JoFRISE 1 (1) (2023)
Journal of Frontier Research in Science and Engineering
https://journal.riau-edutech.com/index.php/jofrise
Publisher :
Andester Riau Edutech
Pusat Inovasi Pendidikan dan Teknologi
ISSN : 0000-0000

An Optimum Design of Tapered Optical Fiber as a Cell Sensor Based on Surface Plasmon Resonance

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Submitted: 18/09/2023
Revised: 29/09/2023
Accepted: 09/10/2023
Published: 22/12/2023
Vol. 1
No. 1

ABSTRACT

Sensors and transducers can basically be considered as a device or device that has the ability to convert physical quantities into electrical quantities whose output can be processed electrically or digitally systems. Fiber optics are transparent materials that act as conductors for light waves. The advantages of optical fiber include: lighter, smaller diameter, resistant to magnetic fields, etc. SPR is a phenomenon that occurs when light falls at the interface between a thin layer of metal (usually gold or silver) and a dielectric medium (e.g. water or solution). An optical cell sensor based on Surface Plasmon Resonance (SPR) refers to an optical sensor that uses the SPR principle to detect refractive changes on the sensor surface.

Keywords: *SPR*, *Sensor Cell, Taperred Fiber Optic.*

1 Introduction

The development of optical fiber in Indonesia cannot be separated from the history of the development of optical fiber in Indonesia in the world, which appeared in Germany in the 1930s. British and Japanese researchers succeeded in developing a type of optical fiber. The development of fiber optic technology today has been able to produce attenuation of less than 20 decibels (dB) / km.

Sensors are devices that receive stimuli and respond with electrical signals. The development of fiber optic technology is widely used as a sensor to measure several quantities by modifying optical fiber (Nasrulloh et al., 2021) Fiber-optic-based sensors are becoming very popular in a wide variety of applications, including strain measurement, vibration, temperature, humidity, magnetic fields, and others (Shiryayev et al., 2022) One example of a sensor system is a fiber optic sensor system using fiber optic capabilities to guide light in the spectral range from ultraviolet (UV) (180 nm) to mid-infrared (IR) (10 µm). (Lu & Fletcher, 2009)

SPR-based Fiber Optic Taperred sensors have been used in many applications, including cancer cell detection, bacteria detection, and pathogen detection. Taperred fiber optics reduce some device limitations and can be much more responsive to changes in fluorescence and absorption properties (Taha et al., 2021) The advantage of this technology is that it can perform real-time detection without labeling and without affecting the cells examined. Surface plasmon resonance technology (SPR) has effectively supported optical fiber sensing in the fields of life sciences, clinical diagnosis, medicine, food safety, and so on (Zhao et al., 2019) The application of one of the most prominent optical biosensor technologies, surface plasmon resonance (SPR) is in the drug process and quality analysis of pharmaceutical compound discovery and specificity. (Olaru et al., 2015) Surface plasmon resonance (SPR) is a phenomenon that occurs when a beam of light hits a metal surface and creates electronic oscillations between the metal surface and its surroundings.

How to Cite :
Irawan, D. *et al*(2023). Optimum Design of Tapered Optical Fiber as a Cell Sensor Based on Surface Plasmon Resonance. *Journal of Frontier Research in Science and Engineering(JoFRISE)*, 1(1), 8-12.

This phenomenon has been exploited in many sensing applications, including molecular and cellular sensors. One of them is also in fiber optic high-temperature sensing systems, where optical fiber is used as a sensor transducer and also as a data transmission medium, or both.(Ma et al., 2022)One example of a fiber-optic-based sensor that has currently been developed is a humidity sensor.(Alfihan Fenny, 2015)

The use of tapered optical fibers as chemical sensors for the detection of volatile organic compounds (VOCs) has been developed and the detection material used is organometallic. (Elosua et al., 2012) There are many kinds of uses of fiber optic tapering, namely as cell sensors, magnesium ion sensors, glucose ions, and molecules. Fiber optics offer a convenient method for creating optical sensors: direct light and collect light from a measurement region called an extrinsic sensor or use the fiber itself as a transducer called an intrinsic sensor. Fiber optic sensors have several advantages over conventional sensor techniques. (Korposh et al., 2019).

