Faculty of Electrical and Electronic Engineering Technology

DESIGN OF KRETSCHMANN-SURFACE PLASMON RESONANCE SENSOR FOR GLUCOSE DETECTION

MOHD IKHWAN BIN KASRI

Bachelor of Electronics Engineering Technology with Honours

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**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours**

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

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I declare that this project report entitled "Design Of Kretschmann-Surface Plasmon Resonance (SPR) Sensor For glucose Detection" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of degree of Bachelor of Electronics Engineering Technology with Honours

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Date : ....

DEDICATION

My deepest appreciation goes out to my great friends, family, and classmates who were always together for me and who have always motivated me to complete my final project successfully. Meantime, I devote my project to Mrs. Najmiah Radiah Binti Mohamad,, my dear Supervisor, who have taught me and encouraged me in completing my final year project. properly. Thank you so much, and I appreciate everything you've done for me. I deeply respect their energy, sincerity, and attention, all of which helped to the project's success. I'd like to express my gratitude for their patience, trust, and belief in my quest to reach my goal.

ABSTRACT

Surface plasmon resonance (SPR) sensors based on the Kretschmann configuration use chromium, gold and polymer nanofilms suitable for unlabeled biomedical sensing. The L9 Taguchi orthogonal array method was used in this study to improve the effect of the incident optical wavelength and thickness of chromium, gold and polymer nanofilms on the performance of Kretschmann -based surface plasmon resonance sensors. The control variables were changed at three levels for multi -response optimization of the Kretschmann -based surface plasmon resonance sensor for lowest reflection, full width at half maximum, and glucose detection sensitivity, carried out using the WINSPALL software method. . Using the Taguchi method, the best control factor setting is A1B2C3D3, which corresponds to an optical wavelength of 633 nm for Larger-is-better, between 3 nm chromium, 50 nm gold layer thickness and 20 nm for polymer, with a minimum reflection of 0.0050 percent, full width at the maximum half of 2.7136, and the glucose sensing sensitivity for It was also found that the chromium nanofilm thickness of 0.5–3 nm, as well as the average surface roughness of its roots, had a small factor influence when compared to other control variables. The optical wavelength, followed by the layer thickness, determines the effect of the full width factor at half the maximum. The optical wavelength, as well as the thickness of the water and glucose layers, determine the sensitivity. Compared to a wavelength near 785 nm, the Kretschmann -based surface plasmon resonance glucose sensor with the best glucose sensing sensitivity is at an optical wavelength of 633 nm with a higher sensitivity value of 183.8463. Finally, the WINSPALL software and the Taguchi approach are suitable for the multi -response optimization of control and noise parameters in Kretschmann -based surface plasmon resonance sensors.

ABSTRAK

Penderia resonans plasmon permukaan (SPR) berdasarkan konfigurasi Kretschmann menggunakan nanofilem kromium, emas dan polimer yang sesuai untuk penderiaan bioperubatan tidak berlabel. Kaedah tatasusunan ortogonal L9 Taguchi digunakan dalam kajian ini untuk menambah baik kesan panjang gelombang optik kejadian dan ketebalan nanofilem kromium, emas dan polimer terhadap prestasi penderia resonans plasmon permukaan berasaskan Kretschmann. Pembolehubah kawalan telah ditukar pada tiga tahap untuk pengoptimuman berbilang tindak balas bagi sensor resonans plasmon permukaan berasaskan Kretschmann untuk pantulan terendah, lebar penuh pada separuh maksimum, dan kepekaan pengesanan glukosa, yang dijalankan menggunakan kaedah perisian WINSPALL. . Menggunakan kaedah Taguchi, tetapan faktor kawalan terbaik ialah A1B2C3D3, yang sepadan dengan panjang gelombang optik 633 nm untuk Lager-is-better, antara 3 nm kromium, 50 nm dan 20 nm ketebalan lapisan emas untuk polimer, dengan pantulan minimum 0.0050 peratus, lebar penuh pada separuh maksimum 2.7136, dan kepekaan penderiaan glukosa untuk Ia juga didapati bahawa ketebalan nanofilm kromium 0.5-3 nm, serta purata kekasaran permukaan akarnya, mempunyai pengaruh faktor yang kecil jika dibandingkan. kepada pembolehubah kawalan yang lain. Panjang gelombang optik, diikuti dengan ketebalan lapisan, menentukan kesan faktor lebar penuh pada separuh maksimum. Panjang gelombang optik, serta ketebalan lapisan air dan glukosa, menentukan sensitiviti. Berbanding dengan panjang gelombang berhampiran 785 nm, sensor glukosa resonans plasmon permukaan berasaskan Kretschmann dengan kepekaan penderiaan glukosa terbaik berada pada panjang gelombang optik 633 nm dengan nilai sensitiviti yang lebih tinggi iaitu 183.8463. Akhir sekali, perisian WINSPALL dan pendekatan Taguchi sesuai untuk pengoptimuman berbilang tindak balas bagi parameter kawalan dan hingar dalam penderia resonans plasmon permukaan berasaskan Kretschmann.

