Disposable Glucose Nanosensor

May 1721

Final Report

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Table of contents

1. Introduction

a. Project Statement

Our group's project is “glucose detection using a disposable nanosensor”. As the project title implies, we are trying to develop a disposable nanosensor and focus primarily on low cost, ease of use and an easy fabrication process. By researching various existing methods of immobilizing glucose, we are use what will best fit our needs and proceed with it. We will also be doing lots of testing ourselves in order to get a first-hand idea about the complications in this area of study.

b. Goals

- Develop a low cost and easy to use disposable glucose nanosensor.
- Designing an easy and effective fabrication process for the nanosensor.

2. System Specifications

2.1 Functional Requirement

- ❖ Develop a functionalize process for said nanosensor.
- ❖ Fabrication process of Anodic Aluminium Oxide (AAO) should take place in Microelectronics Research Center (MRC).
- ❖ The fabricated AAO should be able to accurately distinguish good and bad measurements.

2.2 Non-functional Requirement

- ❖ Able to produce accurate readings.
- ❖ Low cost fabrication process.
- ❖ Easy-to-setup testing system.

2.3 Subsystem Specification

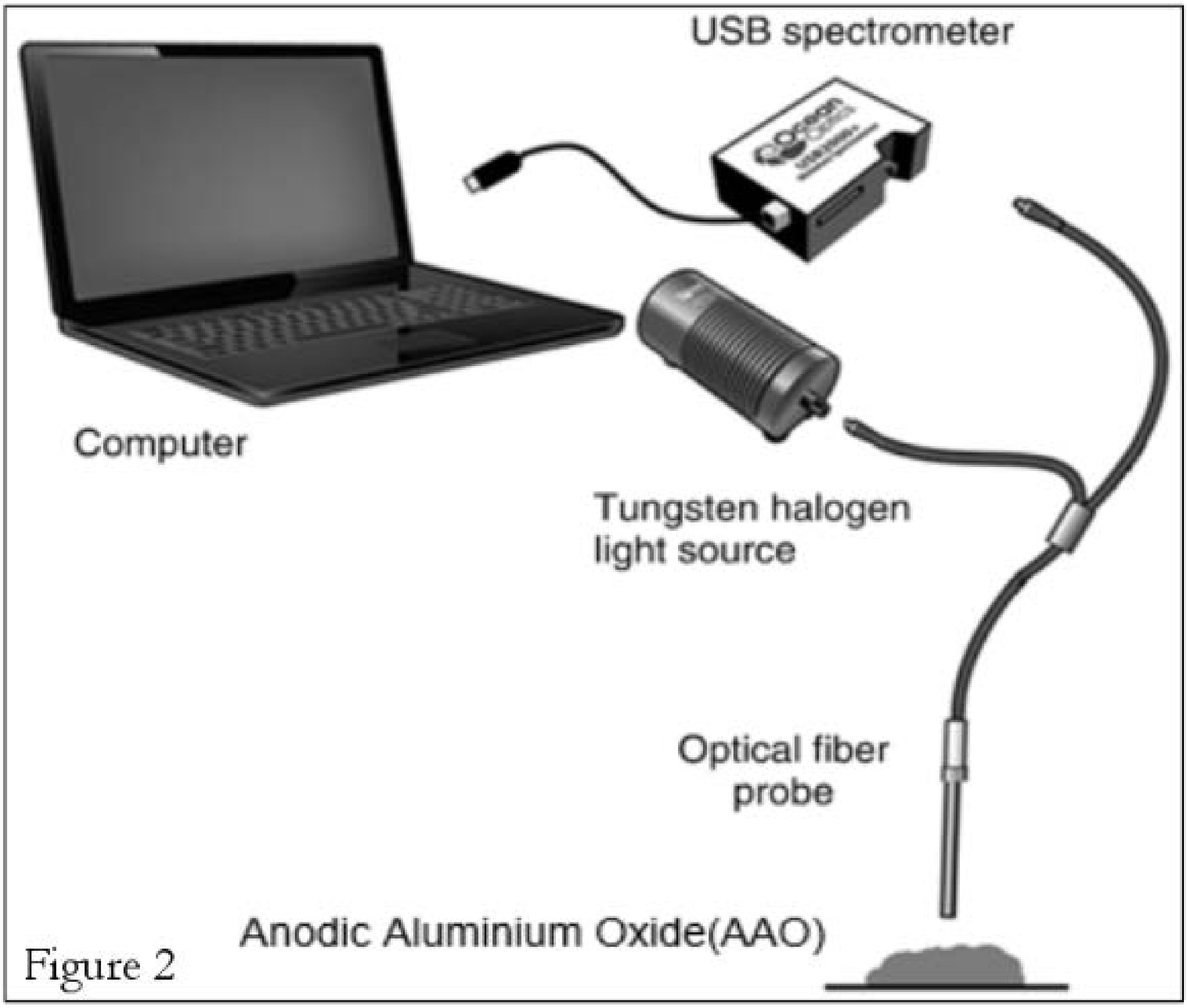


Figure 2

(i) Software

- ❏ OceanView (Product Version: 1.4.1)

OceanView 1.4.1 is a desktop spectroscopy application developed by the company OceanOptics that is available on Windows, Linux, and MacOS. This software allows users to collect real-time display data so that users can evaluate the performance of their experimental setups. Users can also specify how the data is processed by making changes to parameters selected. The changes of spectra can be seen instantly and saved as ASCII(two column text). After hitting the save icon on the software, the data collected can be exported to a third party spreadsheet, such as Microsoft Excel. The shift of spectra is observed after comparing data from different glucose concentration.

