Wearable Chemical Sensing – Sensor Design and Sampling Techniques for Real-Time Sweat Analysis

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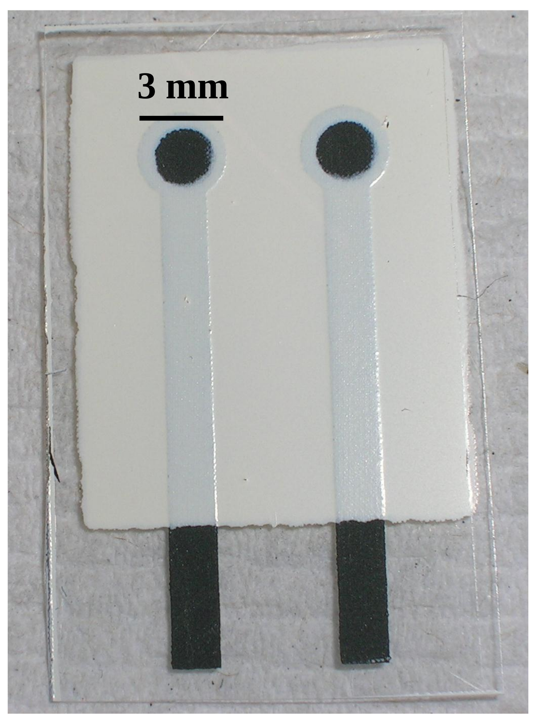
Introduction

Wearable chemical sensors have the potential to provide new methods of non-invasive physiological measurement. This work presents the design of two real-time sweat sensing platforms to analyse sweat loss and composition. The first method uses ion selective electrodes (ISEs) to detect the sodium content in sweat. The second method uses capacitively coupled contactless conductivity detection (C4D) to measure the conductivity of sweat, which is highly correlated to the sodium chloride content.

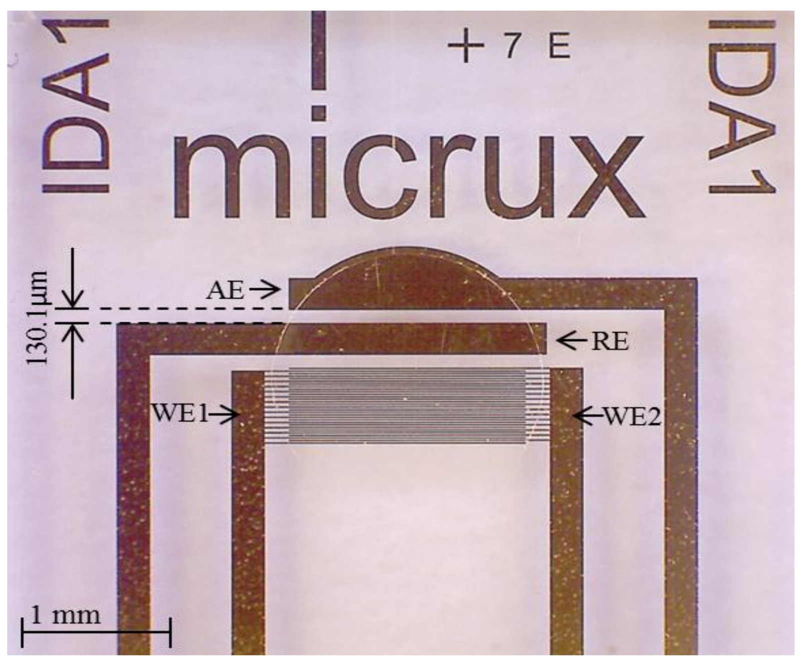
Background

ISEs

The ISEs used in this study are prepared by screen printing. An appropriate solid contact material is interposed between the carbon layer and the drop-cast outer membranes of the ion-selective & reference electrodes. The selective response of the ion-selective membrane is due to the presence of an ionophore, while the reference membrane is insensitive to changes in the sample composition.