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CHAPTER 1

INTRODUCTION

1.1 Background

Surface plasmon resonance (SPR) sensors have been used to identify some medical compounds on a regular basis. The performance and sensitivity of the SPR have also been investigated by applying a variety of methods and sizes. The benefits of using SPR sensors include the ability to determine sensitivity from thickness level, as well as a more user-friendly and low-cost option. SPR (Surface Plasmon Resonance) has shown to be a useful way of monitoring biomolecular interactions in liquids without categorization. Due to its high sensitivity approach, it has been widely employed in various application aspects and uses in industry as biochemical, medical, and visual sensing applications for level measurement and have been for some time.

As a result, several experts experimented with improving sensors' performance in SPR applications. It has a severe impact on the thin metal film layer with dynamic at the relation between two dielectric images with opposite refractive angles and the prism. SPR is an optical instrument for studying modifications in the refractive index of metal surfaces. Surface Plasmon resonance (SPR) sensors have been utilized in biosensing for a long time to detect many biomolecular interactions. A few aspects, such as film thicknesses, thin-film type, and designs, must be investigated to optimize the performance of SPR sensors.

This research aims to find the ideal thicknesses of glucose detection combined with thin films for increasing SPR sensor sensitivity. The solutions are to detect the investigated sensitivity by determining changes in thickness and wavelength in the refractive index, and the development of an SPR sensor with glucose detection. In the experiment, the WINSPALL software is also utilized to assess the sensitivity of various thicknesses and wavelengths by refraction index.

1.2 Problem Statement

As we can see, the detection of glucose affects human diabetes, hence it is necessary to monitor glucose levels in the body for medication purposes. According to statistics, the number of persons diagnosed with diabetes seems to be on the increasing. High blood glucose levels can result in kidney failure, heart attacks, and strokes, all of which can lead to mortality. The variations in refraction index can be used to evaluate the sensitivity and effectiveness of glucose using Surface Plasmon Resonance (SPR).

Then, detecting glucose with a conventional biosensor takes time and is inaccurate and imprecise for the simulation. After that, the overall cost of the SPR sensor is quite expensive due to the materials used in the design. Lastly,he detection may be affected by the thickness of the metal film.

1.3 Project Objective

The study's main goal is to use appropriate materials to more reliably detect glucose levels. The following are the specific objectives:

a) To design a high sensitivity of glucose SPR sensor by varifying the wavlengths and thickness of the nano thin film using WINSPALL software

b) To enhance the SPR's sensor performance for sensing low molarity of glucose in polymer-SPR in real time.

c) To optimize SPR biosensor based on systematic on statical analysis using Taguchi method.

1.4 Scope of Project

To accomplish the objectives of the project, there are numerous scopes that have already been specified. To determine whether the WINSPALL software can identify the sensitivity, several criteria should be considered. The first step is to choose a wavelength and thickness, which are 633,670, and 785 nm for wavelength and 20-50 nm for thickness, with Au (gold) being used because of its optical qualities and optical stability. The WINSPALL simulation is being used to evaluate the sensitivity of glucose detection.

The simulation performed when the prism which is BK7, is contacted with the Cr(chromium) and other metallic layer to create the detection of the sensitivity. The thickness of BK7 is fixed at 0.5nm, whereas the thickness of Cr (chromium) is determined by the wavelength commonly used in research. After the data has been obtained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, in today's world there many applications have been applied to identified the efficiency to detects some of the issues on biomedical sensor. There is a comparable part that has been included to ensure that all project data may be clarified. In this chapter, there are several important topics that have been highlighted. Based on the current and upcoming scope of this topic, the chapter also discusses the SPR sensing principle, its characteristic materials, and its use in a variety of system, as well as some important in previous research linked to SPR sensors..

