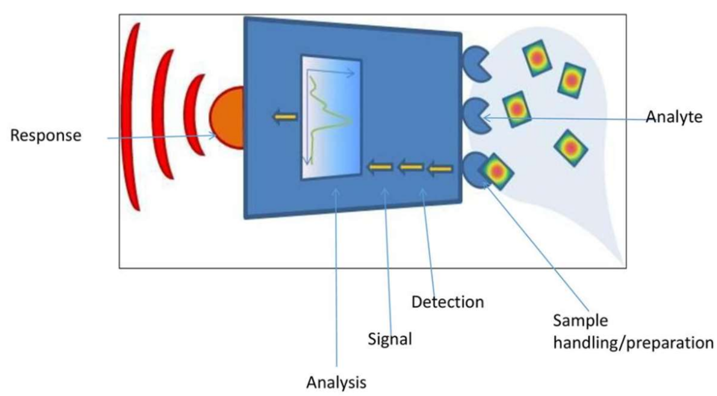

Figure 2: Working of a Biosensor

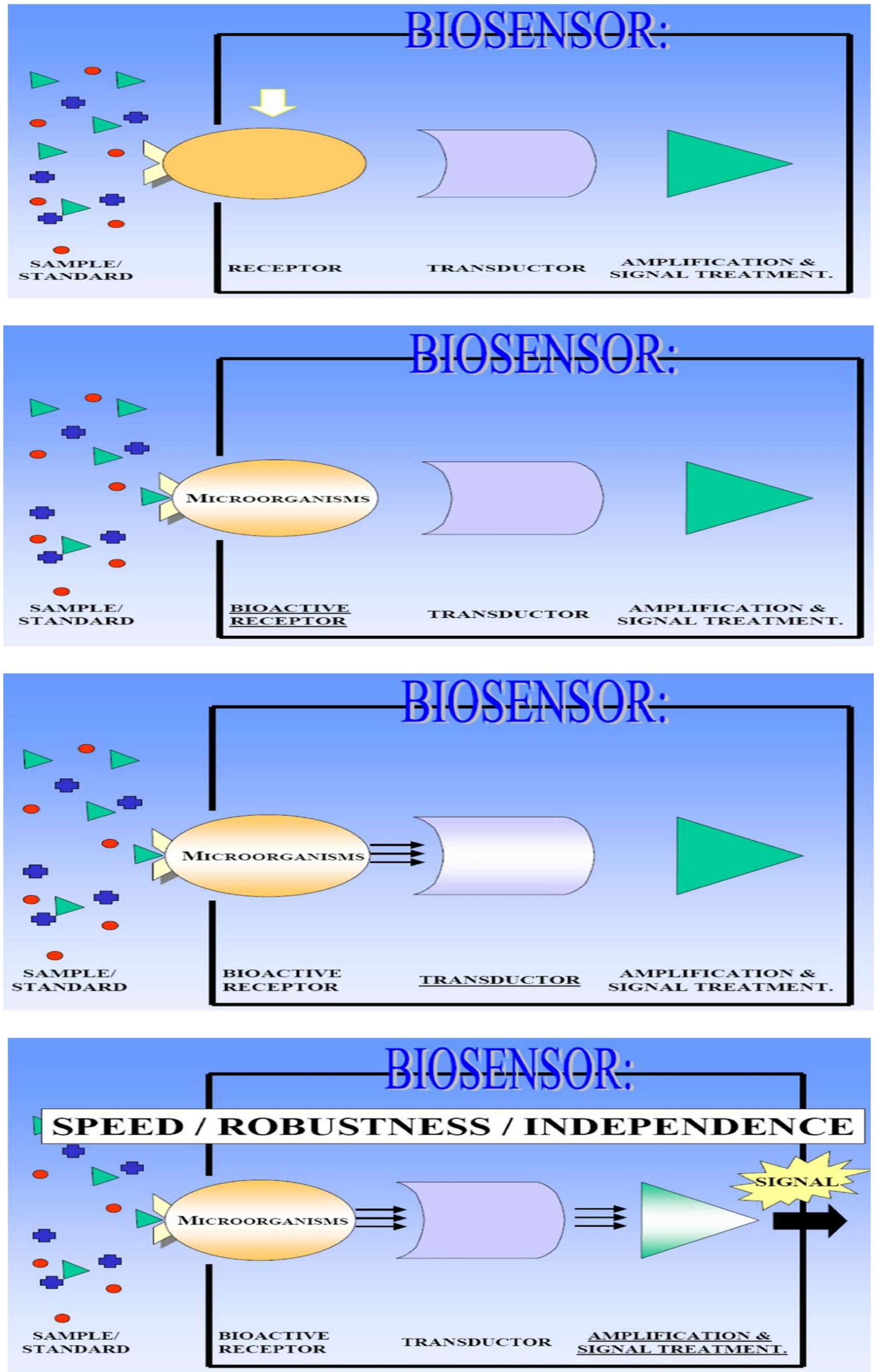

Figure 3: Steps involved in the working of a biosensor

3.2 COMPONENTS OF A BIOSENSOR

1. **Analyte** : An analyte is a substance or chemical constituent that is being detected or measured by a biosensor. It is the target molecule that the biosensor is designed to detect, and its presence or absence, concentration, or activity level is the basis for the biosensor's response. The role of the analyte in a biosensor is therefore critical, as it is the molecule that the biosensor is designed to detect and measure, and the biosensor's ability to accurately detect and quantify the analyte is essential for its performance and utility. The analyte concentration or activity level may be indicative of a disease state, a pollutant level, or a food or drug quality parameter, making biosensors useful in a wide range of applications, including medical diagnostics, environmental monitoring, and food safety testing.
2. **Biological elements :** Biological elements in biosensors are the sensing components that interact with the analyte to generate a measurable signal. These components can be enzymes, antibodies, nucleic acids, cells, or whole organisms, depending on the type of biosensor and the analyte being detected.The role of biological elements in biosensors is to selectively recognize and bind to the analyte, leading to a specific and measurable signal. Biological elements are essential to the functioning of biosensors, as they provide high selectivity and sensitivity, enabling the detection of analytes at very low concentrations. The choice of biological element and its immobilization method can greatly affect the biosensor's performance, including its sensitivity, specificity, and stability.
