A Wearable Non Invasive Blood Glucose Measuring Device For Monitoring Diabetes

Abstract— **Our project is to design a wearable device that measures Blood Glucose. We want to design a new method of measurement of glucose levels rather than the traditional way of pricking the finger. According to a 2017 report from the Centers for Disease Control (CDC), more than 100 million U.S. adults are now living with diabetes or prediabetes. Diabetics require constant and periodical monitoring of their blood Glucose levels. The strain of having to prick their skin multiple times a day to get a blood sample is a hard chore. There is also a risk of infection because even a small puncture of a needle is considered an open wound.**

Our design relies on a noninvasive method where we gather data outside of the skin. Researchers from Penn state university published the details of the noninvasive, low-cost sensor that can detect glucose in sweat in Biosensors and Bioelectronics.

The main idea of the sensor is to have a layer of glucose sensitive material that can detect traces of Glucose in sweat perspiration on an individual's skin. Then, this data can be transferred to an amplifier where there will be a signal coming from a chemical reaction between glucose and Nickel-Gold layer mounted on a laser induced graphene (LIG) plate. The signal can then be digitized and processed through an algorithm that reflects concentration and levels per sample.

The abstract circuit consists of

1 - Sensor (Cobalt Nickel Copper (CoNiCu) alloy layer mounted on LIG plate).

2 - Bio-Signal amplifier.

3 - ADC to digitize.

4 - Bluetooth Module to transmit data.

On the recipient end there will be computation to translate the data acquired into usable data.

IndexTerms—**Blood Glucose, Diabetes, Biosensor ,Glucose Sensitive, CoNiCu, Amplifier, Microcontroller, Insulin, non-enzymatic sensor, laser-induced graphene, Gain, NaOH solution.**

I. Introduction

According to the CDC, diabetes is a chronic health condition that affects how your body turns food into energy.

Most of the food we eat is broken down into sugar and released into the bloodstream. When blood sugar increases, it signals the pancreas to release insulin. Insulin will then allow the blood sugar into the body’s cells for use as energy.

People with diabetes either do not make enough insulin or cannot use the insulin the body makes as well as it should. When there is not enough insulin, cells will stop responding to insulin and blood sugar stays in the bloodstream which in time will create health problems, such as heart disease, vision loss, and kidney disease.

There is no cure for diabetes yet, so measuring glucose levels via blood samples has been the method of measurement for diabetics for quite some time. The problem with this is that the user has to puncture their skin to retrieve the blood sample. One, that is somewhat painful for the user. Two, these punctured holes can lead to infection. Three, depending on the symptoms, the user may have to do multiple tests a day. That is why our team
proposes a wearable, non-invasive glucose measuring device.

II. Related Work

Today there are three commonly used methods to measure glucose levels: Capillary Blood Glucose Test, Venous Blood Sample, and Continuous Glucose Monitoring (CGM).

Capillary Blood Glucose Tests work using a lancet to source a blood drop sample, a glucometer and test strips. The blood sample is typically taken from the fingertip but can be taken from other locations. These locations include the earlobe, heel, forearm and palm. Sourcing a sample from other locations can be less painful but may need a deeper lance. Although this method only requires a small blood sample, test strips are sold separately, have a short expiry date and the results are affected by external factors.

Venous Blood Sample works by taking a blood sample from a vein and processing that sample in a laboratory. This method provides more accurate results but is painful and can cause local tissue damage.

Continuous Glucose Monitoring works by applying a sensor on the upper arm or abdomen and monitoring the patients interstitial fluid glucose levels. This method of glucose monitoring is used with patients who require insulin therapy as it is more cost effective when monitoring glucose overtime.[4]

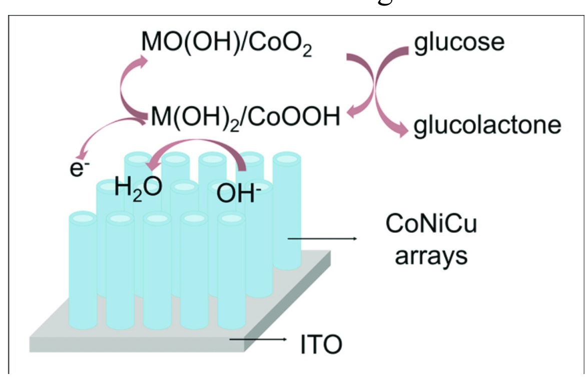
Although these tests can effectively test glucose levels, they are typically invasive, requiring a blood sample to function. Our design will solve this problem by getting rid of the needle for measuring blood glucose over the skin

III. Our Device

The first thing we should talk about is how there is a strong correlation between the glucose in sweat and the glucose in blood. While the concentration of glucose in sweat is about 100 times less than the concentration in blood, our device should be sensitive enough to accurately measure the glucose in sweat[1].