2.2 SPR Sensor

Because of its applicability in optical sensor applications, Surface Plasmon Resonance technology was currently receiving a lot of attention all over the world. The SPR has manage to be a proper way to monitor product biomolecular activities in plasma. Surface Plasmon Resonance also a cheap, sensitive, and continuous technology for observing a specific action on the surface in real time, even when the process description changes just slowly.

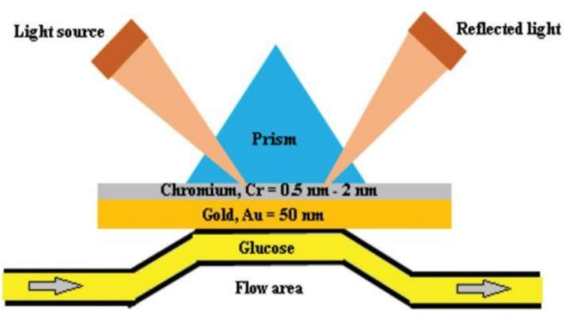

Figure 1: Layer of Spr sensor [4]

Because they use a sensor detection technology that allows biomolecules to be identified in their natural state, Surface Plasmon Resonance biosensors are well suited for a number of medical and biology applications. Surface Plasmon Resonance is a surface plasmon stimulation phenomenon that occurs in systems that monitor and can recover if given enough momentum and energy. Among the SPR sensor applications developed and used are elemental analysis reflection, optical wavelength, optical fiber, and intensity measurement. Biological activity can be recognized on the sensing surfaces of these platforms.

One of the most important factors in determining an SPR sensing system's effective sensing performance, setup, optical design, and real-time data gathering technique is the source of light. In addition, the development of light source technology for SPR sensing systems, particularly in terms of configurations, monitoring methods, reduction, and portable designs, has made this a big issue. In SPR development, a precise wavelength is required to match the incoming laser's light transmission factor at a given angle of incidence. Due of its great sensitivity, limitless detection, timely response, and other unique properties, Surface Plasmon Resonance (SPR) receives more attention than previous methods. To make lightfocused in the core leak easier to the external surface, chemically damaged fibers, tapered fibers, D-shape fibers, U-shape geometries, and other forms of optical fibers and fiber structures have been developed. Because of its fragility, difficulty, and complexity in reprocessing, manufacturing structures is too complex to justify and recover.

2.3 Metal Layer Design

Due to the varied optical and physical effects of materials metal films such as gold (Au) and silver (Ag), a monolayer conventional SPR sensor has limited sensitivity in detecting quality (Ag). SPR biosensors employ a reflectivity curve to detect the shift of the plasmon dip at a given refractive index of the optical connection signal to detect biomolecular connections such as protein and gold nanoparticles. When surface plasmons are produced in SPR devices with a flat thin metal layer, expanding surface plasmon resonance occurs.

SPR sensors based on refractive indexes, such as gold, copper, or silver planar films, have been used to detect material contact on something or close a metal surface for almost 30 years. Glucose, for example, is an "outcome variable" used in biosensors to detect glucose. A bio-receptor is a natural element that contains DNA probes, enzymes, antibodies, and other biological components. The number of contacts between analytes and receptors is equivalent to the optical or electrical signals from specific sensors. The signal-processing unit processes and prepares the transduced signal for display.

