Faculty of Electrical and Electronic Engineering Technology

INITIAL DEVELOPMENT OF A NANOELECTRONIC BIOSENSOR FOR GLUCOSE DETECTION

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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WAN ZARIFF ZIKRI BIN WAN MARZUKI

A project report submitted
in partial fulfillment of the requirements for the degree of
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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

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Date : 24/2/2023

DEDICATION

To my beloved mother, Sayuti binti Mat Ali,
Thank you for supporting me when I continue my studies
for my bachelor degree in UTeM.

To my siblings, Wan Nur Nadia Hanim binti Wan Marzuki,
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ABSTRACT

A nanoelectronic biosensor for glucose 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 with glucose for higher selectively. The binding of glucose to the biomolecule changes the electrical characteristics of the nanomaterial which is evaluated by electrochemical impedance spectroscopy or cyclic voltammetry. However, biosensor development have detection limit, 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. Therefore, in this research, Polypyrrole (PPY)/Multiwalled Carbon Nanotube (MWCNT) nanofilm is fabricated by using choronoamperometry method. This electrodeposition and cyclic voltammetry of fabricated nanofilm is experimented by AutoLAB potentiostat with NOVA 2.0 AutoLAB software. Then, it is characterized by using Fourier transform infrared spectroscopy (FTiR), scanning electron microscopy (SEM), and X-ray diffraction (XRD) to check the morphology and analyse the materials' properties. Based on the chronoamperometry of PPY/MWCNTnanofilm for 1 minute, carbon electrode shows the highest current at 0.001A. However, the result changes after a longer chronoamperometry process. After chronoamperometry for 3 minutes, copper electrode have the highest current at 0.0011A followed by stainless steel electrode at 0.001A. Lastly, for chronoamperometry for 5 minute results, copper electrode maintain the highest current at 0.0011A followed by aluminium electrode at 0.0009A. The cyclic voltammetry of carbon and stainless steel have been set between -0.8V and +0.4V in PBS solution. Based on the cyclic voltammetry results, the current in PBS solution for carbon is at -0.0025A and in glucose solution for carbon is at -0.0037A. Then, the current in PBS solution for stainless steel is -0.0010 A, and the current in glucose solution for stainless steel is -0.0015 A. As conclusion, the changes in current for both PBS and glucose solution shows that the glucose have been successfully detected and nanobiosenser is successfuly developed.

ABSTRAK

Penderia bio nanoelektronik untuk pengesanan glukosa selalunya menggunakan bahan nano sebagai elemen penderiaan seperti tiub nano karbon atau graphene. Bahan nano difungsikan dengan biomolekul seperti enzim yang mengikat dengan glukosa untuk lebih selektif. Pengikatan glukosa kepada biomolekul mengubah ciri elektrik bahan nano yang dinilai oleh spektroskopi impedans elektrokimia atau voltammetri kitaran. Walau bagaimanapun, pembangunan penderia bio 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. Oleh itu, dalam penyelidikan ini, nanofilem Polypyrrole (PPY)/Multiwalled Carbon Nanotube (MWCNT) difabrikasi menggunakan kaedah koronoamperometri. Elektrodeposisi dan voltammetri kitaran nanofilem rekaan ini diuji oleh potensiostat AutoLAB dengan perisian AutoLAB NOVA 2.0. Kemudian, ia dicirikan dengan menggunakan spektroskopi inframerah transformasi Fourier (FTiR), mikroskop elektron pengimbasan (SEM), dan pembelauan sinar-X (XRD) untuk memeriksa morfologi dan menganalisis sifat bahan. Berdasarkan kronoamperometri PPY/MWCNTnanofilm selama 1 minit, elektrod karbon menunjukkan arus tertinggi pada 0.001A. Walau bagaimanapun, keputusan berubah selepas proses kronoamperometri yang lebih panjang. Selepas kronoamperometri PPY/MWCNT selama 3 minit, elektrod kuprum mempunyai arus tertinggi pada 0.0011A diikuti oleh elektrod keluli tahan karat pada 0.001A. Akhir sekali, untuk chronoamperometry pada PPY/MWCNT untuk keputusan 5 minit, elektrod kuprum mengekalkan arus tertinggi pada 0.0011A diikuti oleh elektrod aluminium pada 0.0009A. Voltammetri kitaran karbon dan keluli tahan karat telah ditetapkan antara -0.8V dan +0.4V dalam larutan PBS. Berdasarkan keputusan voltammetri kitaran, arus dalam larutan PBS untuk karbon adalah pada -0.0025A dan dalam larutan glukosa untuk karbon adalah pada -0.0037A. Kemudian, arus dalam larutan PBS untuk keluli tahan karat ialah -0.0010 A, dan arus dalam larutan glukosa untuk keluli tahan karat ialah -0.0015 A. Sebagai kesimpulan, perubahan arus untuk kedua-dua larutan PBS dan glukosa menunjukkan bahawa glukosa telah berjaya dikesan dan nanobiosensor berjaya dibangunkan.

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µM	-	Micrometre
mM	-	Milimetre

LIST OF ABBREVIATIONS

V	-	Voltage
SPR	-	Surface Plasmon Resonanse
FET	-	Field-Effect Biosensor
AuNPs	-	Gold nanoparticles
MOH	-	Oxidative Adsorbed Hydroxide
QCM	-	Quartz Crystal Microbalance
MHz	-	Megahertz
ng/ml	-	Nanograms per Milliliter
fg/ml	-	Femtogram per Molliliter
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
M	-	Reductive Metal Adsorption
FDTD	-	Finite-difference time-domain
CO2	-	Carbon dioxide
SEM	-	Scanning Electron Microscope
XRD	-	X-ray diffraction
FTIR	-	Fourier-transform infrared spectroscopy
Cm	-	Centimeter
XRD	-	X-ray diffraction
GOx	-	Glucose Oxidation

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CHAPTER 1

INTRODUCTION

1.1 Background

Biosensor research and development is becoming a hot issue since they are simple, rapid, low-cost, extremely sensitive, and selective. 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, areexpected to be developed as a result of nanofabrication advances.

1.2 Problem Statement

Biosensors were become used as experts in various fields especially in engineering and medicine, which need large number of trials to overcome the best result. The manufacture of biosensor need integrated laboratory with materials, structures and equipment and this insufficiency in the world. To avoid this problem, the simulation is designed by used of COMSOL Multiphysics software as tool to complete the design with approximate result [1].

The development of biosensors has a detection limit, a detection time, and specificity. When constructing biosensor systems, detection time poses important obstacles, such as selecting a suitable technology while retaining the maximum sensitivity and specificity.

Several techniques for glucose detection such as electrochemical and optical methods.

However, the process for enzyme immobilization of a glucose biosensor requires extra work, time and equipment to ensure covalent bonding occured and maintain the bioactivity during operation.

1.3 Project Objective

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

a) To fabricate PPY/MWCNT nanofilm by using chronoamperometry.
b) To characterize Polypyrrole/MWCNT at nanofilm by using Fourier Transform Infrared Spectroscopy (FTiR), Scanning Electron Microscope (SEM), and X-Ray Diffraction (XRD).
c) To analyze the relationship between voltage and current for different materials of electrodes.

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 are is better at sensitivity for detecting glucose based on sensogram results.
d) Electrodeposition and cyclic voltammetry is experimented by using AutoLAB potentiostat with NOVA 2.0 AutoLAB software.
e) Using different types of electrode materials such as copper, carbon, aluminium and stainless steel.
f) Using PBS and glucose solution for cyclic voltammetry process.