Development of Multifunctional Biosensors for Portable In Vitro Diagnostics

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Thesis Abstract

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Thesis Title

Development of Multifunctional Biosensors for Portable In Vitro Diagnostics

Thesis Summary

Diagnosis as a primary form of prevention plays an essential role in modern healthcare. In fact, *in vitro* diagnostics contribute to over 70% medical decision making. As diseases become increasingly diverse and complex, portable *in vitro* diagnostics (PIVD) - characterized by speed, simplicity, user-friendliness, and affordability - can effectively help alleviate the growing burden on healthcare systems. This work emphasizes interdisciplinary applications and focuses on the development of novel multifunctional biosensors to address unmet clinical needs. Specifically, it targets immunoassays and nucleic acid detection, aiming to overcome the current limitations of PIVD related to single-function capabilities and limited target analytes.

Chapter 1 introduces the importance of diagnostics in modern healthcare, current requirements, and existing limitations, in addition to providing a general overview of the concept of biosensing.

Chapter 2 describes the general background of *in vitro* diagnostics (IVD), highlighting the shift from centralized laboratory testing to point-of-care (POC) settings. It discusses the general composition of biosensors, including biorecognition elements and signal transduction methods. It provides an overview and fundamentals of conventional immunoassays and nucleic acid detection techniques.

Chapter 3 discusses the development of a multiplexed, semi-quantitative lateral flow immunoassay (LFIA) enhanced by 3D printing technology. It introduces a novel immunochromatograpic device capable of detecting multiple analytes using minimal sample volumes. The integrated device incorporates gold nanoparticle-labeled antibodies and inkjet-printing technology, enabling semi-quantitative, naked-eye visible readouts and multiplex analyte detection.

Chapter 4 discusses the development of a user-friendly nucleic acid detection biosensor, a concept not yet applied in PIVD. The system integrates CRISPR/Cas technology coupled with alkaline phosphatase (ALP)-conjugated gold nanoparticles. Acrylic resin is employed as the substrate, enabling portable, rapid, and user-friendly colorimetric detection observable by the naked eye, with additional support for smartphone-based quantitative analysis. This approach combines high sensitivity and specificity, paving the way for accessible nucleic acid testing technologies for end users.

Chapter 5 summarizes the findings of this thesis, emphasizing that the developed biosensor platforms align with the ASSURED criteria (Affordable, Sensitive, Specific, User-friendly, Rapid, Equipment-free, Deliverable). This work highlights the importance of embracing interdisciplinary approaches, especially for advancing biosensor technologies and expanding their potential impact on global healthcare solutions.