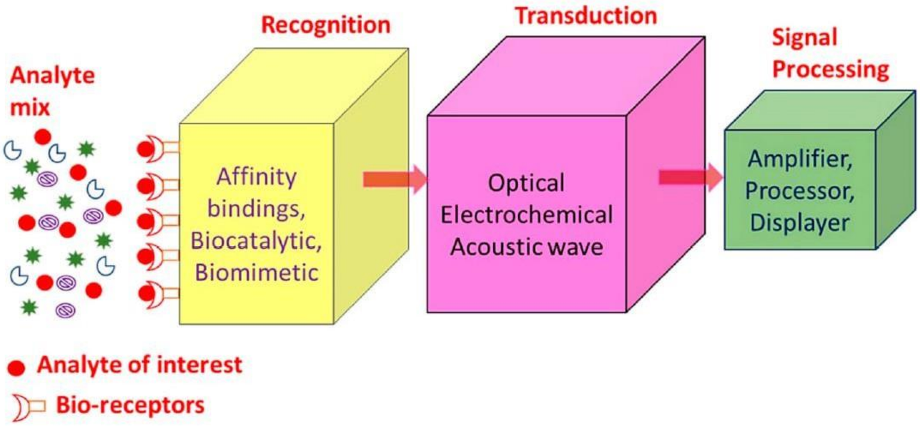

Figure 2: Different biosenseor components [7]

Total internal reflections (TIR) occur when plane-polarized (p-polarized) light contacts a metal layer, causing SPR. Through the prism, it made contact with the metal thin film layer through dielectric negative, which was generated when different dielectric surfaces with opposite refractive angles met. As a result, evaluating the dual transducing layer as a reasonable solution is a good idea. Urine, pH, glucose, and urea are some of the most common health indicators tested in blood or urine during a medical assessment using biosensors and spectroscopy. Urea analysis may be done using advanced biosensor technologies like CO2 gas electrodes and gas selective electrodes. Despite the efficiency of the techniques, the sensors are large, complex, and resistant to interference, necessitating the addition of an additional electrode to compensate for electrical interference, raising the overall cost of the biosensor.

Lumerical's FDTD Solution has become one of the software solutions used in the simulation and planning processes of a virtual SPR-based biosensor. In this work, the Kretschmann prism design is utilized as a system for SPR sensing, with four main components: BK7 glass, chromium layer (Cr), gold layer (Au), and the graphene layer. The Bionavis Navi SPR database was used to gather all associated refractive index and dielectric properties information for the glass and chromium layer.

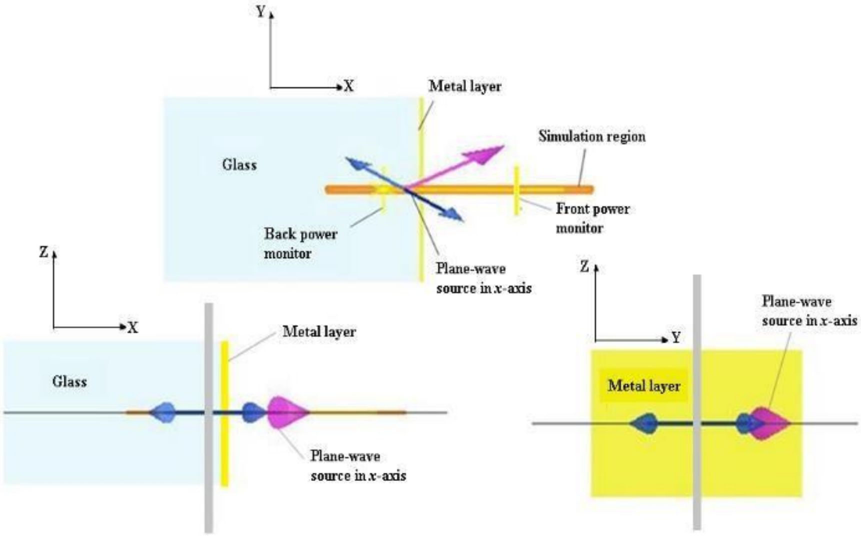

Figure 3: FDTD Simulations Diagram [15]

2.4 Sensitivity and Thickness

While most SPR sensors are sensitive to tiny molecules, only a few approaches for enhancing sensitivity have been investigated. Using an Au nanoparticle-DNA combination as a probe molecule that contacts a sample Glucose molecule collected on a sensor chip, Keating et al. discovered as much as 1000-fold improvement in sensitivity. For highly sensitive detection, as shown in these examples, building a signal transducing system that conveys molecular recognition to another process followed by large changes in dielectric constants is crucial. As a consequence, it was believed that combining the two approachesabove, employing both the sample attaching macromolecule and an Au nanoparticle, would result in a sensing element capable of efficient limited recognition even without probing tools.

