RADemics

Smart Nanosensors for Real Time Detection and Monitoring of Metabolic and Infectious Diseases

S. Geeitha, Amit Kumar Chaturwedi
M KUMARASAMY COLLEGE OF ENGINEERING, DR. C.V. RAMAN UNIVERSITY

Smart Nanosensors for Real Time Detection and Monitoring of Metabolic and Infectious Diseases

[1]S. Geeitha, Associate professor, Department of Information Technology, M Kumarasamy college of Engineering, Thalavapalayam, Karur- 639113, Tamilnadu, India. geethas.it@mkce.ac.in

[2]Amit Kumar Chaturwedi, Researcher, Department of Chemistry, Dr. C.V. Raman University, Kargi Road, Kota, Bilaspur (C.G.) India. 495113. amitchaturwedi1@gmail.com

Abstract

The emergence of smart nanosensors represents a groundbreaking innovation in the real-time detection and monitoring of infectious diseases. These advanced technologies offer unparalleled sensitivity, speed, and portability, enabling rapid and accurate diagnostics at the point of care. Smart nanosensors utilize nanomaterials that can be functionalized to selectively detect specific pathogens or biomarkers, providing a non-invasive, cost-effective, and user-friendly solution for disease detection in both clinical and field settings. Real-time monitoring capabilities allow for dynamic tracking of disease progression and therapeutic responses, thereby enhancing personalized treatment regimens and improving patient outcomes. These nanosensors also play a pivotal role in combating antimicrobial resistance (AMR) by enabling continuous surveillance of infection biomarkers and resistance profiles. Despite the promise of these technologies, challenges such as sensor stability, scalability, and regulatory hurdles must be overcome for broader implementation in healthcare systems. This chapter explores the principles, applications, and future directions of smart nanosensors in infectious disease management, highlighting their transformative potential in diagnostics, patient monitoring, and public health strategies.

Keywords: Smart Nanosensors, Infectious Diseases, Real-Time Detection, Point-of-Care Diagnostics, Antimicrobial Resistance, Disease Monitoring

Introduction

The global healthcare system has faced significant challenges in diagnosing and managing infectious diseases, especially in the context of emerging pathogens and the growing threat of antimicrobial resistance (AMR) [1]. Traditional diagnostic methods, which rely on complex laboratory testing and prolonged turnaround times, often delay timely intervention, leading to worsened patient outcomes and increased disease transmission [2]. In response to these challenges, smart nanosensors have emerged as a transformative solution for the real-time detection and monitoring of infectious diseases [3]. These sensors, built on nanotechnology, enable rapid, highly sensitive, and specific detection of pathogens, revolutionizing diagnostic workflows and patient care [4]. Their integration into clinical and point-of-care settings promises to not only enhance diagnostic efficiency but also contribute significantly to disease management [5].

Nanosensors leverage the unique properties of nanomaterials, such as high surface area, reactivity, and the ability to functionalize with specific biomarkers, making them highly effective for detecting a wide range of pathogens [6]. These sensors can be tailored to detect bacterial, viral, or fungal infections by targeting specific molecular signatures, such as DNA, RNA, proteins, or metabolites [7]. The combination of nanomaterials with advanced detection techniques like surface plasmon resonance (SPR), fluorescence, or electrochemical responses enables the development of devices that offer real-time diagnostics [8]. These innovations significantly shorten the time required for pathogen identification and reduce the need for complex laboratory equipment [9], making them ideal for point-of-care applications [10].

Real-time monitoring of infectious diseases using smart nanosensors presents a new paradigm in personalized medicine. Traditional methods typically provide static data that may not reflect the dynamic nature of an infection [11]. However, with nanosensor technology, continuous monitoring of biomarkers can provide a more accurate representation of disease progression [12], enabling healthcare providers to adjust treatment plans swiftly and effectively. In addition, these nanosensors can track the effectiveness of antimicrobial treatments [13], offering insights into therapeutic efficacy and potentially reducing the overuse of antibiotics—an essential step in combating AMR [14]. The ability to monitor infections in real time also helps in detecting emerging resistance patterns, providing a powerful tool for global health surveillance [15].