C4D

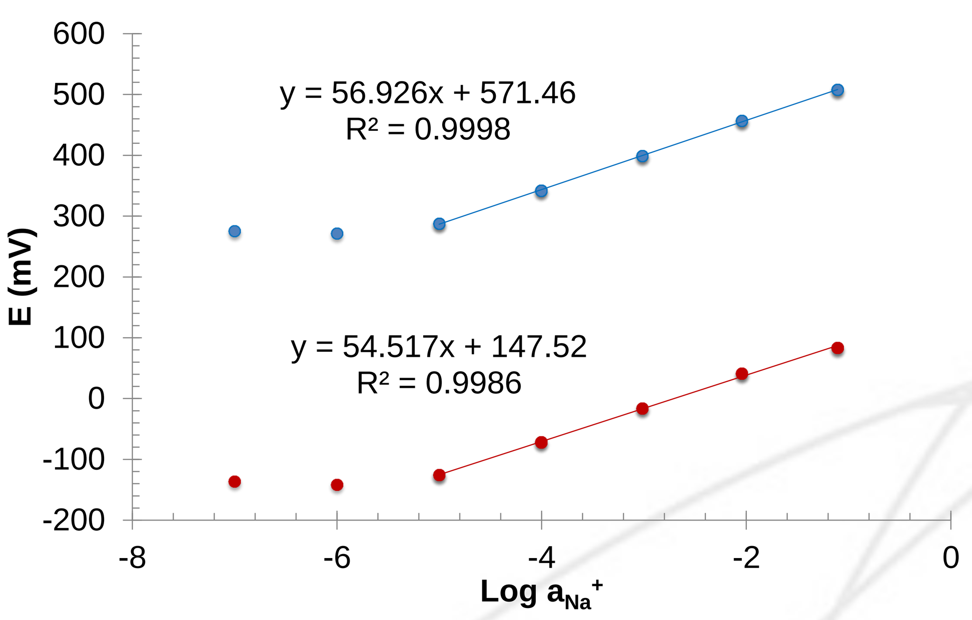


A TraceDec C4D system was used to determine the conductivity of a range of NaCl solutions using a Micrux thin-film interdigitated microarray electrode. The applied frequency, voltage and gain were adjusted for maximum sensitivity. The auxiliary electrode (AE) and reference electrode (RE) were used for all measurements.

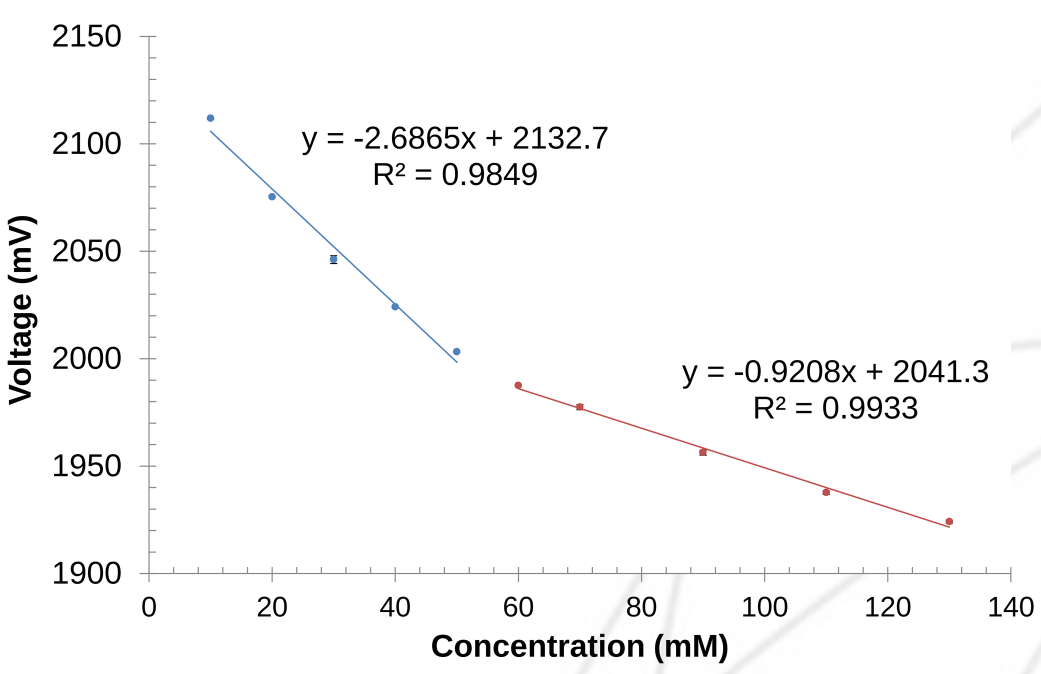
Calibration

ISEs

Average calibration of 3 Na-ISEs vs a standard double liquid junction Ag/AgCl reference electrode and a miniaturised solid contact reference electrode realised on a screen printed substrate.