3. **Transducer :** In a biosensor, the transducer element converts the biological or chemical signal generated by the biological element's interaction with the analyte into a measurable signal, such as an electrical, optical, or thermal signal. The transducer element is typically made of a material that is sensitive to the biological or chemical signal, such as a conductive polymer, a semiconductor, or a piezoelectric material.The role of the transducer in a biosensor is crucial, as it determines the sensitivity, selectivity, and accuracy of the biosensor. The transducer's response to the biological or chemical signal must be fast, reproducible, and linear over a wide range of analyte concentrations. The transducer's output signal is typically amplified and processed by an electronic circuit or a computer algorithm to provide a quantitative measurement of the analyte's concentration or activity level.

4. **Processor :** A processor, such as a microcontroller or a computer algorithm, is an integral part of many modern biosensors. It is responsible for interpreting the output signal generated by the biosensor's transducer element and converting it into a meaningful measurement of the analyte's concentration or activity level. The processor in a biosensor can perform several tasks, such as signal amplification, filtering, and digitization. It can also perform mathematical calculations, such as calibration, normalization, and data analysis, to ensure that the biosensor's output is accurate and reliable. The role of the processor in a biosensor is to provide a user-friendly and efficient interface between the biosensor and the user or the downstream application. The processor's performance and capabilities can greatly affect the biosensor's usability, sensitivity, and specificity, making it a critical component in the design and development of biosensors.