(ii) Hardware

- ❏ Fiber Optic Fluorescence Spectrometer

The OceanOptics USB4000 is a miniature spectrometer that is capable of fluorescence measurements from 360 to 1000nm. This spectrometer is used to configure with OceanView software to perform testing on our glucose nanosensor. The USB4000 is a versatile spectrometer that can support a wide variety of applications.

- ❏ Ocean Optics HL-2000

The Ocean Optics HL-2000 is a Tungsten Halogen Light Source that we used in conjunction with other equipment in order to perform testing on the glucose nanosensor. This equipment offer a diverse choice of performance in order to match the characteristic that we would need in our measurement. HL-2000 is capable of measurement in between 260-2400 nm.

- ❏ OceanView Optical Fiber Probe

Optical fiber probes provides the built-in light routing that allow direct measurements of absorbance, reflectance and fluorescence which in turn acts as our sample detector.

3. Deliverables:

- ➔ Fabricating a nanosensor which has high selectivity and sensitivity for a specific target biomolecule.
- ➔ The nanosensor is low cost, easy to use, easy fabrication process, and disposable.
- ➔ Able to obtain the testing result fast and easy to understand.

4. Project Timeline:

4.1 First Semester:

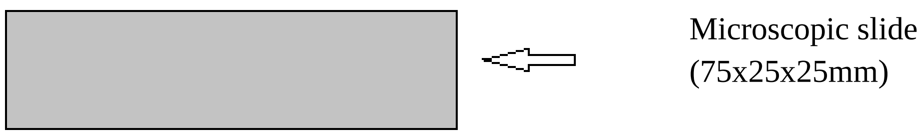
- Understand the key components, concepts and background about the project.
- Set up regular meetings with assigned professor and his PhD students for discussing and updating the information about the project.
- Design several prototype and estimate the components needed for each design.
- Decide on a final design and start procuring the required components.

4.2 Second Semester:

- Start building the nanosensor based on the design did last semester.
- Start performing test on the nanosensor to obtain the characteristic of the sensor.
- Finishing up the project by compiling all results gain from testing.

