Point of Care Insulin Sensor

Destiny Woods, Madison Strong, Arianna Voigt, Daylan Christopher

Project Description

This project aims to develop a point of care insulin sensor to measure unknown concentrations of purified insulin samples. The team is combining mechanical, electrical, and biochemical techniques to develop a process for sensor fabrication and testing methods.

Justification

- Diabetes affects millions of people worldwide and is growing exponentially [1]
- Glucose is the main biomarker for diabetes monitoring, but studies have shown the potential for tighter glycemic management when measuring additional biomarkers, such as glucagon and insulin
- Current methods for measuring insulin require special equipment and personnel, which are not readily available to patients as well as many hours for results, making the methods unreasonable for individual use

Requirements and Specifications

Table 1. *List of functional requirements, related design specifications, and relative standard reference*

Functional Requirement	Design Specification	Standard
Accurate Insulin Reading	<5% error	ISO 15197
Manufacturability	<2day process	ISO 25.220
Small Dimensions	30 x 10 x 0.625 mm	ISO 15197

This table began as the foundation of the project in semester 1. Initially, the table consisted of feedback from a variety of customers – physicians, patients with diabetes, and caretakers/parents of children with diabetes – which was analyzed and condensed to show the top necessities of the product. These customer needs were used to develop the functional requirements which have guided the project and how the design process has progressed.

Design Process

Mechanical

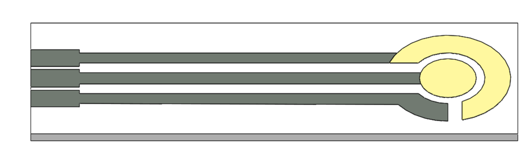

Figure 1. *Electrode base purchased from Zimmer and Peacock*

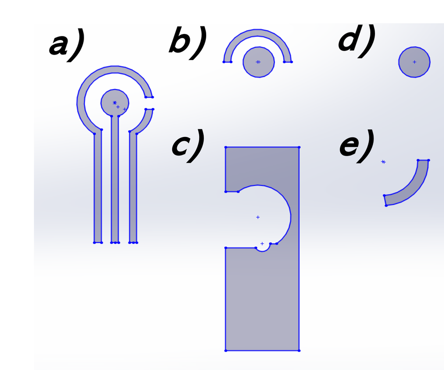

Figure 2. Five layers of electrode base with materials of a) carbon ink b) first of two insulating layers c) final insulating layer d) gold ink and e) silver-silver chloride ink

Biochemical

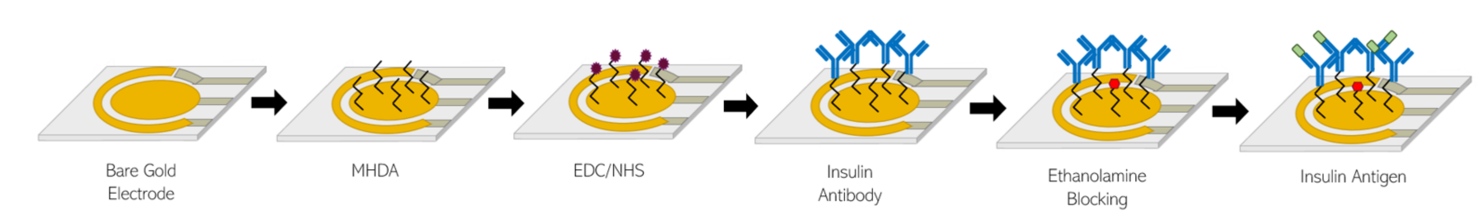

Figure 3. *Immobilization of insulin antibody on gold electrode layer by layer.*

Electrical

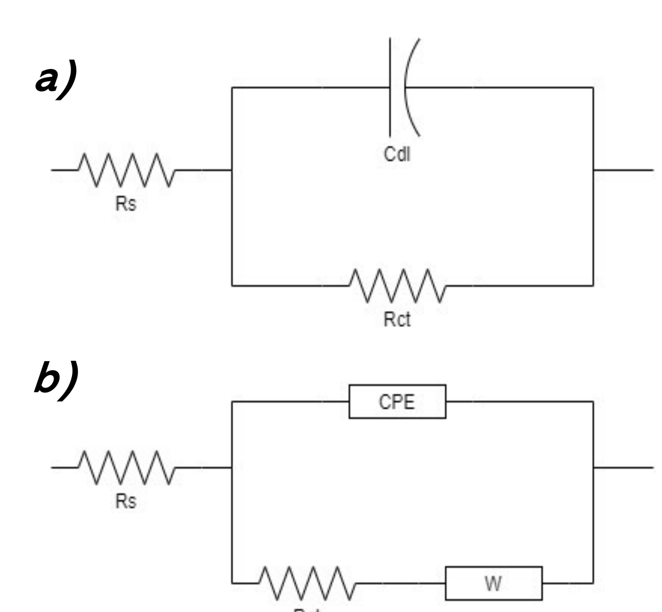

Figure 4. *a) Ideal equivalent circuit, or Randle's circuit model b) measured circuit, or modified Randle's circuit*

The Randle's circuit is comprised of 3 variables:

1. *Solution resistance (Rs)* : Inherent resistance of solution being tested.
2. *Double-layer capacitance(Cdl)* : Resistance of the charge moving from sensor to solution.
3. *Charge-transfer resistance(Rct)* : Resistance of the charge moving from sensor to solution.