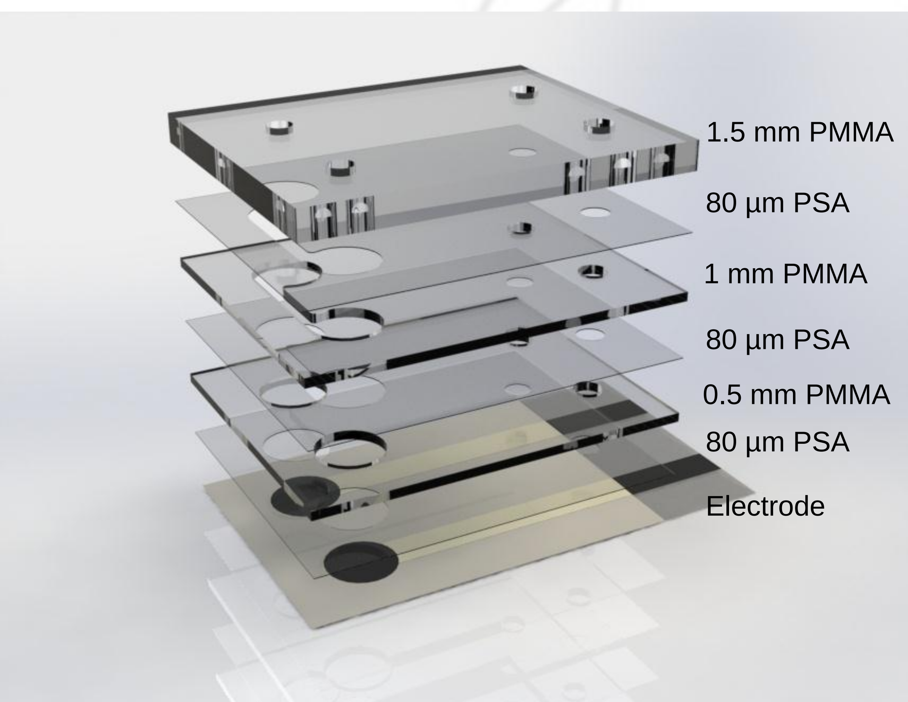


Micrux Electrode



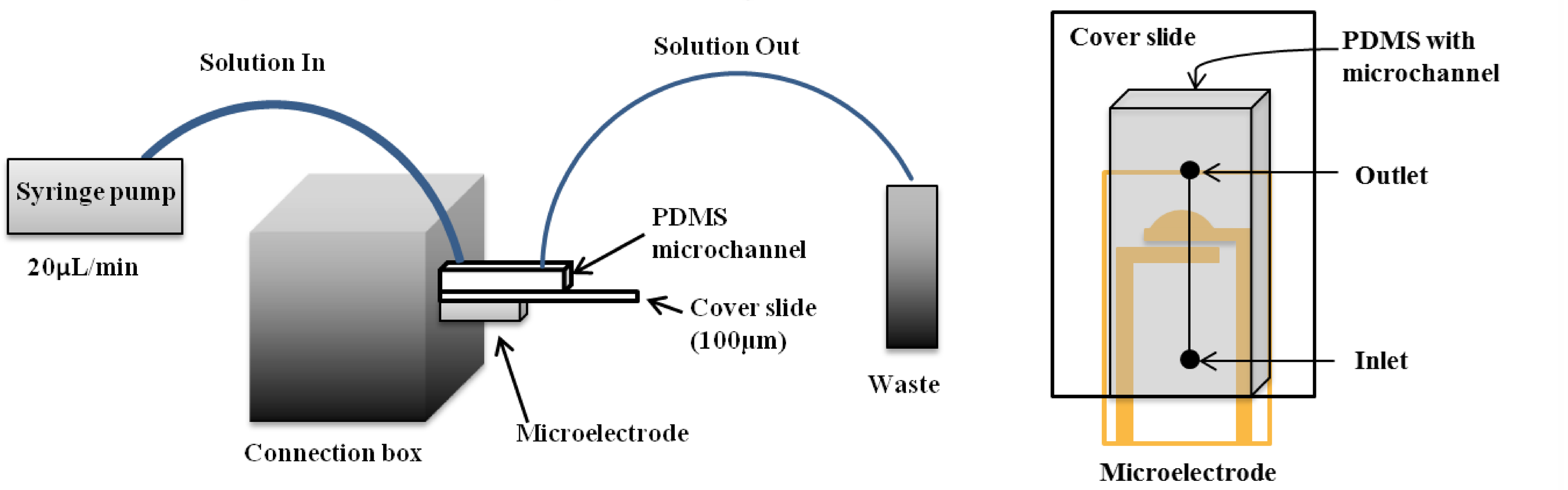
A gold Micrux chip was calibrated with 10-130 mM solutions of NaCl with a flow rate of 20 µL/min. Two distinct linear ranges are sustained; 10-50 mM and 60-130 mM. NaCl concentration variations over the normal range (<60 mM) and elevated values associated with cystic fibrosis (>60 mM) can be clearly distinguished.

