Faculty of Electrical and Electronic Engineering Technology

INITIAL DEVELOPMENT OF A NANOELECTRONIC BIOSENSOR FOR UREA DETECTION

MUHAMMAD AKMAL BIN ABD WAHID

Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DEDICATION

To my beloved mother, Siti Fatimah Binti Shabuddin, and father,Abdul Wahid Haji Othman, thank you for supporting me when I continue my studies for bachelor degree in UTeM.

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ABSTRACT

A nanoelectronic biosensor for urea detection often employs a nanomaterial as the sensing element, such as carbon nanotubes or graphene. The nanomaterial is functionalized with a biomolecule, such as an enzyme that binds urea more selectively. The binding of urea to the biomolecule changes the electrical characteristics of the nanomaterial, which are evaluated by electrochemical impedance spectroscopy or cyclic voltammetry. However, biosensor development has a detection limit, a detection time, and specificity. Detection time introduces significant challenges when designing biosensor systems, such as finding a suitable technology while maintaining the highest sensitivity and specificity. They can also be affected by environmental changes and contamination. In this research, a Polypyrrole (PPY)/Multiwalled Carbon Nanotube (MWCNT) nanofilm is fabricated by using choronoamperometry. This fabricated PPy/MWCNT nanofilm is characterised by using Fourier transform infrared spectroscopy (FTiR), scanning electron microscopy (SEM), and X-ray diffraction (XRD) to check the morphology and analyse the material's properties. Then, the relationship between voltage and current is analysed using the cyclic voltammetry method. The electrodeposition and cyclic voltammetry methods have been used with the AutoLAB potentiostat and NOVA 2.0 AutoLAB software. Based on the chronoamperometry results on PPY/MWCNT for 1-minute results, the carbon electrode has the highest current at 0.001A. The result changes after a longer chronoamperometry process. For chronoamperometry on PPY/MWCNT for 3-minute results, the copper electrode has the highest current at 0.0011 A, followed by the stainless steel electrode at 0.001 A. Lastly, for chronoamperometry on PPY/MWCNT for 5-minute results, the copper electrode maintained the highest current at 0.0011 A, followed by the aluminium electrode at 0.0009A. The cyclic voltammetry of carbon and stainless steel has been set between -0.8 V and +0.4 V. After the repititive potential cycles, the major difference between this two solution which are PBS solution and urea solution are the current. Based on the cyclic voltammetry results, the current in the PBS solution for carbon is -0.0025 A and the current in the analyte (representing urea) solution for carbon is -0.0037 A. Then, the current in the PBS solution for stainless steel is -0.0010 A, and the current in the analyte solution for stainless steel is -0.0015 A. As a conclusion, the changes in current for both PBS and analyte solutions show that the biosensor has been successfully developed .

ABSTRAK

Biosensor nanoelektronik untuk pengesanan urea selalunya menggunakan bahan nano sebagai elemen penderiaan, seperti tiub nano karbon atau graphene. Bahan nano difungsikan dengan biomolekul, seperti enzim yang mengikat urea dengan lebih selektif. Pengikatan urea kepada biomolekul mengubah ciri elektrik bahan nano, yang dinilai oleh spektroskopi impedans elektrokimia atau voltammetri kitaran. Walau bagaimanapun, pembangunan biosensor mempunyai had pengesanan, masa pengesanan dan kekhususan. Masa pengesanan memperkenalkan cabaran penting apabila mereka bentuk sistem biosensor, seperti mencari teknologi yang sesuai sambil mengekalkan kepekaan dan kekhususan tertinggi. Mereka juga boleh terjejas oleh perubahan persekitaran dan pencemaran. Dalam penyelidikan ini, sebuah nanofilem Polypyrrole (PPY)/Multiwalled Carbon Nanotube (MWCNT) dibuat dengan menggunakan koronoamperometri. Nanofilem PPy/MWCNT rekaan ini dicirikan dengan menggunakan spektroskopi inframerah transformasi Fourier (FTiR), mikroskop elektron pengimbasan (SEM), dan pembelauan sinar-X (XRD) untuk memeriksa morfologi dan menganalisis sifat bahan. Kemudian, hubungan antara voltan dan arus dianalisis menggunakan kaedah voltammetri kitaran. Kaedah elektrodeposisi dan voltammetri kitaran telah digunakan dengan perisian AutoLAB potentiostat dan NOVA 2.0 AutoLAB. Berdasarkan keputusan kronoamperometri pada PPY/MWCNT untuk keputusan 1 minit, elektrod karbon mempunyai arus tertinggi pada 0.001A. Hasilnya berubah selepas proses kronoamperometri yang lebih panjang. Untuk chronoamperometry pada PPY/MWCNT untuk keputusan 3 minit, elektrod kuprum mempunyai arus tertinggi pada 0.0011 A, diikuti oleh elektrod keluli tahan karat pada 0.001 A. Akhir sekali, untuk chronoamperometry pada PPY/MWCNT untuk keputusan 5 minit, elektrod kuprum mengekalkan arus tertinggi pada 0.0011 A, diikuti oleh elektrod aluminium pada 0.0009A. Voltammetri kitaran karbon dan keluli tahan karat telah ditetapkan antara -0.8 V dan +0.4 V. Selepas kitaran potensi repititif, perbezaan utama antara kedua-dua larutan ini iaitu larutan PBS dan larutan analit (mewakili urea) adalah arus. Berdasarkan keputusan voltammetri kitaran, arus dalam larutan PBS untuk karbon ialah -0.0025 A dan arus dalam larutan larutan analit (mewakili urea) untuk karbon ialah -0.0037 A. Kemudian, arus dalam larutan PBS untuk keluli tahan karat ialah -0.0010 A, dan arus dalam larutan analit untuk keluli tahan karat ialah -0.0015 A. Sebagai kesimpulan, perubahan arus untuk kedua-dua larutan PBS dan glukosa menunjukkan bahawa biosensor telah berjaya dibangunkan.