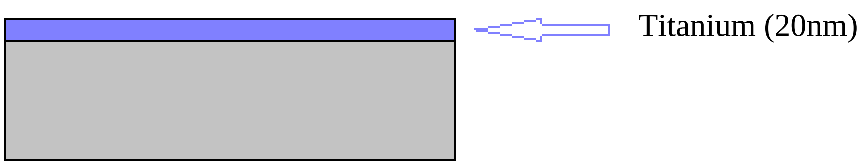
5. Design

Step 1



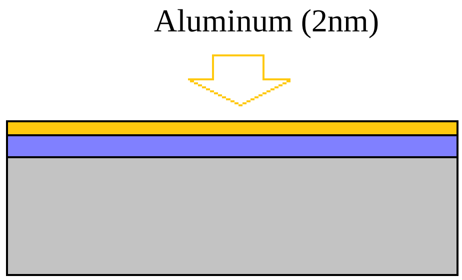
Start with Fisherfinest Premium Clipped Corner microscope slide. Thoroughly clean and blow dry with nitrogen gas to remove any contaminates which can inhibit fabrication.

Step 2



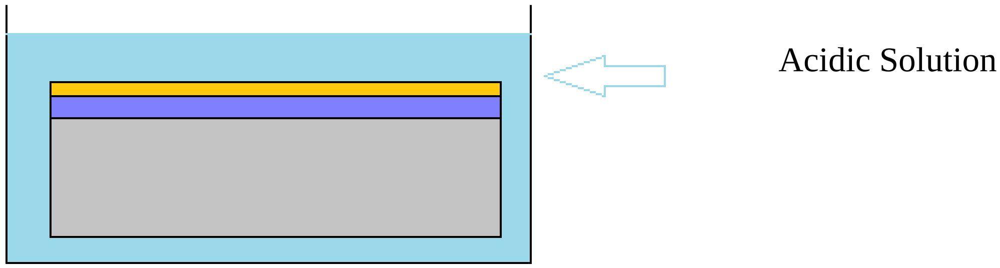
Deposit 20nm of titanium on the glass using electron beam physical vapor deposition(EBPVD).

Step 3



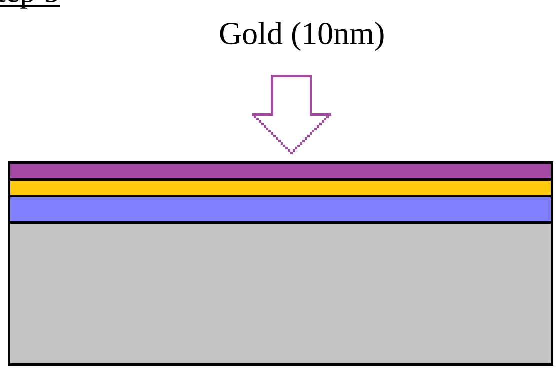
Deposit 2nm of aluminum using electron beam physical vapor deposition(EBPVD) again. The reason we choose aluminum is because aluminum adhere better to titanium.

Step 4



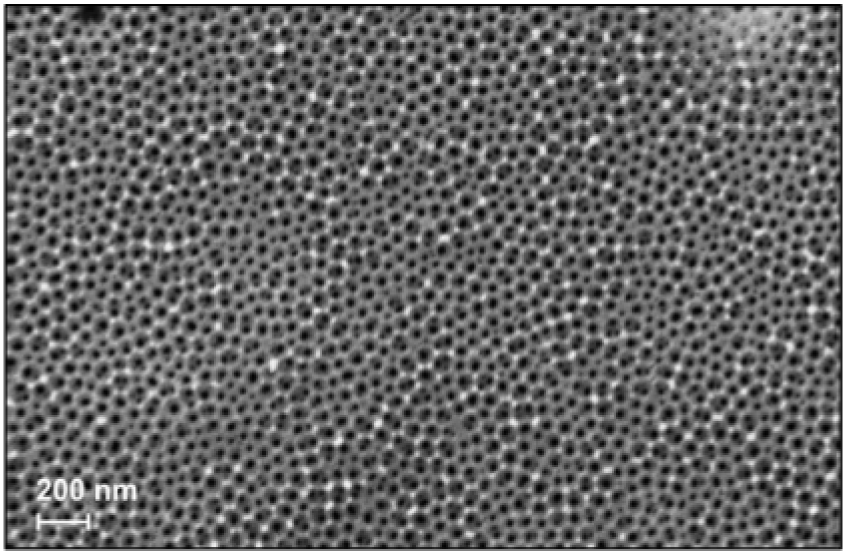
The nanosensor is submerged in an acidic solution to anodize and form anodic aluminum oxide. The particular acidic solution is a mixture of sulfuric acid and glycol.

