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# Sustainable and battery-less self-powered glucose sensor for diabetes screening applications

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## Summary:

Our proposal introduces a glucose sensor designed to make a first screen diabetes stages by measuring the current, which varies according to the glucose level. The developed sensor based on simple electronic system and affordable materials, reduce both cost and environmental impact. The circuit can store various voltage values, each proportional to the glucose concentration in the human plasma sample.

**Keywords:** Diabetes screening, glucose sensor, self-powered strip, screen-printing, sustainable devices.

## Background, Motivation and Objective

In the last decade, diabetes has become a worldwide silent pandemic with millions of undiagnosed patients. Awareness of diabetic conditions is considered to be a crucial first step in changing eating habits and seeking treatment, as the side effects of this condition are generally unnoticed until irreversible damage arises in the kidneys, eyes, or feet [1]. However, campaigns take place in very localized spots, with a very modest impact on the population. Two main reasons are campaign costs, which in low- and medium-income countries are covered by non-governmental organizations, and their modus operandi, which involves glucose level measurement performed by volunteers with glucometer devices at a specific stand during a particular day, where individuals with abnormal glucose levels are informed about their health status. This work aims to address this problem of late detection, especially in lower- and middle-income countries (LMICs), and make the monitoring and treatment of the disease more accessible [2]. Here, we propose a novel and battery-less glucometer that functions upon the addition of a drop of blood, and voltage leads to a result that can be read with a simple voltameter. The solution not only reduces the cost of the device but also the carbon footprint and simplifies end-of-life disposal, adopting eco-friendly features.

## Description of the New Method or System

The device core is based on an enzymatic fuel cell activated by the glucose concentration present in a blood sample. The fuel cell encompasses an anode that oxidizes the glucose and a cathode that performs a non-limiting reduction reaction. In comparison to intricate systems with sophisticated electronics, our circuit operates the fuel cell signal with just two resistors, a capacitor, and a diode. One of the resistors subjects the fuel cell to a high current demand that causes a voltage drop, which depends on the glucose content of the sample. The dropping time is then computed with a parallel RC circuit, in which the built-up voltage in the capacitor is proportional to the initial glucose concentration. The capacitor acts as a physical memory element, readable at any moment [3]. Figure 1 shows the schematic of the circuit.

## Experimental section

The fuel cell electrodes are fabricated by screen-printing method over a PET flexible substrate. The anode consists of a carbon-based electrode in which a mixture of Hexaammineruthenium(III) chloride mediator and glucose oxidase (GOX) enzyme is deposited and dried. The cathode contains a home-made ink based on carbon and AgxO powder. The electrode region has been defined by means of PSA laser-cut adhesives. A 4.6 x 2 mm glass-fiber paper is used to hold the 3.75µl plasma samples. Figure 2 shows our self-powered sensor compared to the commercial glucose strip.

We aimed to demonstrate that the self-powered glucose strip developed in our laboratory can discriminate between normal glucose status (below 100 mg/dL), pre-diabetic (between 100 and 125 mg/dL), diabetic (over 125 mg/dL), and highly alarming status (over 270 mg/dL). Our experiment consisted of measuring different glucose concentrations at values limiting the different classification regions in human plasma. The distinction of these glucose levels, translated into current levels by the battery, is made by resistor R1. Figure 3 shows the evolution of the fuel cell voltage when connected to R1 at different glucose concentrations and the measured built-up voltages across the capacitor for the different tested glucose concentrations. Furthermore, the parallel branch formed by resistor R2 with a higher resistivity value than R1, diode D, and Capacitor C is used to store the charge. The charging time of the capacitor is limited by the diode. Once the voltage of the fuel cell becomes lower than the threshold of the diode, the capacitor stops increasing its voltage. In Figure 4, we can see the final voltage of the capacitor for the different concentrations measured, corresponding to the diabetes limits.

## Illustrations, Graphs, and Photographs

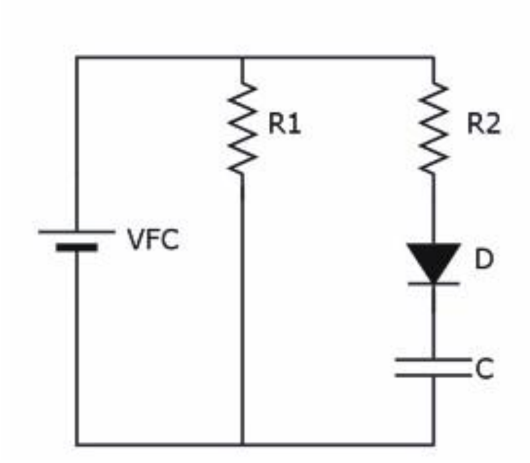

*Fig. 1: Schematic of the circuit.*

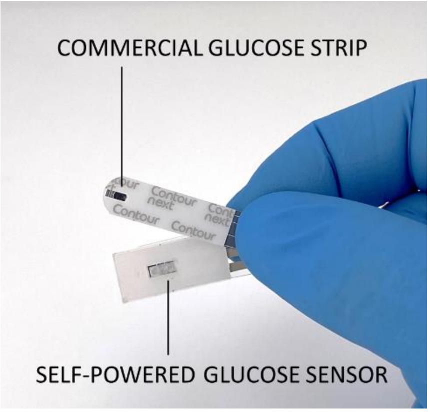

*Fig. 2: Picture of the fabricated self-powered glucose sensor and a commercial glucose strip.*

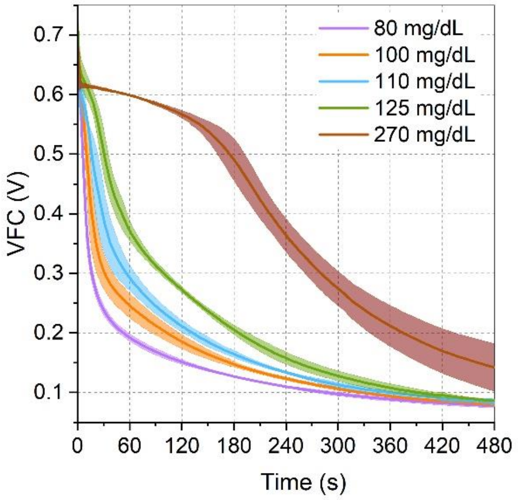

*Fig. 3: Voltage evolution of the fuel cell over time for different concentrations of glucose in plasma sample.*

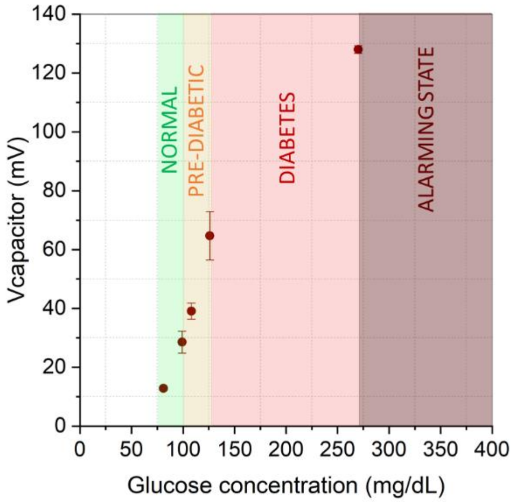

*Fig. 4: Capacitor charged voltage represented within the range of glucose concentration.*

## References

[1] “Diabetes,” World Health Organization, https://www.who.int/es/news-room/fact-sheets/detail/diabetes (accessed May 15, 2024).

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