Microfluidic Potentiometric Strip

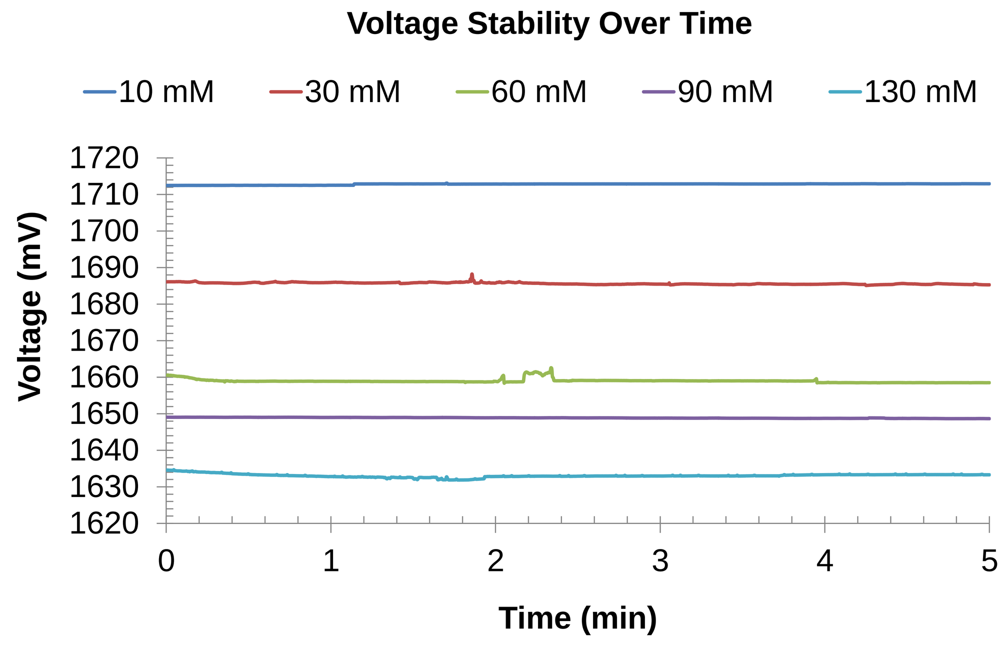


Expanded view of the different layers used to realise the microfluidic chip that was mounted on top of the potentiometric strip. This configuration allows sweat to be collected through a Mega-Duct sampler directly connected to the microfluidic channel.

Laboratory Conductivity Testing

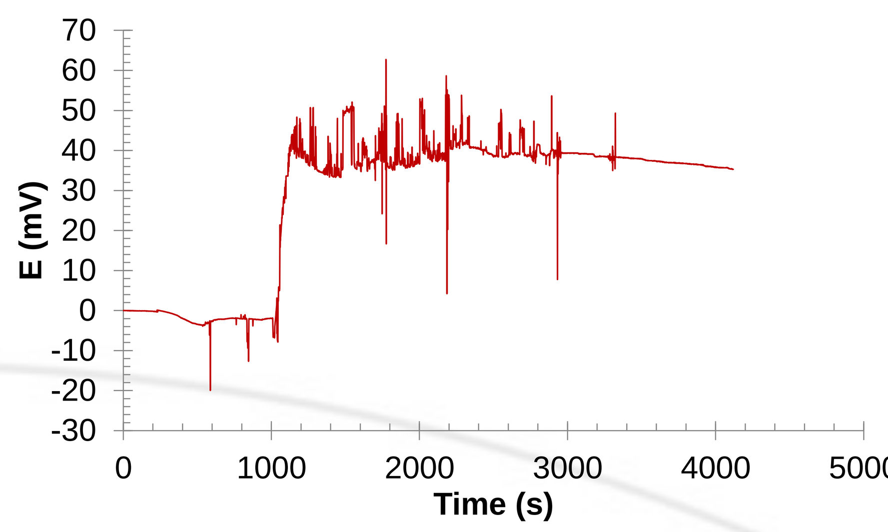


C4D measurements were taken over 5 minute intervals to measure stability over time. The relative standard deviation for the 5 solutions was calculated to be between 0.0017%-0.0860% for n=5940.



