THE ABSTRACT OF DOCTORAL THESIS

a) Introductory Information:

- Author: Huynh Thi Thuy Linh
- Thesis title: "Research and Development of a Lab-on-a-Chip Device for Diagnosing White Spot Syndrome Virus in Penaeid Shrimps"
- Field of Study: Electronic Engineering Code: 9520203
- Institution: University of Engineering and Technology, Vietnam National University Hanoi

b) Abstract Content:

White Spot Syndrome Virus (WSSV) is one of the most devastating pathogens in shrimp aquaculture in Vietnam and many Asian countries, causing significant productivity losses and severe economic damage. The polymerase chain reaction (PCR) method is currently the most accurate diagnostic technique. However, it requires specialized laboratories, skilled personnel, and high costs, which limit its applicability for rapid on-site detection, especially under farm conditions. As the aquaculture industry moves toward real-time disease management, the development of a portable electrochemical biosensor for rapid WSSV detection is both urgent and highly applicable.

The objective of this thesis is to research, design, and develop an electrochemical biosensor system integrated with Internet of Things (IoT) technology for on-site rapid detection of WSSV. The research aims to master the modification of the electrode surface to enhance charge transfer efficiency and active surface area, the functionalization of the electrode surface for specific biological recognition through antibody immobilization, and the development of a measurement system with real-time data processing and visualization software.

The research content of this thesis comprises three main parts:

- Surface modification of the electrode using electrochemical methods, in which gold nanoparticle deposition is employed to enhance charge transfer ability, increase the active surface area, and control the density of biomolecular binding sites.

- Surface functionalization with a self-assembled monolayer (SAM) formed from the thiolated compound 11-mercaptoundecanoic acid (11-MUA), activated by EDC/NHS to immobilize anti-VP28 antibodies onto the electrode surface, thereby enabling specific recognition of the VP28 protein, a biomarker of WSSV.

- Design and development of a portable electrochemical measurement system with IoT connectivity, enabling real-time data transmission via the MQTT protocol to control software on a computer or mobile application for rapid on-site detection and remote monitoring.

The research methodology employed in this study consists of:

- Electrochemical methods: cyclic voltammetry (CV), square wave voltammetry (SWV), and electrochemical impedance spectroscopy (EIS) were used to evaluate the surface modification process, charge transfer ability, stability, and sensitivity of the biosensor.

- Morphological and material characterization methods: the surface morphology and elemental composition of the electrode were analyzed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).

- Optical and molecular biology methods: fluorescence microscopy was employed to directly observe the successful capture of fluorescently labeled proteins, the Western blot technique was used to confirm the specific binding between the anti-VP28 antibody and the VP28 protein.

The results show that the electrochemical deposition of gold nanoparticles significantly improved the electrochemical characteristics of the electrode, enhancing charge transfer ability and increasing the active surface area. A stable 11-MUA SAM was successfully formed, enabling efficient immobilization of anti-VP28 antibodies through amide bond formation with the activated carboxyl groups. CV, SWV, and EIS measurements demonstrated electrochemical signal variations corresponding to each step of electrode functionalization and bio-recognition, clearly reflecting changes in impedance and redox peak current.

The developed biosensor exhibited high sensitivity, good selectivity, and a low limit of detection toward the VP28 protein, with stable signals and excellent reproducibility. Validation by the Western blot technique confirmed the specific binding between the anti-VP28 antibody and the VP28 protein. The portable IoT-based electrochemical measurement system operated stably, capable of measuring and transmitting real-time electrochemical data, and its results were consistent with those obtained from the PCR method.

Experimental results on WSSV-positive shrimp samples in the laboratory showed that the electrochemical signals were consistent with the PCR result, confirming the feasibility of the developed device. The system demonstrated outstanding advantages in speed, low cost, portability, and simple operation, making it suitable for use in shrimp farms, hatcheries, and disease monitoring centers.

The thesis proposes a novel approach that integrates molecular biotechnology with advanced electrochemical techniques and electronic engineering to develop a biosensor platform capable of rapid and accurate on-site detection. This research offers high practical value for monitoring and early detection of aquatic diseases, contributing to smart aquaculture applications. The device, fabricated from commonly available components, low-cost, and easy to operate, has strong potential for commercialization to support Vietnam’s strategy for sustainable high-tech agricultural development.

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