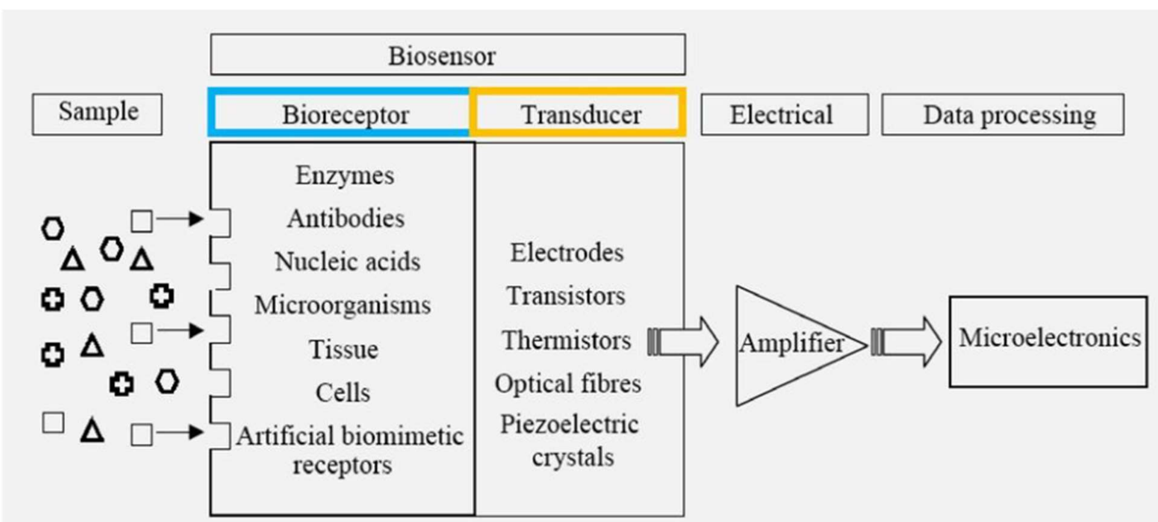

Figure 4 : Principle of operation of Biosensors

CHAPTER-4

OPTICAL BIOSENSORS

An optical biosensor is a device that detects the presence or concentration of biological molecules, such as proteins, nucleic acids, or cells, by measuring the interaction between the molecules and a specific optical signal. The optical signal can be generated by various means, including surface plasmon resonance, evanescent wave sensing, fluorescence, and bioluminescence. In general, an optical biosensor consists of a sensor surface that is functionalized with a specific biological recognition element, such as an antibody or DNA probe, which selectively binds to the target molecule. When the target molecule binds to the recognition element, it induces a change in the optical signal, which can be detected and measured using a detector, such as a photodetector or a camera. Optical biosensors have many potential applications in medical diagnosis, environmental monitoring, and food safety, among others, due to their high sensitivity, specificity, and speed.

Optical biosensors have exhibited worthwhile performance in detecting biological systems and promoting significant advances in clinical diagnostics, drug discovery, food process control, and environmental monitoring. Without complexity in their pretreatment and probable influence on the nature of target molecules, these biosensors have additional advantages such as high sensitivity, robustness, reliability, and potential to be integrated on a single chip.

Biosensors can be classified into different groups depending on the method of signal transduction: optical, electrochemical, thermometric, piezoelectric or magnetic. Optical biosensors are the most commonly reported class of biosensors. Optical detection is performed by exploiting the interaction of the optical field with a biorecognition element. Optical biosensing can be broadly divided into two general modes: label-free and label-based. Briefly, in a label-free mode, the detected signal is generated directly by the interaction of the analysed material with the transducer. In contrast, label-based sensing involves the use of a label and the optical signal is then generated by a colorimetric, fluorescent or luminescent method. Simple molecules such as glucose can be detected by enzymatic oxidation using label-assisted sensing. The glucose analysis of blood is the most commercially successful (so far) application of a biosensor, i.e. the handheld glucose meter used by diabetics. However, in some situations, e.g. antibody–antigen interaction where a label is conjugated with one of the bio reactants, labelling can alter the binding properties and therefore introduce systematic error to the biosensor analysis.

4.1 WORKING OF AN OPTICAL BIOSENSOR

1. **Capture of the analyte:** The sample containing the analyte of interest is introduced to the biosensor. The analyte can be any biomolecule, such as proteins, enzymes, nucleic acids, or small molecules.
2. **Binding of the analyte:** The analyte binds to the sensing surface of the biosensor. The sensing surface can be a thin film of a material that interacts specifically with the analyte or a layer of immobilized biomolecules, such as antibodies or DNA probes, that recognize the analyte.
3. **Transduction of the signal:** The binding of the analyte causes a change in the optical properties of the sensing surface, which can be detected as a signal. The change can be in the refractive index, absorption, fluorescence, or polarization of the surface.
4. **Amplification of the signal:** The signal is amplified by various means, such as by using a resonant cavity, a waveguide, or a surface plasmon resonance phenomenon. This increases the sensitivity and selectivity of the biosensor.
5. **Conversion of the signal:** The signal is converted into an electrical signal by a detector, such as a photodiode or a camera. The electrical signal can be analyzed using various methods, such as spectroscopy, imaging, or interferometry.
6. **Analysis of the data:** The data obtained from the biosensor is analyzed to determine the concentration, kinetics, or affinity of the analyte. This can be done by comparing the signal obtained from the sample with that obtained from a standard or a reference.