A. Our Sensor

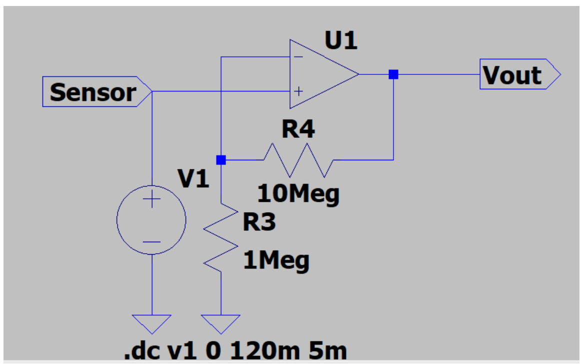
We want our sensor to be non enzymatic. The reason is, enzymatic sensors can be inconsistent when measuring blood glucose levels because they have to be kept at certain temperatures and cannot be stored for long[1]. To begin capturing a sample for the sensor, we collect a sample of sweat from the skin. We use a collection inlet to absorb the sweat off the finger. You just need to place your finger on the inlet for around a minute for it to absorb the sweat[2]. The sweat will then be transferred and be mixed with our alkaline solution. This alkaline solution consists of a 0.1M concentration of NaOH solution[3]. On the other end, we have our CoNiCu alloy. We use this alloy because we need something that is highly sensitive with the glucose molecule because our laser-induced graphene(LIG) is not. An LIG is “a material consisting of atom-thick carbon layers in various shapes”[1]. We need this LIG because it is highly conductive and will be able to easily transfer our electrical signals to our device and read it. The reason why we pair it with the CoNiCu is because the LIG is not sensitive to glucose. If there is no reaction, there is no electrical signal. Now back to the design. When the glucose in the sweat enters the alkaline solution, a chemical reaction is created between the alloy and the glucose in the sweat. This creates a current of electrons. Since this is a chemical reaction, there is no need for our device to filter the signal. The illustration below shows the reaction of the metal and the glucose.



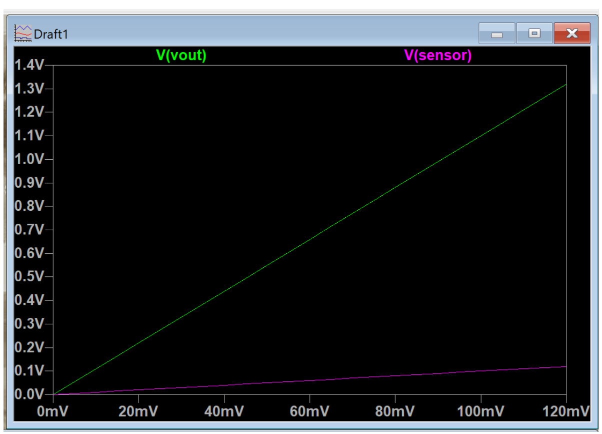
The electrons travel through the conductive LIG and into a copper wire that connects our sensor to the amplifier.

B. Our Amplifier

The amplifier that we use is the LTC2063. The main reason we went with this amplifier is because our circuit is very basic, we only need the circuit to amplify the signal, and our device will consume low power. We want something low powered because we want this device to be portable. Since sweat glucose is 100 times less concentrated than blood glucose, total design will have a gain of 100 as well. In our circuit, we collected a voltage signal that varies from 10-110mV[3]. The microcontroller's input range is 0-2V. In order for our microcontroller to read the signal better, we amplify the signal by a gain of 10. That is shown in our circuit below.



Here is our amplifier in action with a DC sweep from 0-120mV with an increment of 5mV.

