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Case Report

Near-IR Biosensor Utilizing Silver-Phosphorene Nanoribbons for Surface Plasmon Resonance in Photonic Crystal Fiber Detection

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ABSTRACT

Near-infrared (Near-IR) biosensors employing silver-phosphorene nanoribbons integrated with Surface Plasmon Resonance (SPR) in photonic crystal fibers (PCFs) represent a cutting-edge development in biosensing technology. This novel hybrid material combines the plasmonic properties of silver nanoparticles with the unique optical characteristics of phosphorene, offering enhanced sensitivity and specificity in biomolecular detection. The integration of silver-phosphorene nanoribbons into PCF-based SPR biosensors capitalizes on the precise control over light propagation and interaction within the PCF structure. Near-IR detection capabilities facilitate deeper penetration into biological samples and reduce background noise, thereby advancing applications in biomedical diagnostics and environmental monitoring. This abstract highlights the potential of silver-phosphorene nanoribbon-based Near-IR biosensors to revolutionize real-time, label-free detection of biomolecular interactions with high sensitivity and selectivity.

Keywords: Near-IR biosensor, Silver-phosphorene nanoribbons, Surface plasmon resonance (SPR), Photonic crystal fiber (PCF), Biomolecular detection

INTRODUCTION

Near-infrared (Near-IR) biosensors have emerged as crucial tools in various scientific and technological domains, particularly in biomedical diagnostics and environmental monitoring. These sensors leverage the Near-IR spectral range, which offers advantages such as reduced photobleaching and deeper penetration into biological samples compared to visible light. Surface Plasmon Resonance (SPR) is a well-established phenomenon exploited in biosensors for label-free detection of biomolecular interactions based on changes in refractive index near the sensor surface [1,2]. Integrating SPR with photonic crystal fibers (PCFs) enhances the sensitivity and versatility of biosensors. PCFs are optical fibers with a periodic microstructure that enables precise control over light propagation and interaction. By confining light in unique ways, PCFs facilitate efficient coupling of evanescent fields with analytes on the sensor surface, thereby amplifying the SPR signal. A promising advancement in Near-IR biosensing involves the use of silver-phosphorene nanoribbons[3,4]. Silver nanoparticles are renowned for their strong plasmonic properties in the Near-IR range, while phosphorene, a two-dimensional material composed of phosphorus atoms, exhibits tunable optical properties suitable for sensor applications. Combining these materials into nanoribbons enhances their collective benefits, offering improved sensitivity and compatibility with Near-IR detection [5-7]. In recent years, biosensors have become indispensable tools in various fields, from medical diagnostics to environmental monitoring. Among the many types of biosensors, those utilizing Surface Plasmon Resonance (SPR) have garnered significant attention due to their high sensitivity and label-free detection capabilities [8,9]. Integrating SPR with photonic crystal fibers (PCFs) has further enhanced their performance, especially in terms of sensitivity and versatility [10].

Introduction to surface plasmon resonance (SPR)

Surface Plasmon Resonance is a phenomenon that occurs when light strikes a metallic surface under specific conditions, causing the collective oscillation of electrons (plasmons) on the surface of the metal. This resonance is highly sensitive to changes in the refractive index of the surrounding medium, making it ideal for detecting biomolecular interactions without the need for labels.

Photonic crystal fibers (PCFs) and their advantages

PCFs are optical fibers with a periodic microstructure that enables precise control over their optical properties. These fibers can confine

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light in novel ways, allowing for the enhancement of various optical processes such as SPR. The combination of PCFs with SPR has led to the development of highly sensitive and compact biosensors capable of real-time and multiplexed detection.

Silver-phosphorene nanoribbons: a novel material for near-IR detection

Silver (Ag) nanoparticles are commonly used in SPR-based biosensors due to their excellent plasmonic properties in the visible and near-infrared (Near-IR) spectral regions. Phosphorene, a two-dimensional material akin to graphene but composed of phosphorus atoms, has also emerged as a promising material due to its tunable bandgap and strong interaction with light. Silver-phosphorene nanoribbons represent a novel hybrid material that combines the plasmonic properties of silver nanoparticles with the unique optical characteristics of phosphorene. This hybrid material offers enhanced sensitivity and compatibility with Near-IR light, which is advantageous for biological sensing applications due to reduced interference from background signals.

Integration into photonic crystal fiber biosensors

Integrating silver-phosphorene nanoribbons into PCF-based biosensors leverages the unique properties of both materials. The PCF structure allows for efficient light guidance and manipulation, ensuring maximum interaction between the evanescent field of guided light and the analyte molecules on the sensor surface. The Near-IR detection capabilities enabled by silver-phosphorene nanoribbons enhance the sensitivity of SPR-based biosensors. Near-IR light has deeper penetration into biological samples and offers reduced photobleaching compared to visible light, making it suitable for applications where sample integrity and longevity are crucial.

Applications in biomedical and environmental sensing

The development of Near-IR biosensors utilizing silver-phosphorene nanoribbons opens up new possibilities in biomedical diagnostics and environmental monitoring. These sensors can detect biomolecular interactions in complex biological fluids with high sensitivity and specificity, offering potential applications in disease diagnosis, drug development, and environmental pollutant detection.

Challenges and future directions

While significant progress has been made in the development of Near-IR biosensors based on silver-phosphorene nanoribbons and PCFs, several challenges remain. These include improving the stability and reproducibility of nanoribbon synthesis, optimizing sensor design for enhanced sensitivity, and expanding the range of detectable analytes. Future research directions may focus on further enhancing the integration of nanomaterials with PCFs, exploring new two-dimensional materials beyond phosphorene, and advancing signal processing techniques for real-time monitoring and multiplexed detection.

CONCLUSION

Near-IR biosensors utilizing silver-phosphorene nanoribbons integrated into photonic crystal fibers represent a promising advancement in biosensing technology. By combining the plasmonic properties of silver nanoparticles with the unique optical characteristics of phosphorene, these sensors offer enhanced sensitivity, reduced background noise, and improved compatibility with biological samples. Continued research and development in this field hold great promise for revolutionizing biomedical diagnostics, environmental monitoring, and other areas where sensitive and reliable detection of biomolecular interactions is essential. The use of Near-IR light offers several advantages, including reduced background interference, enhanced sensitivity, and deeper penetration into biological samples, making it ideal for real-time and label-free biomolecular detection. The precise control over light propagation and interaction within PCFs further enhances the performance of SPR-based biosensors, enabling highly sensitive and selective detection of analytes. Applications of Near-IR biosensors utilizing silver-phosphorene nanoribbons extend across various fields, from biomedical diagnostics to environmental monitoring. These sensors hold promise for detecting biomolecular interactions with high specificity and sensitivity, thereby contributing to advancements in disease diagnosis, drug development, and environmental analysis.

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