Zimmer & Peacock

Sensor Manufacturing and Technology

Hybrid electrochemical sensor platform – *wearable platform suitable for CGM*

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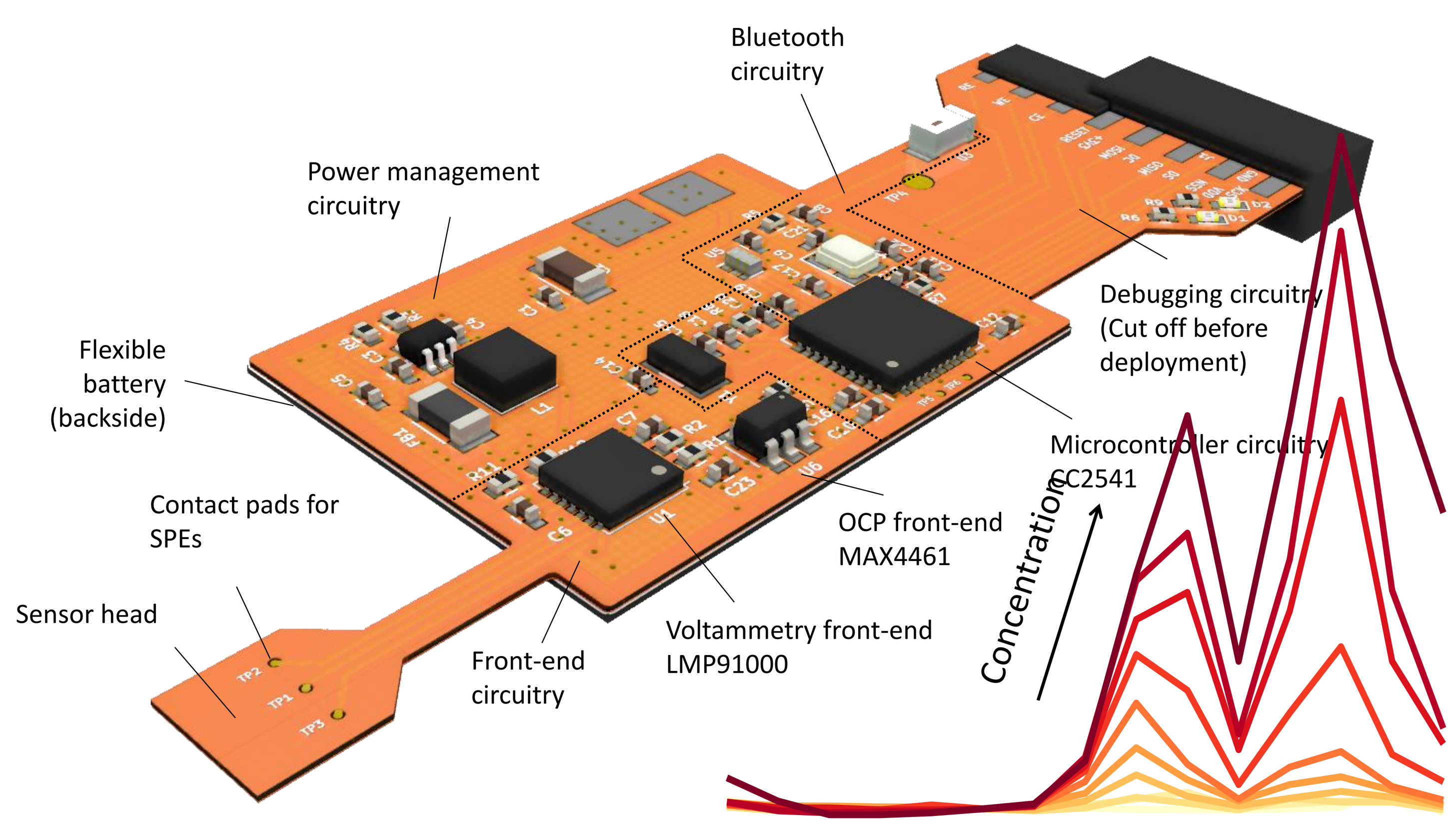

Introduction

The objective was to make a continuous glucose monitoring sensor on a flex circuit, where the entire package from the sensor to the flex circuit was one piece; the sensor was fully integrated with the electronics, therefore both removing the connection vulnerability and a common source of electrical noise caused by the connection between the sensor and the electronics.