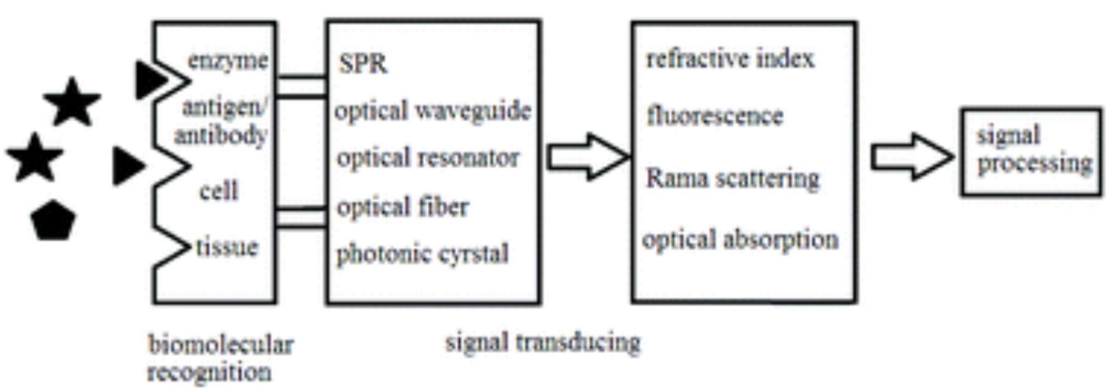

Figure 5: Working of an Optical Biosensor

4.2 COMPONENTS OF AN OPTICAL BIOSENSOR

1. **A light source** :The light source is a crucial component of an optical biosensor that provides the energy needed to activate the sensing surface and detect biological molecules. The light source generates a signal that is dependent on the optical properties of the sensing surface and the analyte, which can be detected by a detector. The light source can be optimized to enhance the sensitivity and selectivity of the biosensor, and real-time monitoring of binding events can be achieved by observing the changes in the signal. Overall, the light source is an essential part of an optical biosensor and plays a critical role in its ability to detect and analyze biological molecules.
2. **An optical transmission medium** : An optical transmission medium refers to a material or structure that is used to guide or transmit light to and from the biosensor sensing region.In order to transmit the light to and from the sensing region, an optical transmission medium such as a fiber or waveguide is often used. The transmission medium can guide the light from the light source to the sensing region and then back to the detector or analyzer. An optical transmission medium is an important component of biosensors that enables the efficient transmission of light to and from the sensing region for the detection and analysis of biological or chemical analytes.
3. **Immobilized biological recognition element** : an immobilized biological recognition element refers to a biological molecule or microbe that is attached or fixed onto a solid support material, such as a surface of a biosensor, to selectively interact with a target analyte in a sample. The biological recognition element is a key component of a biosensor as it is responsible for the specificity and selectivity of the sensor which is needed for accurate detection and quantification of target analytes in a sample . It recognizes and interacts with the target analyte in the sample, leading to a measurable signal that can be detected and quantified. Examples of biological recognition elements commonly used in biosensors include enzymes, antibodies, and microbes.

4. **Optical probes for transduction :** an optical probe refers to a molecule or material that is used to transduce or convert the biological or chemical interaction between the biosensor and the target analyte into a measurable optical signal, such as fluorescence. Optical biosensors rely on the use of optical probes for transduction, as they enable the conversion of the biological or chemical signal into a measurable optical signal that can be detected and quantified. optical probes are an important component of biosensors that enable the transduction of the biological or chemical interaction between the biosensor and the target analyte into a measurable optical signal. Fluorescent markers are a commonly used type of optical probe in biosensors, but other types of optical probes can also be used depending on the specific application and detection requirements.
5. **An optical detection system :** an optical detection system refers to the components and instrumentation used to detect and quantify the optical signal generated by the biosensor transducer. Optical biosensors rely on the use of light to detect and quantify biological or chemical interactions between the biosensor and the target analyte. The detector is used to measure the intensity, wavelength, or polarization of the light signal generated by the biosensor transducer. The detector can be a photodiode, a photomultiplier tube (PMT), or a spectrometer, depending on the specific application and detection requirements. An optical detection system may also include other components, such as filters, lenses, and polarizers, to optimize the performance and sensitivity of the system. Overall, an optical detection system is a critical component of optical biosensors, enabling the detection and quantification of biological or chemical interactions between the biosensor and the target analyte. The specific components and instrumentation used in the optical detection system will depend on the specific application and detection requirements of the biosensor.

CHAPTER-5
APPLICATIONS

Optical biosensors have exhibited worthwhile performance in detecting biological systems and promoting significant advances in clinical diagnostics, drug discovery, food process control, and environmental monitoring. Without complexity in their pretreatment and probable influence on the nature of target molecules, these biosensors have additional advantages such as high sensitivity, robustness, reliability, and potential to be integrated on a single chip.

1. **Medical Diagnostics:** Optical biosensors have a significant impact on medical diagnostics, particularly in the field of point-of-care (POC) testing. Optical biosensors can be used to detect and quantify biomarkers associated with various diseases, such as cancer, diabetes, and cardiovascular diseases. They are also used for detecting infectious agents, such as viruses and bacteria.
2. **Environmental Monitoring:** Optical biosensors are used in environmental monitoring to detect and quantify pollutants and toxins in water, soil, and air. Optical biosensors can be designed to selectively detect specific pollutants, such as heavy metals, pesticides, and organic compounds.
3. **Food Safety:** Optical biosensors are used in the food industry to detect and quantify toxins and pathogens in food products. Optical biosensors can be used to detect pathogens, such as Salmonella and E. coli, in real-time, ensuring the safety of food products.
4. **Biodefense:** Optical biosensors can be used in biodefense to detect and quantify biological agents, such as bacteria, viruses, and toxins. Optical biosensors are also used in detecting and monitoring potential bioterrorism threats.
5. **Drug Discovery:** Optical biosensors are used in drug discovery to identify and quantify interactions between drug candidates and biological targets. Optical biosensors can also be used to screen libraries of compounds for drug discovery purposes.

Overall, the applications of optical biosensors are vast, and their use continues to expand as technology advances and new opportunities arise.