Step 5



We use sputtering process to deposit a thin layer of gold (10nm). The testing of glucose will be performed on this layer.

6. Methodology



SEM Image of AAO Coating Obtained in Acidic Solution

- The process of creating AAO- metal can utilize an inexpensive and simple method of electrochemical metal deposition

- The AAO membrane – AAO self-organizes into a honeycomb like structure. This structure is high in density and uniform which is ideal for creating a reproducible experiment. The pores have a diameter of around 80nm. The diameter is controllable by the oxidation process. This nanostructure is great because it allows us to have a tight design parameter without needing to use a complicated process of photolithography and etching which can have high margins of error.

- This electrochemically obtained porous layer of AAO is used as a sensor to detect glucose optically

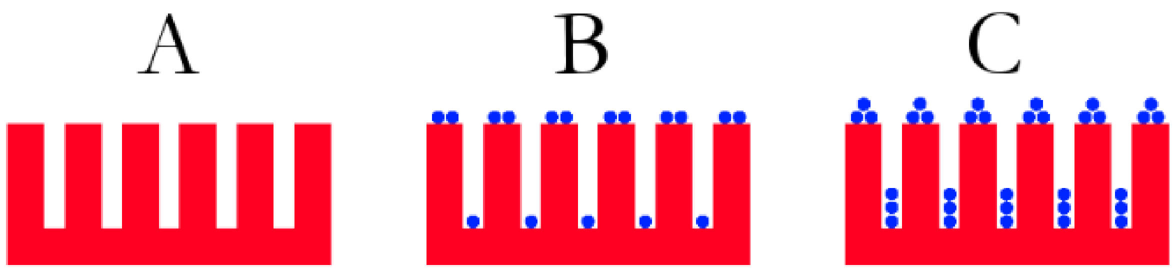


Figure A shows the nanopore structure before any glucose is deposited.
Figure B shows the nanopore structure with small amount of glucose deposited.
Figure C shows the nanopore with high concentration of glucose.

7. Challenges

- When we finish the first prototype of the nanosensor, we tried to make it non-disposable by re-using it, though it end up failing due to the fact that the AAO surface had already been contaminated by the previous testing, making the second attempt of using the nanosensor again results in failure as shown by illogical output from the spectrometer.

- Another challenge that we faced throughout the whole project is the fact that we came into this project with no prior knowledge about biosensor itself. As such, we had to spent a long time to browse through various research paper related to method of oxidising glucose, method of producing different glucose sensor and such as suggested by our advisor. This challenge had been more troublesome than we thought as we did not expect that these studying would take up almost one whole semester.

8. Result

Below are the shifts in wavelength by combining all data sets from a single AAO sample at different applied concentrations of glucose.