The platform has both amperometric, voltammetric and potentiometric capabilities and can be used for the detection of a number of analytes including **glucose, lactate, potassium, sodium, pH and oxygen**.

Methods

The integrated flex circuit sensor system was manufactured by low-cost manufacturing techniques, which are scalable into high volume manufacturing. The sensor package showed excellent sensitive and very low noise.

Continuous Glucose Monitoring is proving to be a clinically and commercially successful technology. This work focuses on applicability, affordability, simplicity and **expanding the analytes range** through a reusable, low-cost **sensor platform** with on-board electronics, power source, telemetry and **unmodified** screen-printed carbon **electrodes** (Figure 1c).

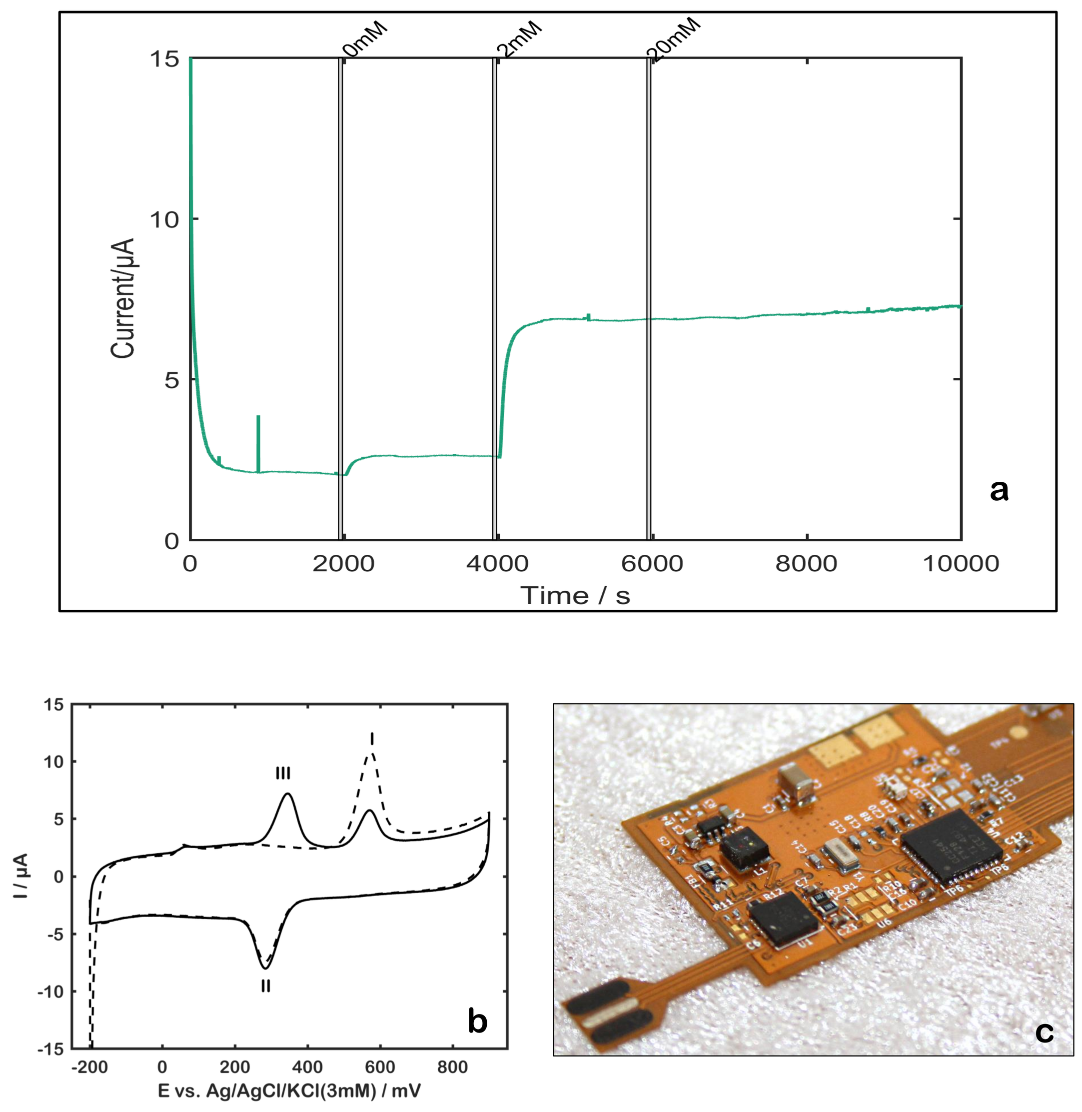