CHAPTER-6

ADVANTAGES AND DISADVANTAGES

ADVANTAGES:

Biosensors offer numerous advantages over traditional analytical methods. Here is an explanation of some of the key advantages of biosensors:

1. **Selectivity and specificity:** Biosensors can be designed to selectively detect specific analytes, providing high selectivity and specificity. This is because biosensors utilize biological recognition elements, such as enzymes, antibodies, or DNA, which specifically bind to the target analyte.
2. **Remote sensing:** Biosensors can be used for remote sensing in situations where direct measurement is difficult or impossible. For example, biosensors can be deployed in remote locations or in hazardous environments to monitor environmental conditions or detect pathogens.
3. **Isolation from electromagnetic interference:** Biosensors use optical or electrochemical methods for detection, which are immune to electromagnetic interference, making them highly reliable and accurate.
4. **Fast, real-time measurements:** Biosensors can provide fast and real-time measurements, allowing for rapid detection and analysis of analytes.
5. **Multiple channels/multiparameters detection:** Biosensors can be designed to detect multiple analytes simultaneously, enabling multiparameter detection.
6. **Compact design:** Biosensors can be designed in a compact form factor, making them highly portable and easy to use.
7. **Minimally invasive for in vivo measurements:** Biosensors can be designed to be minimally invasive for in vivo measurements, reducing the discomfort and potential for complications.
8. **Choice of optical components for biocompatibility:** Optical biosensors can utilize biocompatible materials, making them suitable for use in biological systems.
9. **Detailed chemical information on analytes:** Biosensors can provide detailed chemical information on analytes, such as their concentration and molecular properties, allowing for precise and accurate analysis.

Overall, the advantages of biosensors make them highly useful and versatile tools for a wide range of applications in various fields, including medical diagnostics, environmental monitoring, and food safety.

DISADVANTAGES:

While optical biosensors offer many advantages, they also have some limitations and disadvantages. Here are some of the disadvantages of optical biosensors:

1. **Cost:** Optical biosensors can be expensive due to the complex equipment required for the optical detection system.
2. **Complexity:** The design and development of optical biosensors can be complex, requiring expertise in multiple fields such as optics, biology, and chemistry.
3. **Sensitivity to environmental conditions:** Optical biosensors can be sensitive to environmental conditions such as temperature and humidity, which can affect their performance.
4. **Limited shelf life:** The biological recognition elements used in optical biosensors have a limited shelf life, which can affect their long-term performance.
5. **Limited detection range:** Optical biosensors may have a limited detection range, which can limit their usefulness in certain applications.
6. **Interference from other compounds:** Optical biosensors can be affected by other compounds present in the sample, which can interfere with their detection of the target analyte.
7. **Sample preparation:** Optical biosensors may require specific sample preparation procedures, which can be time-consuming and labor-intensive.

Overall, while optical biosensors have significant advantages, it is important to consider their limitations and disadvantages when choosing the appropriate analytical tool for a given application.

CHAPTER-7

FUTURE ENHANCEMENT

Optical biosensors have a wide range of potential future enhancements, and here are some of the future scopes:

1. **Multianalyte Detection**: Optical biosensors can be developed to detect multiple analytes simultaneously, enabling multiparameter detection. The ability to detect multiple analytes can provide a more comprehensive analysis of biological samples, and it has great potential for use in fields such as medical diagnostics and environmental monitoring.
2. **New Biorecognition Molecules:** The development of new biorecognition molecules, such as aptamers and molecularly imprinted polymers, offers exciting possibilities for optical biosensors. These molecules have unique properties that can make them more selective, stable, and cost-effective than traditional recognition molecules, and they can expand the range of analytes that can be detected.
3. **Fluidics:** The integration of microfluidics with optical biosensors can improve their sensitivity, speed, and accuracy. Microfluidic systems can control the flow of samples and reagents, and they can provide a more efficient and automated method for sample preparation and analysis.
4. **In Vivo Sensors:** Optical biosensors can be developed for in vivo monitoring of biological parameters such as glucose, pH, and oxygen. These sensors can provide real-time information on physiological conditions and help to improve disease diagnosis and management.
5. **Chemical Identification Biosensors:** Optical biosensors can be developed to identify specific chemicals or molecules in a sample, which has potential applications in areas such as food safety, drug discovery, and environmental monitoring.
6. **Data Processing, Pattern Recognition, and Automation:** The development of advanced data processing and pattern recognition algorithms, along with the automation of biosensor systems, can improve the accuracy and efficiency of optical biosensors. This can lead to improved performance and reduced costs, making optical biosensors more accessible for a wider range of applications.

