# Accepted Manuscript


Mathematical model for the electrochemical impedance response of a continuous glucose monitor

Ming Gao, Morgan S. Hazelbaker, Rui Kong, Mark E. Orazem

PII: S0013-4686(18)30859-4

DOI: 10.1016/j.electacta.2018.04.103

Reference: EA 31670

To appear in: *Electrochimica Acta*

Received Date: 18 January 2018

Revised Date: 28 March 2018

Accepted Date: 14 April 2018

Please cite this article as: M. Gao, M.S. Hazelbaker, R. Kong, M.E. Orazem, Mathematical model for the electrochemical impedance response of a continuous glucose monitor, *Electrochimica Acta* (2018), doi: 10.1016/j.electacta.2018.04.103.

# Mathematical Model for the Electrochemical Impedance Response of a Continuous Glucose Monitor☆

Ming Gao[a], Morgan S. Hazelbaker[a], Rui Kong[b], Mark E. Orazem[a,*]

[a]*Department of Chemical Engineering, University of Florida, Gainesville, FL 32611*
[b]*Medtronic Inc., Diabetes, 18000 Devonshire St., Northridge, CA 91325*

**Abstract**

A mathematical model is developed for the impedance response of immobilized glucose oxidase electrochemical biosensors. The coupling between the homogeneous reactions and heterogeneous reactions considered in the model included anomerization between $\alpha$-D-glucose and $\beta$-D-glucose and four reversible enzymatic catalytic reactions transforming $\beta$-D-glucose and oxygen into gluconic acid and hydrogen peroxide. The electroactive hydrogen peroxide was considered to be reversibly oxidized or reduced at the electrode. The electrochemical system was modeled mathematically as a one-dimensional boundary-value problem and solved by use of Newman's BAND algorithm. The corresponding impedance was calculated for each specified frequency. The resulted limiting current, reaction profiles, and impedance response provide insights into the influence of system parameters such as interstitial glucose concentration and enzymatic rate constants. This model has a potential application in predicting sensor design and diagnosing sensor failure mechanisms.

*Keywords:* continuous glucose monitor, electrochemical impedance spectroscopy, mathematical model, numerical simulation

## 1. Introduction

Diabetes is a chronic metabolic disease, to which, in 2012, 1.5 million deaths worldwide were directly attributed [1]. Since the treatment requires frequent testing of blood glucose levels, the development of highly sensitive, pain-free, and low-cost glucose biosensors has attracted broad attention over the past five decades. The research on glucose biosensors was pioneered by Clark and Lyons [2], who raised the concept of biosensors in 1962. Their work was followed by Updike and Hicks [3], who developed the first practical enzyme-based glucose sensor in 1967. Three generations of glucose biosensors have been developed to date. The first-generation glucose biosensors were amperometric sensors based on the oxygen–hydrogen peroxide pair as a mediator. They either detected the consumption of oxygen by applying a negative potential [3] or monitored the production of hydrogen peroxide by applying a positive

☆Submitted to the special issue of *Electrochimica Acta* dedicated to the 2017 Annual Meeting of the *International Society of Electrochemistry* in Providence, Rhode Island. Paper presented in Symposium S03 "Electrochemical Approaches to Clinical Diagnostics and Medical Devices."

*Corresponding author
*Email address:* meo@che.ufl.edu (Mark E. Orazem)