Figure 1. (a) detection of glucose **(b)** platform can do other electrochemical techniques(--) and second (—) scan. **(c)** Electrochemical sensor platform, dimensions of body: 29 × 21 × 1.2 mm, weight: 1.2 g.

Analytical Methods Available

The platform can be used for a range of analytes including **glucose, lactate, sodium, potassium and oxygen**, this is due to the amperometric, potentiometric and voltammetric functionality available from the platform.

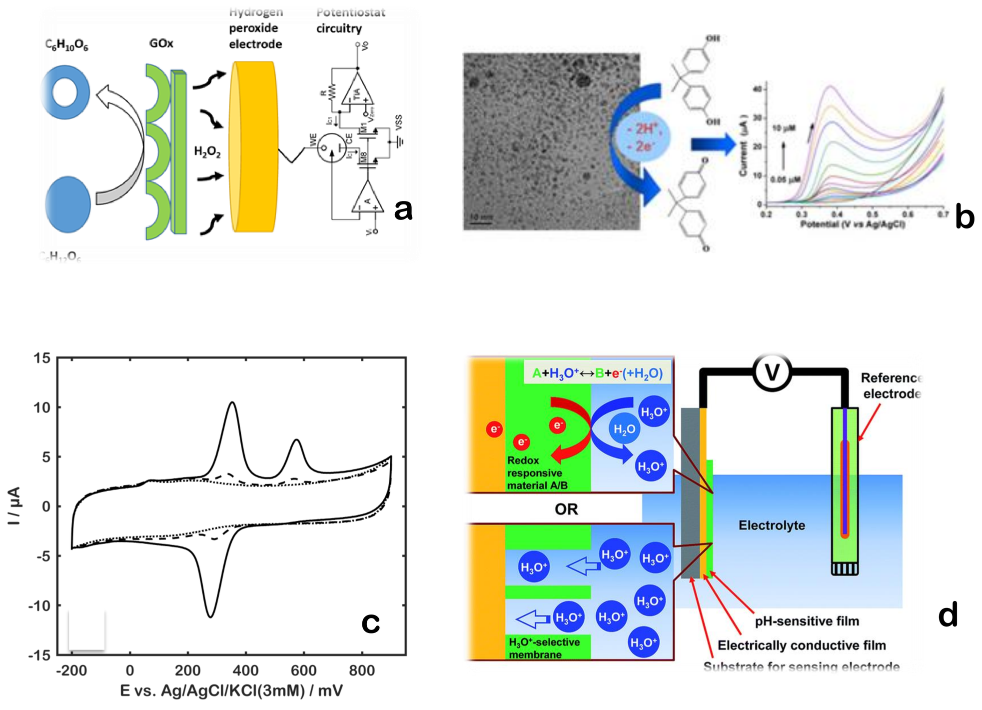

Figure 2. (a) Amperometric detection of glucose **(b)** voltametric detection of electrochemically active species **(c)** Baseline corrected voltammogram (—) obtained through subtracting the baseline (··) from the raw signal (--). **(d)** Potentiometric of ions including, sodium, potassium and pH.