7. **Test for Tuberculosis :** Optical biosensors can be used to detect tuberculosis (TB) by targeting specific biomarkers associated with the disease, such as lipoarabinomannan (LAM). An antibody or aptamer that can bind to LAM is immobilized onto the biosensor, and when a sample containing MTB is added, LAM present in the sample will bind to the recognition element. The binding event can be detected using various optical transduction methods such as surface plasmon resonance (SPR), fluorescence, or colorimetry. Optical biosensors offer advantages such as high sensitivity and real-time measurement, but further research is needed to optimize the biosensor and validate its use in clinical settings.
8. **Optical biopsy sensor :** An optical biosensor uses light to detect and measure biological or chemical substances, while an optical biopsy sensor uses light to non-invasively examine tissues and provide information about their structure and composition for medical diagnostics. These technologies have different applications, with optical biosensors being commonly used in laboratory settings and optical biopsy sensors being designed specifically for medical imaging and diagnostics.
9. **Medical Telesensor :** An optical biosensor can be used as a medical telesensor, which is a sensor that remotely monitors a patient's health and transmits the data to a healthcare professional. By using an optical biosensor, healthcare professionals can remotely monitor a patient's health in real-time by measuring and transmitting the patient's biological signals, such as blood glucose levels, heart rate, and oxygen saturation levels. This technology can be particularly useful for patients who require continuous monitoring or live in remote areas, allowing healthcare professionals to provide timely and accurate medical care.

In conclusion, optical biosensors have great potential for future development and application in various fields, and the advancement of technology and new research can further enhance their performance, accuracy, and versatility.

CHAPTER-8
CONCLUSION

Optical biosensors are expected to grow most in importance in the healthcare, biomedical and biopharmaceutical sectors. They can provide new analytical tools with reduced size as well as facilitate large-scale high-throughput sensitive screening of a very wide range of samples for many different parameters . Various sensitivity-enhancement techniques for optical biosensors have been developed which improve the signal-to-noise ratio and reduce the detection limit , and optical biosensors have been successfully tested in many fields such as medicine, pharmacy, food safety, environment, biotechnology, defence and security. On the other hand, the broad practical application of optical biosensors is still under development and is limited mostly to academic and pharmaceutical environments. The exceptions are lateral flow assay biosensors commercialized as test strips for home-testing, point-of-care testing or laboratory use. When developing new optical biosensor devices for practical applications all the methodological and practical aspects such as robustness, reproducibility, simplicity and shelf life should be carefully taken into account. The main challenge for further research and innovation in the field of optical biosensors is that the optical detection principle allows construction of sensitive, simple and cheap analytical devices with a wide variety of possible applications in portable biosensor systems for *in situ* screening and monitoring, for example, in personalized medicine, remote areas or in developing countries where the availability of inexpensive diagnostic tools could save many lives.

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Fibre Optics Biosensors for the Detection of Bacteria – a review

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Abstract— Optical fiber Biosensing for bacteria detection is an emerging technology in the past two decades, which has advantages of high sensitivity, small size, and capability for real time monitoring. In this paper, different types of optical fiber bacteria biosensors were classified and summarized.

Keywords—Optical, Biosensor, Bacteria, Affinity

I. Introduction

Bacteria are microscopic single-celled organisms that are found in the entire ecosystem. Some bacteria are beneficial to human health and are a must for the existence of the ecosystem. For example, Cyanobacteria produces oxygen during photosynthesis and nitrogen fixation for the marine environment [1]. Similarly, Bacillus Thuringiensis is used in agriculture instead of pesticides [2]. Lactic acid bacteria help in the preparation of cheese, soya sauce, vinegar, yogurt, and pickles [3]. Also, in the human digestive system bacteria employs enzymes and proteins to break down the nutrients of the food into different forms of energy for the body [4]. However, some bacteria such as pathogenic bacteria, which can be airborne, waterborne, foodborne, and bloodborne, are harmful to the health and good-being of humans and other living organisms in an ecosystem. They can be harmful and can cause deadly diseases. For example, bacteria like Shigella, Campylobacter, Salmonellae can cause diarrheal disease with annual death rate of 2.1 million [5]. Pneumonia is one of the severe deadly respiratory infections and is caused by the bacteria like Streptococcus and Haemophilus influenzae [6]. Mycobacterium Tuberculosis causes Tuberculosis and could spread quickly [7]. Meningitis is caused by Neisseria meningitidis and Streptococcus pneumoniae bacteria which need to be detected quickly [8]. Thus, there should be a deep understanding of the role of bacteria to ensure the safety of the environment and living beings. More importantly, bacterial can be used for biological warfare from the military point of view [9].

There is an urgent need to detect bacterial, where the primary objectives are i) to assure food safety and to avoid any kind of disease outbreaks. ii) to prevent airborne and waterborne infections from the spread in the ecosystem. iii) to provide national security from terrorism from the use of biological weapons.