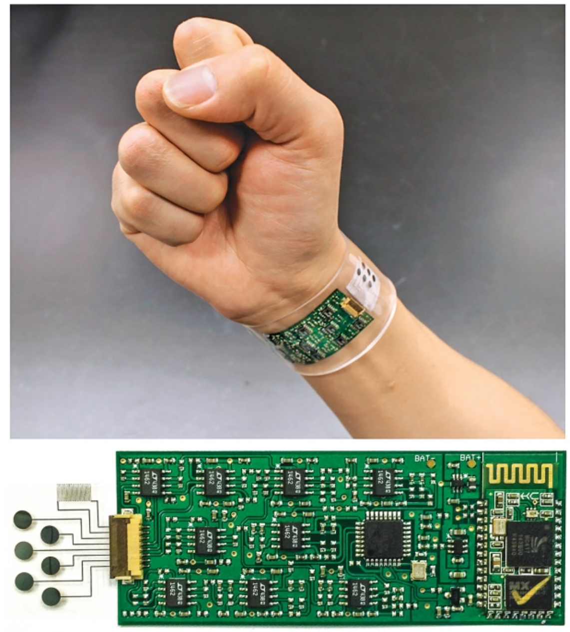


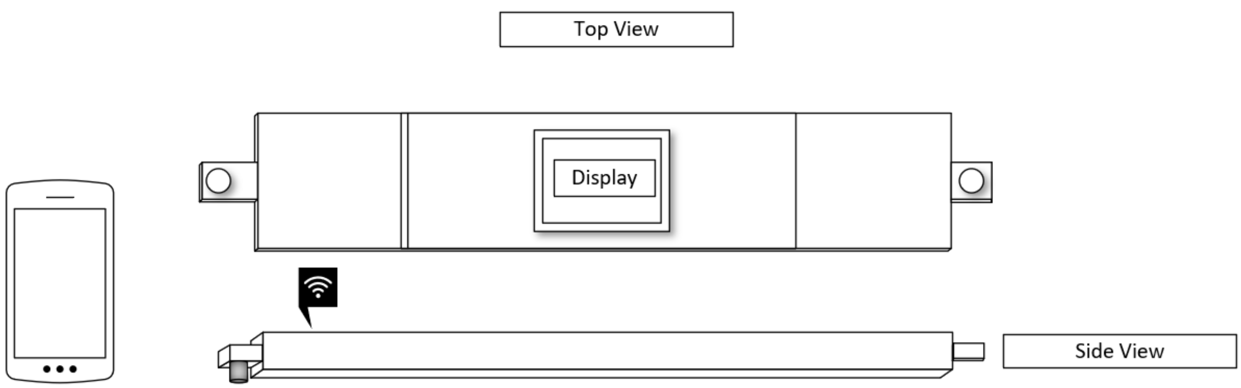
The signal is passed through our amplifier and is sent to our microcontroller.

C. Our Microcontroller

The main idea was for this product to be portable. The microcontroller we went with is the nRF5340 BLE microcontroller from Nordic Semiconductor. This low power microcontroller has a 1 MB flash with 512 kB ram allowing for more data processing when communicating with other diabetic devices.

When the signal is passed to our microcontroller, we run it through an analog to digital converter. With the now converted digital signal, we want to apply a gain of 10 to this signal so the sweat glucose can match the blood glucose levels. Our signal is finally finished. We will then run it through an algorithm for us to know what blood glucose level the user has. This algorithm will be able to tell us when our blood glucose level is too high, too low, or at a normal level. Finally, we will be able to send the data wirelessly to other devices through our microcontrollers bluetooth capabilities. The device will be run on a rechargeable 3V coin battery because the device will be portable.. One example of wireless communication would be between our watch and the user's insulin pump. In theory, our watch will let the insulin pump know when the user needs insulin consistently. Therefore, the user's insulin levels could stay relatively balanced. Below is our circuit and the microcontroller we will be using and an example of how our product will look.





IV. Conclusion

We proposed a device that can non invasively measure someone's blood glucose level. In the future, we can conduct large scale studies to better calibrate the algorithm in our microcontroller to better our accuracy from one person to another. In initial trials, blood samples will be required to test the accuracy of our device to the individual's blood sample. The potential future of this device is limitless. If this product goes mainstream, the technology in this device can be implemented in other smartwatches as well. This would allow the general consumer to know what their blood glucose levels are at any time. This can further prevent type one diabetes and help people with or without diabetes live a better life.

V. References

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