Manufacturing and versatility

The sensing platform is manufactured from standard parts and processes including: pcb manufacturing, screen-printing and digital printing. The form factor is made possible thanks to thin lithium polymer batteries.

The chip-set allows for a plurality of sensors and assays, so this is truly a platform technology.

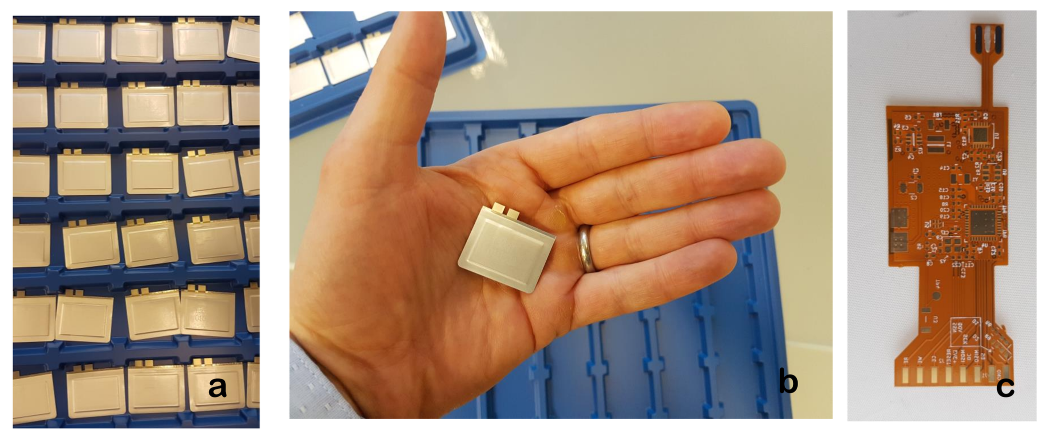

Figure 3. (a) The think lithium polymer battery **(b)** The think lithium polymer battery **(c)** The biosensor and electronics are mounted on the same flex pcb.

Continuous Glucose Monitoring

One of the first application for the platform is CGM, either as Type 1, Type 2 or Type Glucose sensor.

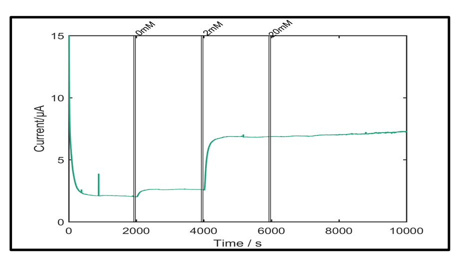

Figure 4. Data from a Type 1 CGM glucose sensor.

Beyond amperometry - Coarse squarewave voltammetry

Though CGM sensors are often limited to amperometry, this ignores a host of very powerful electorchemical, technical including **coarsely** stepped cyclic squarewave voltammetry - (CCSWV) was employed (Figure 5a), using 60 mV step size and amplitude. The waveform of the sensor platform was compared to that of a **simulated** one (Figure 5b, E = 0.987 × I_R × R mV + 10.709 mV, R^2 = 1.000, N = 60).