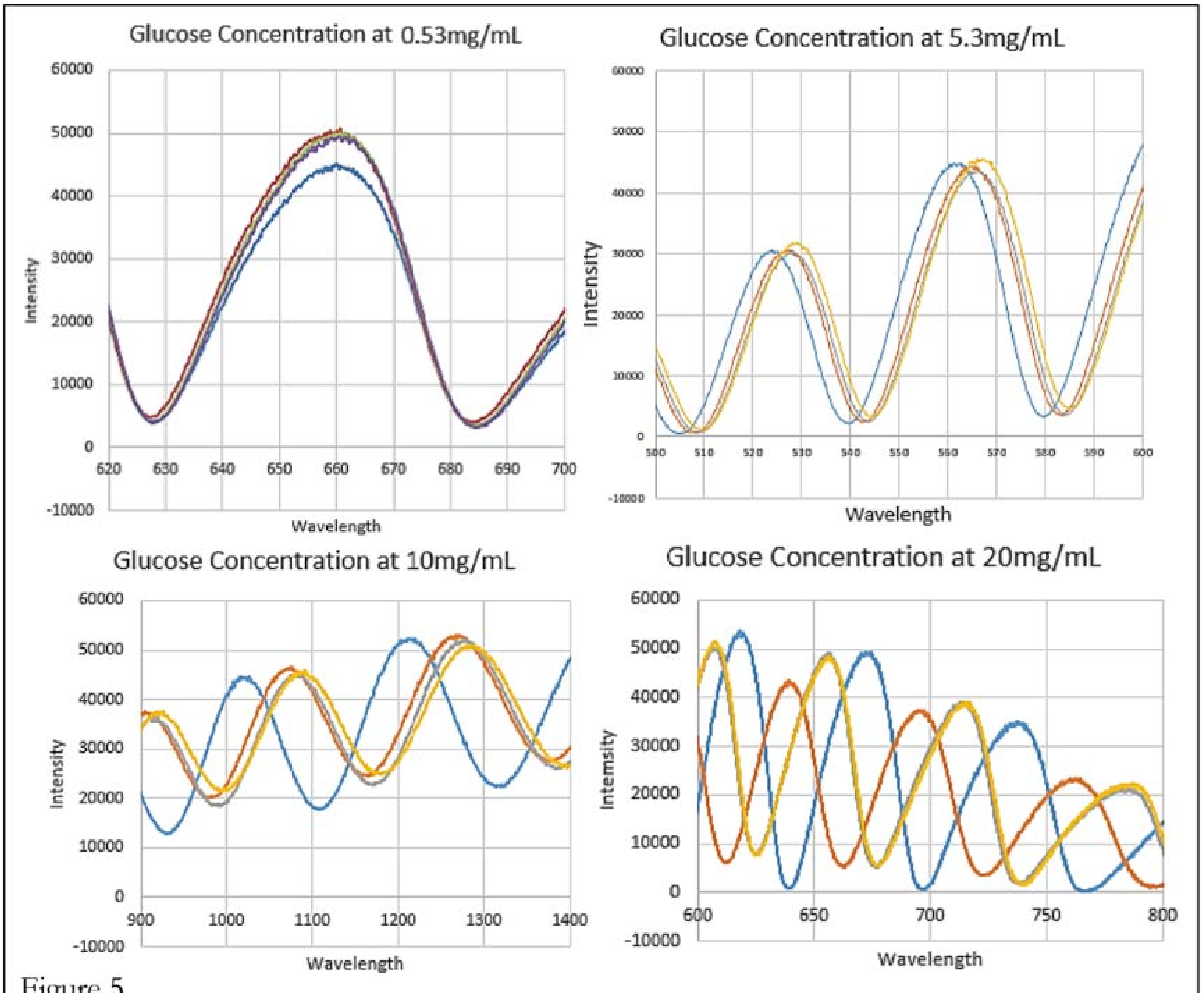
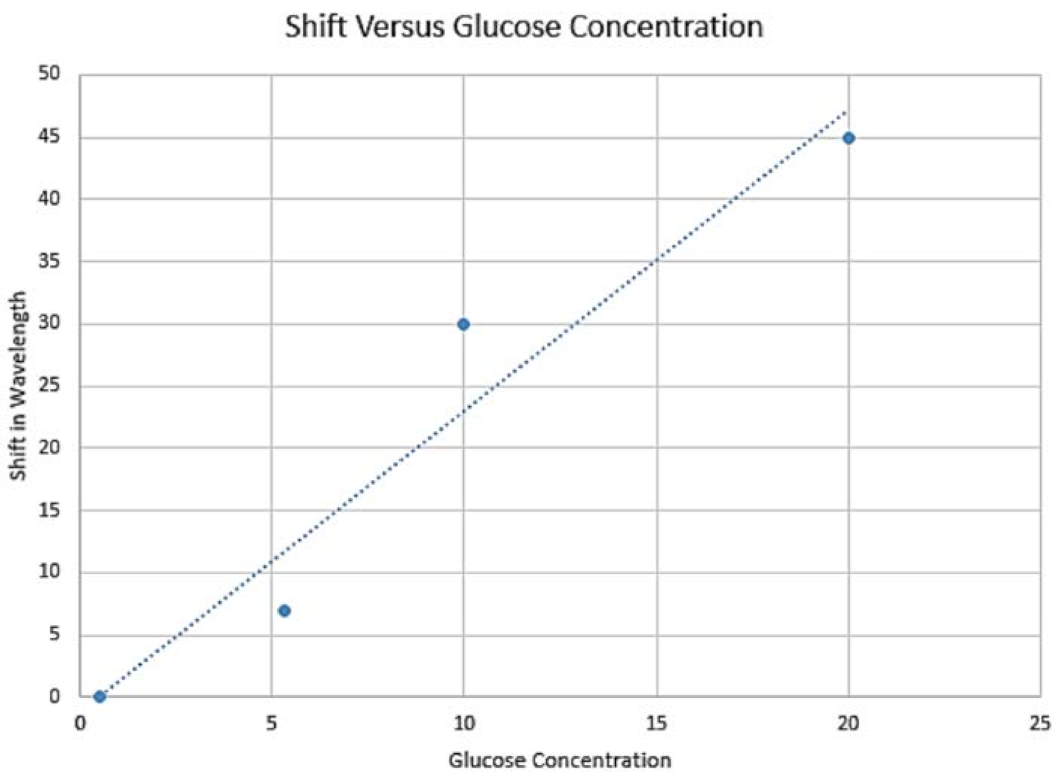