On-body Testing

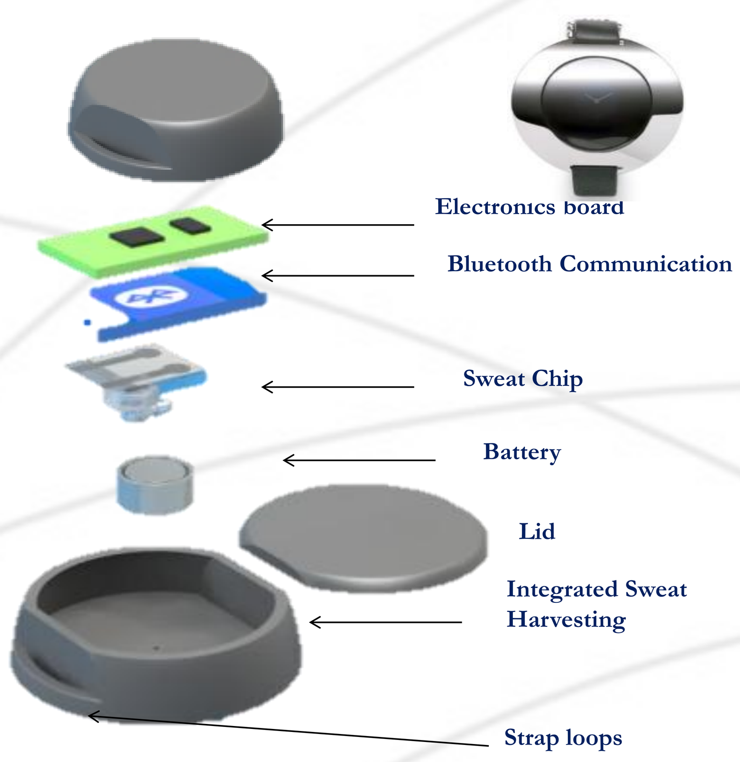
ISEs



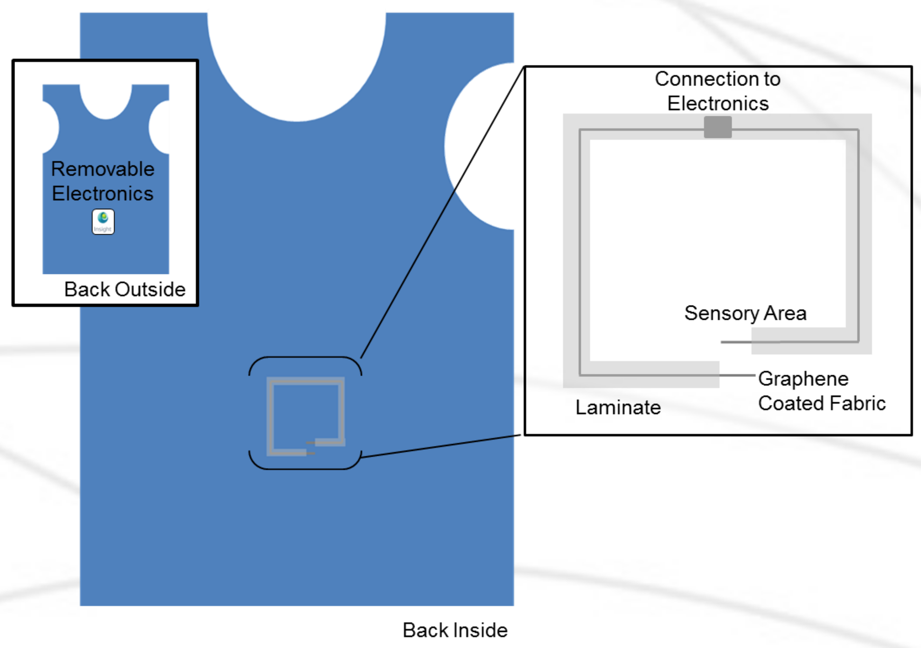
The potentiometric strip was integrated into a wearable device using a Mega-Duct to deliver the sample to the electrode. Real-time tests were carried out measuring the real-time potential variation during a stationary cycling trial.

Future Work

ISEs



Conductivity Sensor



Conclusions

Wearable sensors open the door to continuous monitoring for sports, exercise and health applications. These types of sensors have the potential to prevent injury, decrease rehabilitation time and reduce medical costs. Eventually, it is conceivable to integrate multiple sensors into one garment for whole body wellness monitoring.

Acknowledgments

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