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μ	-	Micro

LIST OF ABBREVIATIONS

V	-	Voltage
SPR	-	Surface Plasmon Resonanse
FET	-	Field-Effect Biosensor
AuNPs	-	Gold nanoparticles
DNA	-	Deoxyribonucleic Acid
QCM	-	Quartz Crystal Microbalance
MHz	-	Megahertz
ng/ml	-	Nanograms per Milliliter
fg/ml	-	Femtogram per Mollilitter
pH	-	Potential of Hydrogen
MoS_2	-	Molybdenum Disulphide
EGFET	-	Extended Gate Field Effect Transistor
PPy	-	Polypyrrole
MBs	-	Magnetic Beads
GO	-	Graphene Oxide
NiO	-	Nickel Oxide
LED	-	Light-Emitting Diode
MTM	-	Multi-mode Thincore Multi-mode
Ag NPs	-	Silver nanoparticle
RuO2	-	Ruthenium(IV) oxide
T	-	Time
mV	-	Millivolt
FWHM	-	Full Width at Half Maximum
FDTD	-	Finite-difference time-domain
CO2	-	Carbon dioxide
SEM	-	Scanning Electron Microscope
XRD	-	X-ray diffraction
FTIR	-	Fourier-transform infrared spectroscopy
Cm	-	Centimeter
DAFc	-	Direct alcohol fuel cells
SnS	-	Stannous sulphide
MLG	-	Multilayered graphene
REFET	-	Reference field effect transistors
EnFET	-	Enzyme field effect transistors

INTRODUCTION

1.1 Background

Biosensor research and development is becoming a hot issue since they are simple, rapid, and low-cost. They enable improvements in point-of-care applications like disease marker detection. Surface chemistry advances have opened up a slew of new possibilities for constructing target molecule identification systems. New transducers, as well as the downsizing and integration of high-throughput biosensors, are expected to be developed as a result of nanofabrication advances.

1.2 Problem Statement

For urea determination, a number of approaches have been developed, including direct and indirect detection. The chromatographic and colorimetric techniques for urea testing are reliable and have been widely utilised for general monitoring. These procedures, on the other hand, need time-consuming sample preparation and/or expensive equipment, rendering them unsuitable for online or onsite monitoring [1]. For many therapeutically important targets and qualitative or semi-quantitative outcomes, certain traditional biosensors have relatively low sensitivity [2] . However, the clinical application of biosensing devices has not yet reached this level, and there are several significant scientific and technological obstacles that must be overcome before the devices can be manufactured and used on a large scale [3].

1.3 Project Objective

This project's major objective is to develop a nanoelectronic biosensor for urea detection. The following below are the specific objectives:

a) To fabricate PPy/MWCNT nanofilm using chronoamperometry .
b) To characterize PPy/MWCNT at nanofilm using Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), and X-Ray Diffreaction (XRD).

c) To analyze the relationship between voltage and current for different materials of electrodes during analyte detection.

1.4 Scope of Project

To avoid any ambiguity about the project's scope owing to various limits and constraints, the project's scope is stated as follows:

a) Study the relationship between the voltage, current and the surface area by using cyclic voltammetry method
b) Design and simulate the experiment using software for simulation electrochemistry.
c) Comparing the electrodes on which is better at sensitivity for detecting urea based on sensorgram results.
d) Electrodeposition and cyclic voltammetry are experimented by using AutoLAB potentiostat with NOVA 2.0Autolab software.
e) Using different types of electrodes materials such as copper , carbon , aluminum and stainless steel.
f) Using PBS and urea solution for cyclic voltammetry process.

CHAPTER 2

LITERATURE REVIEW

1.5 Introduction to Biosensor

A biosensor is analytical tool made up from two main parts: an immobilised biocomponent and a transducer that converts to a detectable electrical signal from a biological signal . The fact that urea is toxic in excess of certain levels underscores the importance of this research, and continuous real-time monitoring in environmental, clinical, and food-related settings is critical. Traditional analytical processes are time consuming and often laboratory restricted, but biosensors provide the advantages of ease of use, mobility, and the potential to deliver real-time information. Biosensor research and development became the most widely studied discipline because easy,rapid, and low-cost biosensors contribute to advances in next-generation medicines such as individualised medicine and ultrasensitive point-of-care detection of disease markers.

This chapter evaluated traditional biosensors and biosensing techniques from the perspective of smart biomaterials, focusing on recent developments in important biosensors such as SPR-based biosensors, FET-based biosensors, and AuNPs-based biosensors. The various techniques for immobilising the urease enzyme, the stability and response time characteristics, and the transducers used in biosensor development are all summarised in this review. The case examples presented here clearly show that biosensor research is really interdisciplinary. Improvements in nanofabrication technology also promise the development of novel transducers as well as the downsizing and integration of high-throughput biosensors. Multidisciplinary efforts outside of typical specialisations are required for the development of novel biosensors. As a result of the fusion of significant interdisciplinary talent, biosensor development will be expedited and biological domains will be revolutionised [4].

1.6 Purpose of biosensor

A biosensor is a device that assesses biological or chemical reactions by using signals proportional to the concentration of an analyte in a reaction. Biosensors are utilised in illness