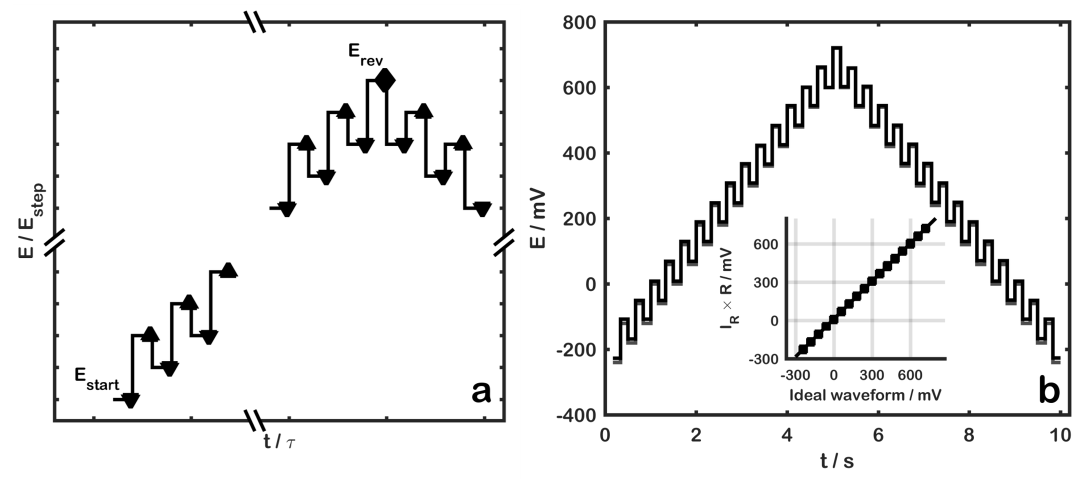

Figure 5. (a) Squarewave voltage waveform. Down-pointing and up-pointing triangles marks where the reverse and forward current is sampled, respectively. **(b)** Simulated waveform (gray) and waveform from sensor platform (black) obtained by multiplying the squarewave current I_R, with the load resistance, R. The inset shows the relationship between actual and simulated waveforms.

The resulting voltammograms (Figure 6) are spiky, but **reflects the data from more elegant techniques including the traditional cyclic voltammetry.**

The sensor platform has a potential range (±720 mV). Since the voltammograms shift more positively with increasing concentration, the signal of peak I, and consequently peak II and III lowers and appear indistinguishable from lower concentrations. However, the **emergence of a peak I'** on the reverse scan made possible a criterion, enabling the use of the **full range** explored:

$$i_{corr} = \begin{cases} I_{III} + I', & r\ I_I \geq I_{III} \\ I_{III}, & otherwise \end{cases} \qquad Eq.(1)$$

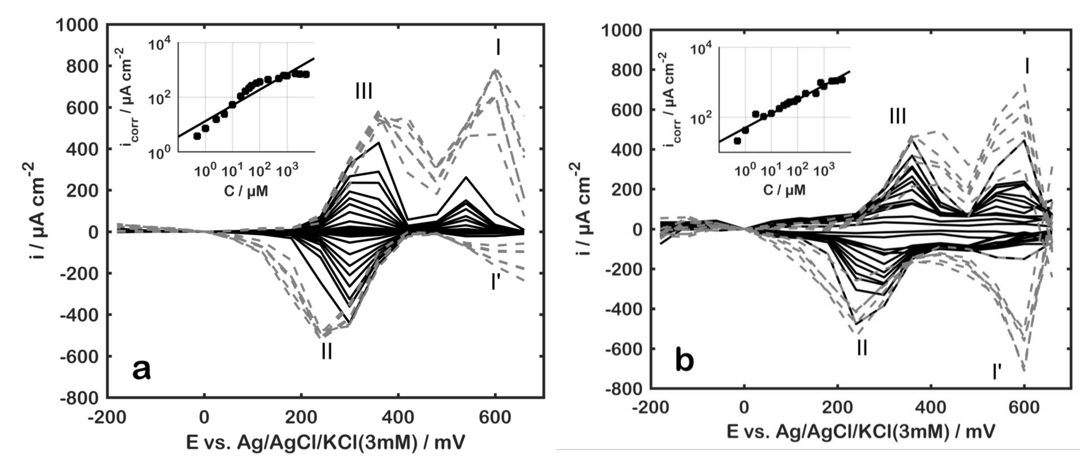

Figure 6. Baseline corrected coarse cyclic squarewave voltammograms (second scan) from **(a)** commercially sourced electrodes and potentiostat, and **(b)** sensor platform with integrated electrodes and electronics. The dotted lines (--) represent the signals which satisfies I ≥ I_{III}. The insets show the corresponding calibration curves from Eq. (1).

Conclusions

The result was a sensor package whose functionality, method of manufacture and cost means that it is possible to have a fully integrated wearable package which has a greater accuracy due to the reduction in the electrical noise, otherwise encountered in more traditional CGM systems. The flexibility of the technology allows for a number of analytes including **glucose, lactate, potassium, sodium, pH and oxygen**.