Traditional bacteria detection method is the microbiological culturing method, which is the top standard method till the 20th century, due to its exceptional sensitivity and specificity. The microbiological culturing method can analyze a single cell of bacteria in a sample but are very slow (typically 1-2 days, sometimes requires more time to detect bacteria), which might delay the purpose of targeted detection. Also, the microbiological culturing method is expensive, immobile, and need tedious sample preparation and processing of measured values. To solve these problems a wide range of biosensors has been created in recent years. A biosensor is an analytical device that is used to detect and recognize an analyte or group of analytes that combines a biological component with a physicochemical detector [10]. They convert biological changes into electric signals. Based on signal transduction, biosensors are classified into optical, electrochemical, thermal, magnetic, and piezoelectric biosensors [11].

Developing a biosensor with all the above advantages is a difficult task. Some biosensors are quick and only need a few samples for processing, however, lack in the area of sensitivity. Other biosensors have excellent sensitivity yet are sluggish because of the time consumed for sample preparation processes. While the biosensors which offer quick sample preparation and high sensitivity might need costly apparatus and technicians who are qualified. Thus, the biosensors with all these benefits in a single device must be implemented.

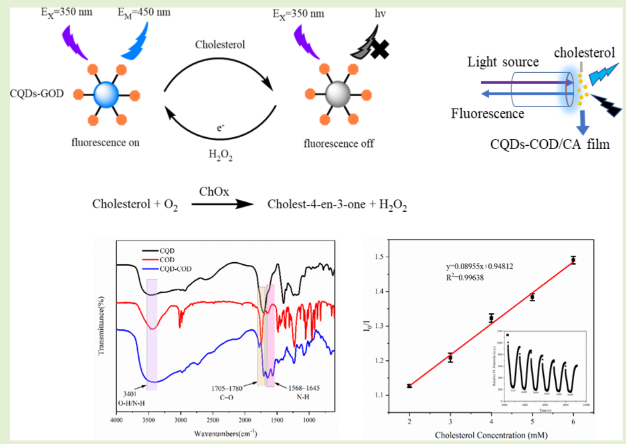
II. OPTICAL BIOSENSORS

Optical Biosensors generate output depending on the light transmitted or emitted in the presence of analyte or group of analytes in biological systems for bacteria detection. The output of the optical biosensor is measured by analyzing the changes in

A Cholesterol Optical Fiber Sensor Based on CQDs-COD/CA Composite

Qin Li, Liyun Ding, Yumei Zhang, and Tian Wu

***Abstract*—A novel optical fiber biosensor based on carbon quantum dots (CQDs) fluorescent probe was developed for cholesterol sensing, in which CQDs-COD/CA composite acted as the sensitive film. The electron charge transfer between H_2O_2 and CQDs resulting from the specific reaction of cholesterol and cholesterol oxidase leads to fluorescence quenching. The fluorescence properties and surface morphology of CQDs-COD complex and complex sensitive film were characterized by Scanning electron microscope (SEM), transmission electron microscope (TEM), and Fourier transformation infrared (FTIR), fluorescence and ultraviolet spectroscopy. The fluorescence response of the sensor to cholesterol solution in micromole and millimole concentration ranges was studied, and the linear relations were obtained with R^2 = 0.99022 and 0.99638, respectively. The results obtained in this study showed that the CQDs-COD/CA composite sensor has good biocompatibility and selectivity for cholesterol.**



***Index Terms*—Optical fiber sensor, carbon quantum dots, fluorescence quenching, cholesterol sensing.**

I. Introduction

CHOLESTEROL mainly comes from the daily diet and plays an important role in building cell membranes, maintaining normal cell activities and building cell structure. The concentration of cholesterol in healthy people ranges over 1.16-2.02 mg/ml [1]. An anemia will be caused and resistance will be reduced when the cholesterol concentration is too low. However, if the concentration is too high, obesity will be caused and the risk of cardiovascular diseases will be increased [2]. Therefore, it is very important to measure cholesterol content and control the cholesterol concentration in the normal range, which has important practical significance for clinical disease diagnosis and prevention.

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Carbon quantum dots (CQDs) are nanoparticles with a size generally less than 10 nm and a quasi-spherical structure in appearance [3]. Synthesized by the different raw materials and the synthesis methods, carbon quantum dots have great differences in composition, structure and performance, so the performance of carbon quantum dots can be regulated by controlling the carbon source or changing the synthesis conditions [4]. Compared with semiconductor quantum dots, metal quantum dots and traditional organic fluorescent dyes, carbon quantum dots have a wide range of raw materials, photoluminescence characteristics, good solubility, low toxicity, photobleaching resistance, good biocompatibility and good chemical stability. Therefore, carbon quantum dots have broad prospects in biomedicine, biosensing, biomarkers and other practical applications [5]–[9].

