Purdue Materials Engineering

"DEVELOPMENT OF ELECTROCHEMICAL AND COLORIMETRIC SENSING PLATFORMS FOR AGRICULTURE AND HEALTHCARE APPLICATIONS"

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Purdue MSE PhD Dissertation

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ABSTRACT

Fully portable, rapid, and user-friendly sensors can successfully lead to the continuous monitoring of toxins present in the ecosystem as well as the detection of biomarkers to prevent diseases. Towards this goal, we explore electrochemical and colorimetric methods to develop platforms for the on-site detection of pesticides, heavy metals, and inflammation biomarkers.

This thesis presents work with the primary aim of developing non-biological and biological-based platforms. Chapter 2 describes a fully roll-to-roll electrochemical sensor with high sensing and manufacturing reproducibility for detecting nitroaromatic organophosphorus pesticides (NOPPs). This sensor is based on a flexible, screen-printed silver electrode modified with a graphene nanoplatelets coating and a zirconia coating. This chapter outlines the evaluation of the electrocatalytic activity of zirconia towards the reduction of NOPPs, using methyl parathion as a pesticide sample. Furthermore, it describes the fundamentals of electrochemistry focused on voltammetry techniques used for surface characterization and quantification. The topics reviewed serve as the first step to further manufacturing sensors through large-scale methods (e.g., roll-to-roll). Chapter 3 describes the development of a dual-modality sensing system for the detection of mercury in river waters with high accuracy and precision. The objective of this project was to incorporate colorimetric platforms into the electrochemical methods to create a dual detection design and avert false positives and negatives. Here, novel bio-functional aptamers were incorporated in a sensor containing a paper test that detects mercury by a color change and an electrochemical test that measures charge transfer resistance changes upon aptamer-target interaction. For this platform, the colorimetric test demonstrates the utilization of two systems that consist of silver and gold citrate-capped nanoparticles bio-functionalized with highly specific aptamers. The mechanism of detection of these two systems is through Ps-AgNPs and Ps-AuNPs aggregation as a result of ssDNA-Hg^{2+} interaction. Using Ps-AuNPs microparticles, Chapter 4 describes a fully colorimetric and smartphone-based biosensor for detecting cardiac troponin T, a biomarker for diagnosing acute myocardial infarction. Here, a comparison in detection performance between Whatman grade 1 and high-flow filter paper is reviewed. Finally, Chapter 5 evaluates the colorimetric detection performance of Ps-AuNPs microparticles towards imidacloprid and carbendazim, two of the pesticides most found in imported produce in the United States. The chapter compares gold-based microparticles in which different aptamers were immobilized, and image acquisition approaches.

All sensors reported in this thesis are especially suitable for environmental contaminants monitoring or point-of-care diagnosis applications. The materials selection, use or synthesis, and platforms' performance optimization, development, and feasibility for scale-up manufacturing are expected to advance on-site biosensing technologies and their commercialization.

Date: Monday, November 14, 2022
Time: 9:00am
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