Figure 5

Our AAO samples were able to detect glucose concentrations from a range of 0.53mg/mL to 20mg/mL with observable wavelength shifts.



The figure above demonstrated that the shift of wavelength in terms of glucose concentration is in a linear relationship. This allows wavelength data to be translated into a specific concentration of glucose.

The picture of the right is the final product of our senior design project.

9. Conclusion

In the end, we were successful in demonstrating a functioning product which met our design criteria. We developed a cheap, nanoscale structure which can detect the presence of glucose via optics. The chips are disposable and our design is simple and easy to reproduce. There is much more research to be done in the field of biomedical nanosensors and their practical applications. Our chip is not ready for commercial use, but our data shows promise in the possibilities. The mean normal blood glucose level for humans is about 1mg/mL, which we were able to detect small changes at. At this time, we do not believe the sensor is accurate enough on the low end to be used reliably for human blood sugar measuring. Animals have wildly different glucose concentrations so it is possible that our sensor could be useful for veterinarians or zoos.

10. References / Index

(1) K. Besteman et al, "Enzyme-coated carbon nanotubes as single-molecule biosensors," Nano Letters, vol. 3, no. 6, 727-730, Mar. 2003.

(2) T. Zhang et al, "Nanostructured optical microchips for cancer biomarker detection," Biosensors and Bioelectronics, vol. 38, no. 1, 382-388, Oct. 2012.

(3) P. Pathank and L. Que, "Characterization of field effect transistor biosensors fabricated using layer-by-layer nanoassembly process," Journal of Nanoscience and Nanotechnology, vol. 15, no. 12, 9689-9692, 2015.

APPENDIX I: Operating Manual

a. Measure the AAO (anodic aluminum oxide) without any glucose solution
b. Obtain a wavelength versus intensity graph using OceanView
c. Deposit a fixed amount of glucose solution (5ml) onto every AAO sample using a precision pipette
d. Place the AAO on a hot plate of 80 ^{o}C to speed up the evaporation process
e. After complete evaporation, the AAO is placed under the fiber probe to obtain the wavelength-intensity graph
f. Repeat step 3 to 5 for two more times with exactly the same amount of glucose solution (5ml)
g. This experiment is repeated with different glucose concentration.