The modified Randle's circuit is comprised of Rs and Rct, along with two additional elements:

1. *Constant phase element (CPE)* : Imperfect capacitor due to the rough surface.
2. *Warburg element (W)* : Added to indicate diffusion of charge throughout the system.

Data

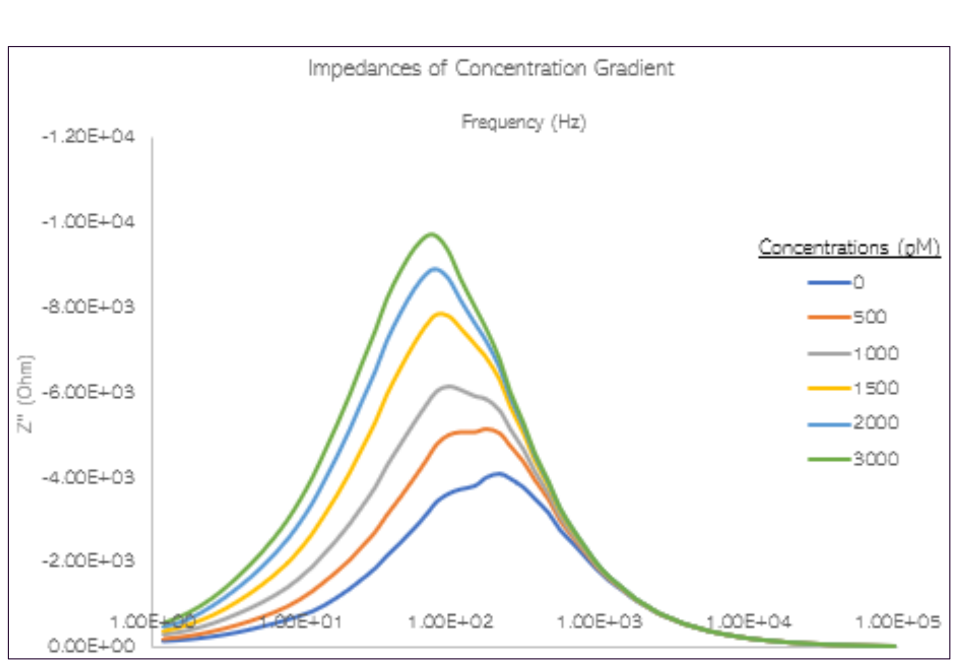

Figure 5. *Impedance measures of concentration range which demonstrates an increase in resistance with increasing insulin concentration*

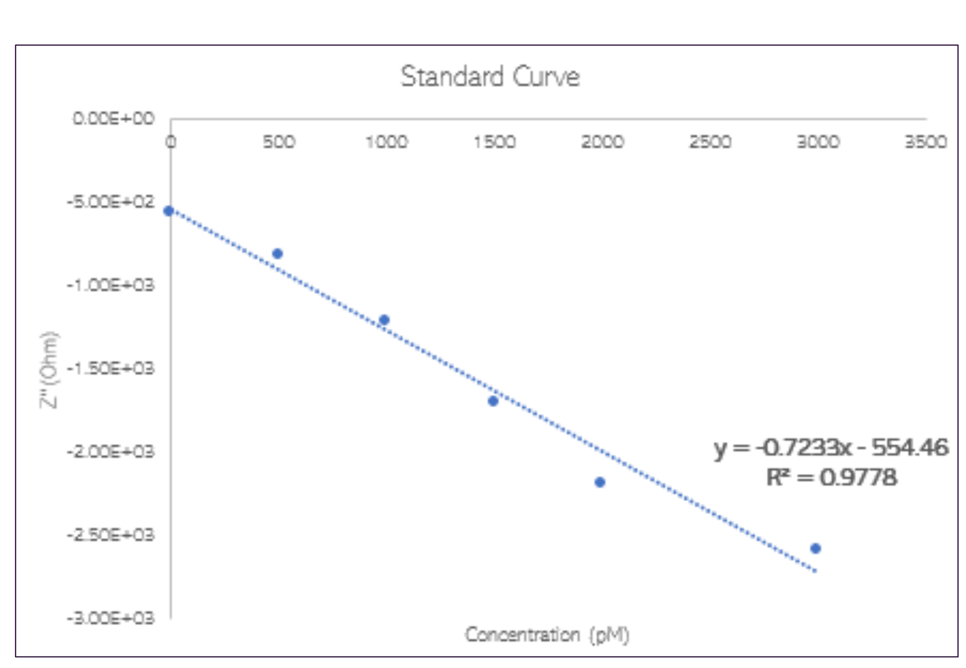

Figure 6. *Standard curve produced from testing a range of purified insulin concentrations on gold disk electrodes*

