An Electrochemical Sensor for Glucose and Oxygen Detection

Lauren Bell[1], David Alexander[1], Yu Zhao Ph.D.[1], Frédérique Yiannikouris, Ph.D.[2], Guigen Zhang Ph.D.[1]
[1]F. Joseph Halcomb III, M.D. Department of Biomedical Engineering, University of Kentucky, USA
[2]Department of Pharmacology and Nutritional Sciences, University of Kentucky, USA

Statement of Purpose: The need for a rapid, specific, reliable detection of pathogenic targets or biomarkers is a prevalent challenge faced in routine healthcare. Biosensors are supposed to meet this need and yet the signs of unmet needs in rapid biosensing and detection are everywhere, including the testing medium used for gathering data, proof of the ability of the biosensor to function as a point-of-care device, and consistent and acceptable sensitivity and selectivity, to name just a few. The long-term goal of this project is to develop an accurate and selective electrochemical biosensor that can monitor and analyze the concentration of various biomarkers, in-situ and in real-time. In this specific work, we aim to demonstrate the feasibility of detecting biomarker concentration changes by testing glucose and oxygen detection using three-electrode, electrochemical biosensors. Stepwise current response to the addition of glucose solution and changing oxygen concentration show the ability of the sensor to detect concentration changes.

Methods: Two amperometric biosensors in a three-electrode configuration were developed using commercially available three-electrode sensor chips purchased from Metrohm USA, Inc. (Riverview, FL, USA). These chips consist of a ceramic base, silver reference electrode, gold working electrode and gold counter electrode. The glucose detection biosensor is prepared by immobilizing 1.97 mg/mL of glucose oxidase on the working electrode through the electropolymerization of pyrrole to functionalize the electrode.

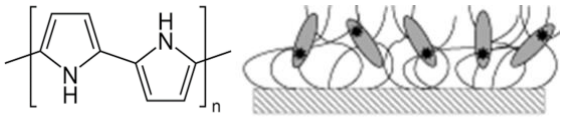

Fig.1 Pyrrole (left) and schematic of electropolymerization (right).

The functionalized electrode for glucose detection is then integrated into a PDMS microfluidic platform that was designed and constructed in the lab. Glucose detection experiments are performed with a potentiostat through amperometric measurements conducted by holding the functionalized working electrode at 0.35V versus an Ag reference electrode for 900 seconds. At 300 seconds and every subsequent minute, a solution containing 0.1 phosphate buffered saline, 3mM p-Benzoquinone, and an increasing concentration of glucose solution was added to the microfluidic system and pumped through the fluidic biosensor. The resulting current response was recorded. The oxygen detection biosensor is functionalized by first applying a hydrogel layer to the electrodes (40 wt% acrylamide, 5 wt% N,N'-methylene-bis-acrylamide, 0.1mg/mL riboflavin 5'-phosphate sodium, 1mL/mg N,N,N',N'-tetramethyl ethylenediamine, 1:1 ratio of water to glycerol) followed by a permeable membrane layer (0.5 wt% 2,2-dimethoxy-2-phenylacetophenone). Oxygen detection testing was performed under four different conditions: applying different voltage in DI water and 4M KCl, and applying constant voltage in different molar concentration of KCl and at different pressure settings in a vacuum chamber. The resulting current response was recorded for each condition.

Results: Fig.2 shows the calibration curve for the glucose detection biosensor, obtained from the current response to increasing glucose concentration. The sensing capability within normal physiological range is shown between 3.9-7.1 mM (70-130 mg/dL) with a R^2 value of about 0.9895.

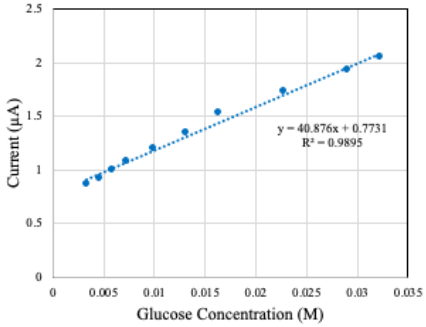

Fig.2 Calibration curve of glucose detection biosensor.

Fig.3 displays the calibration curve showing the current response at various oxygen levels with a R^2 value of 0.9842. Note that normal arterial oxygen partial pressure is within 75-100 mmHg.

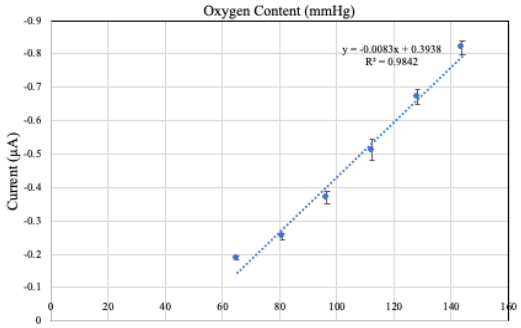

Fig.3 Calibration curve of oxygen detection biosensor.

Conclusions: The success of both biosensors shows great potential in addressing the mentioned unmet needs. As the glucose concentration increases, the current response also increases. The glucose biosensor also exhibits desirable repeatability and detectability within the necessary physiological range. Similarly, the oxygen biosensor detects changes in oxygen content. An increase in oxygen content resulted in an increase in the magnitude of the current response. The developed sensors can provide a more cost effective and easy-to-deploy method for physiological biomarker detection than what is currently used in the research and clinical setting. Additionally, the microfluidic platform that is utilized for the glucose detection biosensor is reusable and future work includes expansion of the design to create a device capable of combination detection using multiple sensors to allow for simultaneous biomarker detection and monitoring.