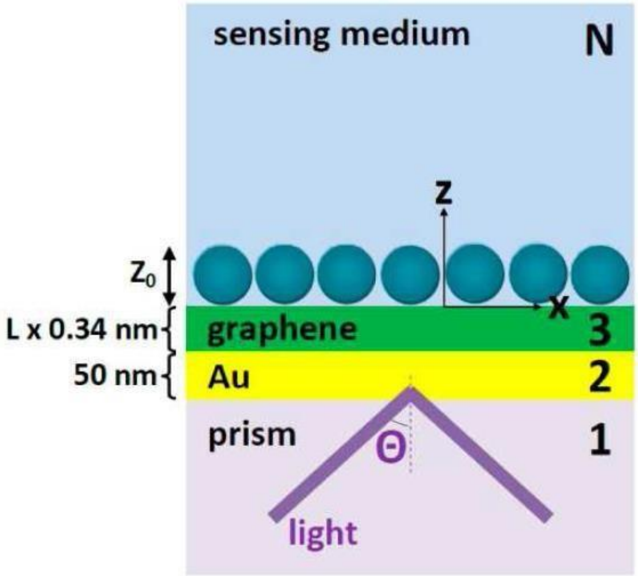

Figure 4: N-Layer model for SPR Biosensor [8]

However, according to optical theory, no light is refracted over the surface over a certain crucial incidence angle. The intensity of the reflected wave starts to drop once the interface between the materials is plated with a thin layer thickness and the light is monochromatic and p-polarized. At a given refractive index, this results in a huge drop in reflection. It's also common to see a good fit between the resonance frequency and the mass density of chemical recognition components like proteins, DNA, and carbohydrates. There are always some charged particles on the surface of the biosensors, which absorb the incoming light and turn it into surface plasmon pulses. When a component of the refractive index travels through a material with a lower refractive index, total internal reflection occurs. A substantial drop in the reflection curve is created at a particular angle above this, known as the plasmon angle. The plasmon angle's location is heavily influenced by the difference in refractive index between the prism and cover material, the next two infinite media. Because these numbers are known for a certain system, the angle is fixed. The location of the plasmon dip is assessed once again after the formation of a wavelength biomolecular layer on the thin film's surface.

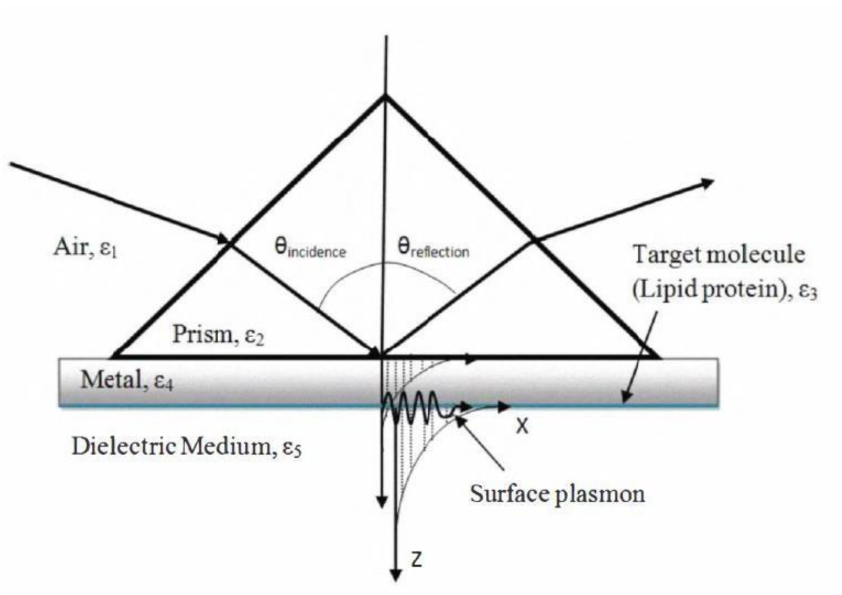

Figure 5: Basic Kretschman of Prism [9]

A thin metallic film is coated on one side of the prism in the SPR biosensor design to separate the sensing material from the prism. In fact, gold is usually selected because of its resistance to oxidation and corrosion in a number of conditions. On the other hand, biomolecules attach to gold wells. Another attractive method for boosting SPR biosensor sensitivity is to form the gold film with biomolecular recognition elements (BRE) to strengthen biomolecule attachment on the gold surface. This feature allows for a larger change in reflectivity at the graphene sensing medium interface than the prior SPR biosensor because graphene has a larger change in refractive index at the graphene sensing medium interface than the prior SPR biosensor. It will be shown that the graphene SPR biosensor is significantly more accurate than conventional SPR biosensors. Understanding the optical property of graphene is necessary to assess the sensitivity of a graphene-based optical sensor. Graphene thickness is a natural fact, according to current data on transmitted light through fixed graphene layers (depends on the wavelength).