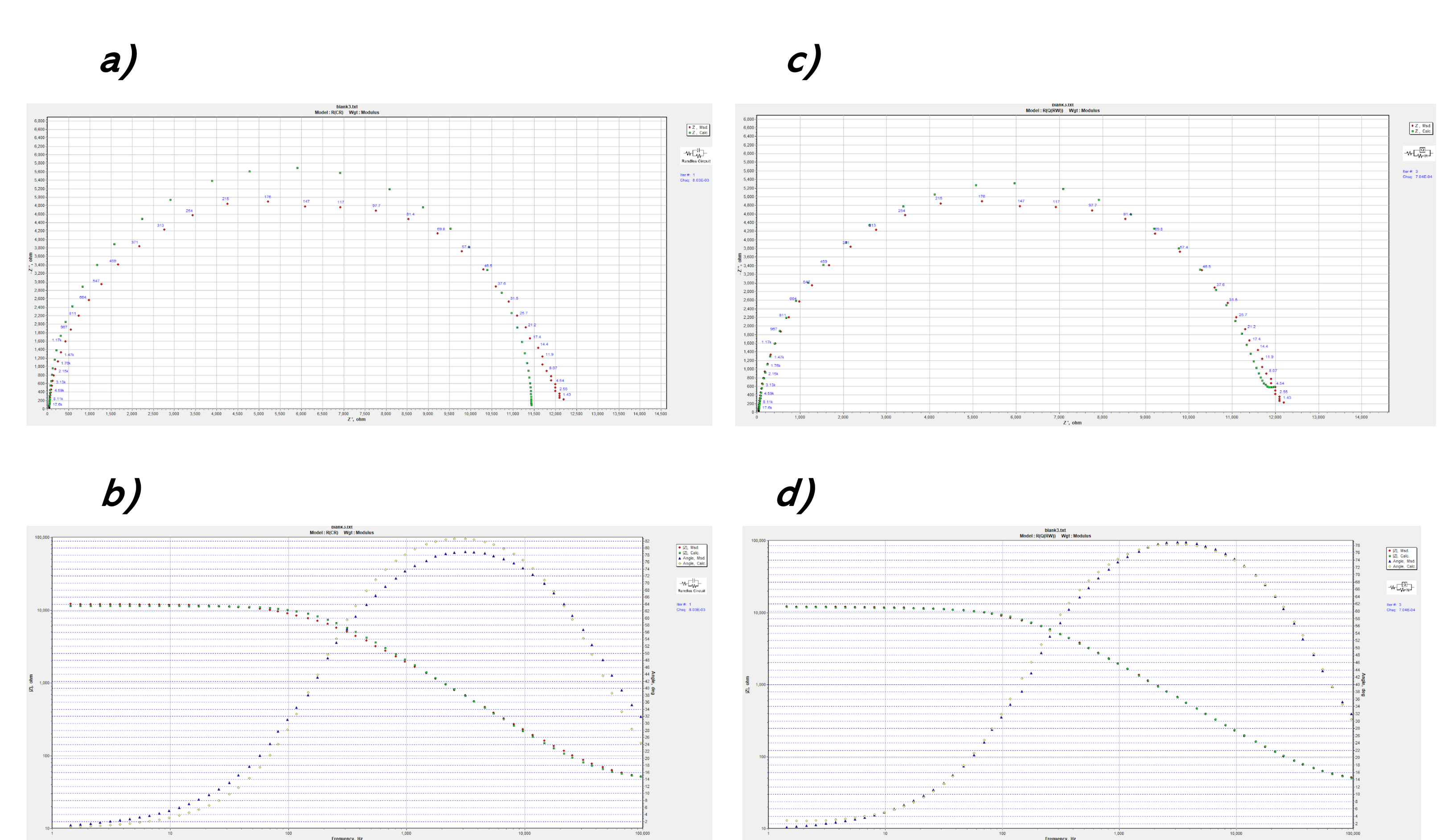

Figure 7. *Model of circuit using ZSimpWin software comparing measured vs theoretical plots using Randle's Circuit of a) Nyquist plot and b) Bode plot and measured vs theoretical plots using the modified Randle's Circuit of c) Nyquist plot and d) Bode plot*

References

[1] CDC Web Archive. (2017). New CDC report: More than 100 million Americans have diabetes or prediabetes. Retrieved from https://www.cdc.gov/media/releases/2017/p0718-diabetes-report.html

Acknowledgement

The team would like to thank Dr. La Belle, Connor Beck, Blake Marrow, and Mason Buseman for their mentorship and guidance, as well as the Helmsley Charitable Trust Foundation for their support and funding.