2 Research Methodology

2.1 Biosensors for living cells

Information regarding the behavior and function of living cells monitored by each sensor is very limited. Recently, it has been reported that there is a dual biosensor platform for the analysis of living cells that can provide additional information about the function and behavior of living cells, namely the use of SPR biosensors (Yanase et al., 2019)The use of SPR biosensors is gaining popularity in biology, health sciences, drug development, diagnostics, clinical and environmental monitoring, and agriculture. SPR is rapidly gaining popularity in the field of quantitative analysis in clinical laboratories for the diagnosis of Preterm Atrial Contraction (PAC), such as immunoassay, mutation detection, therapeutic drug monitoring dose control (TDM), and toxicity risk management to improve drug therapy, with excellent reuse capabilities (Putra Rachmad Almi et al, 2021) However, despite being rated very well, the applied SPR imaging system must be efficient enough to allow assessment of the potency, specificity, selectivity, toxicity, and efficacy of a compound at the individual cell level. (Mir &; Shinohara, 2017).

2.2 Diagnosis of cancer with SPR

In 1982, Liedeberg and Nylander demonstrated the usefulness of surface plasmon resonance (SPR) as an optical biosensor. Since then, SPR has promoted surface chemistry by facilitating similarities between chemistry, physics, and biology. SPR is widely used as an optical biosensor in thousands of research papers covering academia, industry, and technology. The widespread use of SPR as an optical biosensor has been marketed under different trade names by different companies (Singh, 2016)

In addition to detecting cancer, markers will help determine the type and stage of cancer. To date, no known marker can be combined with methods that allow identification and is considered a truly satisfactory diagnostic tool. The discovery of new markers is expected to be similar to the development of new identification tools. (Falkowski et al., 2021). Recently, many studies have shown that exosome proteins are promising biomarkers for cancer screening, early detection, and prognosis. Among many detection techniques, surface plasmon resonance (SPR) is a label-free, real-time optical detection method. Commercial prism-based wavelength/angle modulation SPR sensors offer high sensitivity and resolution, but their large size and high cost limit their suitability for clinical environments. (Wu et al., 2022).

2.3 SPR imaging for single cell analysis

A wide variety of biopharmaceutical, therapeutic recombinant monoclonal antibodies (mAbs) are currently in production with large quantities being used for therapeutic applications. This requires a cell line capable of producing the desired product with a high yield. The most widely used technology for single-cell insulation boundary dilution and ClonePIX FL™ (Molecular Devices, LLC.) (Abali et al., 2017) Although SPR sensors have great potential to unravel the nanoscale effects of living cells, traditional SPR sensors only capture the average RI changes in the presence of thousands of cells. The sensor consists of a light source (LED 640 nm), CMOS detector, optical prism (RI = 1.72) and a sensor chip with a thin gold film

(50 nm) applied to the prism with a liquid corresponding to the refractive index is Using this system (Horii et al.) also detected the allergic response of RBL-2H3 cells using a high-magnification 2D SPR imaging system.

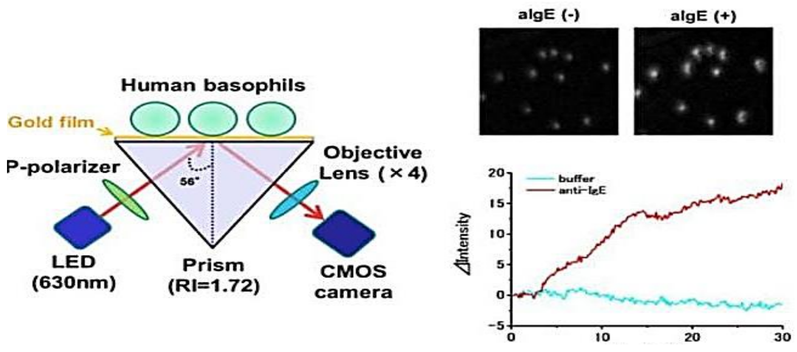

Figure 1. Source: Suraniti E., Sollier E., Calemczuk R., Livache T., Marche PN, Villiers MB, Roupioz Y

3 Results and Discussion

Based on the point of view of electronic systems, sensors and transducers can basically be considered as a device or device that is able to convert physical quantities into electrical quantities whose output can be processed electrically or digitally systems. Sensors are used in everyday life and in their applications cover various fields such as automotive, mechanical, medical, industrial, aerospace.

Fiber optic sensor technology has been known since 1967, when the Fotonic sensor was first patented. Over the years, sensors have evolved along with improvements in fiber technology. The resulting surface plasmon resonance effect on fiber-optic elements is a relatively new sensing technique. It dates back to 1990, when Villeuendas and Pelayo introduced SPR sensors with modified fiber tips.