2.5 Wavelength and Refraction Index

On top of the linking prism, a metal layer of gold (Au) or silver (Ag) is placed, and a material layer for a biomolecular sensing platform is applied on the metal film surface. The layer thicknesses will be in the nanometer (nm), and the functioning wavelength of the SPR sensor is set at 633 nm to provide optimum performance. To refer to the refractive index (RI) for the wavelength in this investigation, it picked a prism made of BK7 glass. Because optical nonlinearity may arise at a higher frequency and the total sensitivity of the sensor may be obtained at a low frequency with restricted bandwidth, the Refractive Index of every structure's wavelength, such as 633 nm, is selected as the working point.

The material for the prism in SPR sensors is often chosen based on modification of the incident light, with a more appropriate Refraction Index of prisms leading to decreased angle of resonance. These materials will be used by the better SPR. A metal SPR sensor was embedded in a liquid storage system that acted as an optical mixer and a measurement unit, to prevent oxidation and sample contact, the chip's conductive surface is encased in a neutral gas chamber. This method was similarly highly received, with advantages such as a thinner layer and the ability to change the refractive prism index simply by changing the liquid prism supply. A better choice of materials (metal, glass, plastics) and related advances may eventually lead to a reconsideration about how aesthetic and functional layout is accomplished as a result of the introduction of new technologies such as three-dimensional scanning. In general, intensity modulation, incidence angle interrogation, incident wavelength interrogation, and phase interrogation are the four ways for detecting SPR signals. This method may be used to create a new version using an SPR sensor, which is referred to as SPR imaging (SPRi). For monochromatic light sources (lasers), the angular interrogation technique is necessary, however for variable wavelength light sources, the wavelength interrogation approach is necessary. The phase interrogation method is employed in SPR equipment that has a light source as a component. Furthermore, this technology's optical setup is more difficult than the other three. A notable disadvantage is that just a few studies have documented this technique for SPR sensor devices.

The solution of varied glucose levels was investigated using a Kretschmann-based SPR system, which detected differences in the refractive index of the materials at 670 nm and 785 nm optical wavelengths. Lumerical's FDTD software has been used to determine the process variables for this study, which included the appropriate reflected wavelength and the thickness of the nano-laminated gold/chromium sheet. The refractive index of glucose solution was obtained using the Bionavis glucose sensor. To confirm that the SPR sensor simulation result was accurate, the device was simulated using FDTD. The results are expected to be used as a basis for a more accurate technique of detecting glucose levels in the future, and hence might be used for cost-benefit analysis.

2.6 Angle Resonance

In order to match the refractive index characteristic of the incoming light at an exact angle of incidence, a given wavelength in the SP generation demands a certain design. The desired light source has an influence on the importance of inspecting and adjusting the overall sensor design. When employing a polychromatic light source, for example, wavelength interrogation is required to compute SPR reflectivity. Angle interrogation for the SPR reflectivity characteristic display is critical in the monochrome source of light applications. In the development of SPR sensors, the light source and wavelength preferences (polychromatic or monochromatic) are significant. A monochromatic light source, on the other hand, is defined as a source of light with a single or very limited wavelength range. The kind of light source used to contact the SPR may affect the angular (or incidence angle) and wavelength discussions.

The angular inquiry method is developed when applying monochromatic light (single wavelength), such as light. Phase interrogation is another approach for obtaining SPR signals. Furthermore, as compared to the other three methods, this technique's optical setup is more difficult. The methodologies for angular and wavelength inspection for SPR measurements are shown. Furthermore, as compared to the other three methods, this technique's optical setup is more complex. Because of this constraint, only a few investigations have found this method for SPR sensor devices, notably in industrial items. One of the SPR sensor's benefits is its capacity to monitor the refractive index change in the medium near the detecting surface in real-time.