There are many cholesterol detection methods reported until now, including gas-liquid chromatography-mass spectrometry [10], [11], molecular luminescence [12], colorimetry [13]–[15], electrochemical method [16], etc. Enzymatic determination has the advantages of simple operation, good selectivity and high sensitivity. At present, most detection methods are based on enzymatic approach [17]. The commonly used detection methods include electrochemical method [18] and fluorescence method [19]. The electrochemical method uses chemically modified electrodes to detect cholesterol substrates and convert the corresponding concentration into electrical signals. The strength of the electrical signal is proportional to the concentration of cholesterol. The modifying agent of

Plasmonic Fiber Optic Absorbance Biosensor for MDR-*Mtb* detection using Padlock Probing

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***Abstract*—India is one among the 14 countries that have a high burden of Multidrug Resistant-Tuberculosis (MDR-TB), thereby demanding robust clinical and diagnostic attention. This study explores the development of a plasmonic fiber optic absorbance biosensor (P-FAB) for the detection of Rolling Circle Amplification (RCA) products to detect MDR genes of *Mycobacterium tuberculosis*. RCA is used as a nucleic acid amplification strategy for the specific and sensitive detection of DNA samples using the P-FAB platform. RCA-generated amplicons, when detected using U-bent optical fiber probe sensor with a nanoparticle-labeled DNA assay, provides adequate scope for the required clinical sensitivity towards multiplexed TB detection.**

Keywords— rolling circle amplification, U-bent fiber optic sensor, DNA assay, P-FAB

I. Introduction

Tuberculosis (TB) is a chronic respiratory infection caused by the pathogen *Mycobacterium tuberculosis* (*Mtb*).The increasing development of resistance of the pathogen has limited the effect of the drug on its treatment. The resistance of *Mtb* to at least one of the first line anti-TB drugs of isoniazid and rifampicin classifies it as multi-drug resistance (MDR) strain. Thus, there is a dire need for detection platforms capable of monitoring the spread of MDR TB strains.

Currently, Polymerase Chain Reaction (PCR) has been the gold-standard for the detection of nucleic acid samples. The need for expensive equipment (such as thermal cycler) and skilled personnel limits its application in resource-limited and point-of-care settings. In the context, Rolling Circle Amplification (RCA) is one of the promising isothermal methods of DNA or RNA amplification for generating long single-stranded DNA or RNA with tandem repeats [1]. For RCA, padlock probes (PLPs) are used, which are single-stranded DNA with its both end sequences complementary to the target sequence, **Figure 1**. The PLPs circularize after hybridizing with the target sequence through ligation of the nick. Upon ligation, the circularized PLP acts as a template, amplified using Phi29 polymerase, which possesses significant processivity and strand displacement activity. The amplified RCA product (RCP) collapse into a random coil conformation. The intermediate backbone (linker sequence) within the PLP can be used for the detection of these RCA products. Owing to its high specificity and multiplexing abilities, it is a potential strategy for rapid, and efficient monitoring and control of infectious disease outbreaks.

U-bent optical fiber sensor probes have been proven to exhibit significant evanescent absorbance (EWA) sensitivity and could detect analytes down to sub-femtomolar concentrations using plasmonic gold nanoparticle (AuNP) labels with high extinction co-efficient [2] . In this study, we explore the utility of plasmonic-fiber optic absorbance biosensor (P-FAB) platform for the detection of RCPs upon amplification of nucleic acid sequences specific to drug-resistant genes for MDR TB detection. Specifically, sequences corresponding to *rpoB* and *katG* in *Mtb* are targeted for assay development.

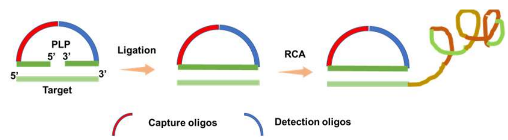

Figure 1:Schematic of Rolling Circular Amplification.

II. Experimental sections

A. Materials

Glass optical fibers (FT200UMT) of 200 µm core diameter and NA 0.39, were procured from Thorlabs. Chemicals including hydrogen peroxide (30%, Fisher Scientific), sulphuric acid (98%, Fisher Scientific), APTES (Sigma Aldrich), ethanol (Hayman), acetic acid (Merck), glutaraldehyde (25%, Merck) were of analytical grade. Single stranded DNA (ssDNA) oligonucleotides for capture, detection oligo and target. DNase free water was used for the assays.

B. Padlock probes and Rolling Circle Amplification

Design of PLP ssequences for the RCA were obtained from NCBI for *Mtb* H37Rv (NCBI Reference Sequence: NC_000962.3). The padlock probes were designed from a previous study on RCA based detection of MDR *Mtb* strains [3].

Table 1: List of sequences for the RCA study

Sequence type	Sequences (5'-3')
katG PLP	PO_4-TGGTGATCGCGTCCTTACCGTGTATGCAGCTCCTCAGTAATAGTG TCTTACCTCAGCCGATGCAGTGTATCATACGACCTCGATGCCGC
katG Target	GAGCTCGTATGGTAAGGACGCGATCACCAGCGGCATCGAGGTCGTATG
	NH2-TTTTTCCTCAGTAATAGTGTCTTAC
Detection oligo	CTCAGCCGATGCAGTGTAATTTTT-SH

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