An optical cell sensor based on Surface Plasmon Resonance (SPR) refers to an optical sensor that uses the SPR principle to detect refractive changes on the sensor surface. SPR has been widely used in the study of secretory systems because of its ability to detect highly dynamic complexes that are difficult to study with other techniques. One of them is, evaluation using SPR on the inhibition of sea sulfate glycans on the protein-heparin interaction of MPXV A29 and A35.(Peng et al., 2023)

Here are some developments in the use of tapered fiber optic in current technology:

1. Fiber Optic Sensor: Tapered fiber optic is used in various types of fiber optic sensors. Fiber optic sensors have proven to have advantages over conventional sensors and have great potential for a wide range of applications, especially in the biomedical field.(Cano Perez et al., 2021) By designing the appropriate taper shape, optical fiber can be used as a sensor to detect changes in temperature, pressure, humidity, vibration, and various other physical parameters.
2. Optical Communication: Tapered fiber optic is also used in optical communication. Taper optical fibers allow for more efficient and accurate transmission of optical signals. Tapered fiber optic can be used as a link between optical fibers of different sizes or as a link between optical fiber and other optical components.
3. Biosensor and Medical Testing: Tapered fiber optic is used in biosensor development and medical testing. Taper optical fibers can serve as sensor platforms to detect biological molecules, such as proteins, DNA, or disease biomarkers.

Development of tapered fiber optic systems and one of them is fiber optic connectors. Apart from being an optical tool, switches, especially directional switches, which are usually in the form of single or multimode optical fiber, can also be used as micromotion sensors based on the development of tapered fiber optic systems and one of them is a fiber optic connector. In addition to optical devices, switches, especially direction switches, which are usually single-mode or multi-mode optical waveguides, can also be used as micro-motion sensors based on intensity modulation.

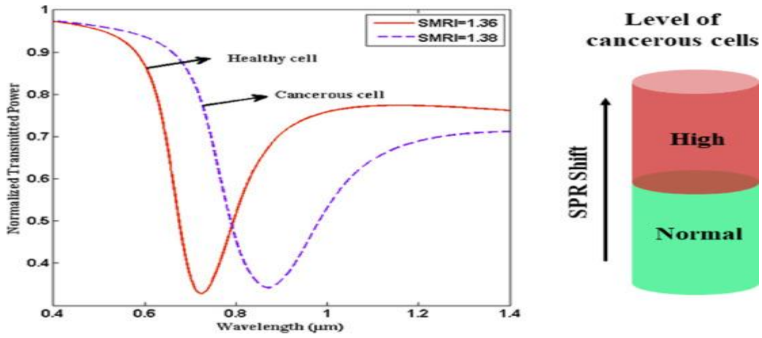

Figure 2. Source: ACS Omega 2023, 8, 5, 4627-4638

One of the designs of tapered fiber optic cell sensors with SPR is a cancer detector. For early cancer detection, uniformly sized tapered fiber optic Surface Plasmon Resonance (SPR) biosensors coated with graphene-antimonene have been demonstrated. The proposed optical biosensor outperforms many refractive index (RI) variants, including biological solutions, and is designed to detect a wide range of cancer cells in the human body with RI 1.36 to 1.4. Sensor design and analysis was carried out using a simulation platform based on the transmission matrix method and the effect of the taper ratio was also studied. The performance of the proposed SPR biosensor is evaluated by performance parameters such as sensitivity, full width at half height, detection accuracy (DA), factor of excellence (FOM) and detection limit (LOD). Numerical results show that the designed sensor can provide sensitivity of 7.3465, 10.9250, 11.8914 and 15.2414 µm/RIU respectively to detect skin, cervical, blood, and skin cancers of the adrenal glands with a maximum FOM of 131.1525 RIU–1, DA 14.2126 µm–1 and LOD 7.2 × 10–5 RIU. (Vikas &; Saccomandi, 2023).

4 Conclusion

Optical fiber has several advantages including high measurement accuracy, practicality, non-electric and ionizing radiation resistance, small size and remote monitoring capabilities. These advantages make fiber optic sensors innovate a lot. SPR-based Fiber Optic Taperred sensors have been used in many applications, including cancer cell detection, bacteria detection, and pathogen detection. The advantage of this technology is that it can perform real-time detection without labeling and without affecting the cells examined. Cells can be detected by observing changes in the pattern of light reflection of the cell surface on the metal surface. When the cell attaches to a metal surface, the refractive index of the surrounding medium changes, thereby changing the pattern of light reflection at the ends of the fibers. There are many kinds of uses of fiber optic tapering, namely as cell sensors, magnesium ion sensors, glucose ions, and molecules.

5 Acknowledgement

We would to thanks to Department of Physics Education, PMIPA, FKIP Universitas Riau for great support in this research.

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