Centre for
Data Analytics

Insight

A Wearable Platform for Harvesting and Analysing Electrolyte content in Sweat

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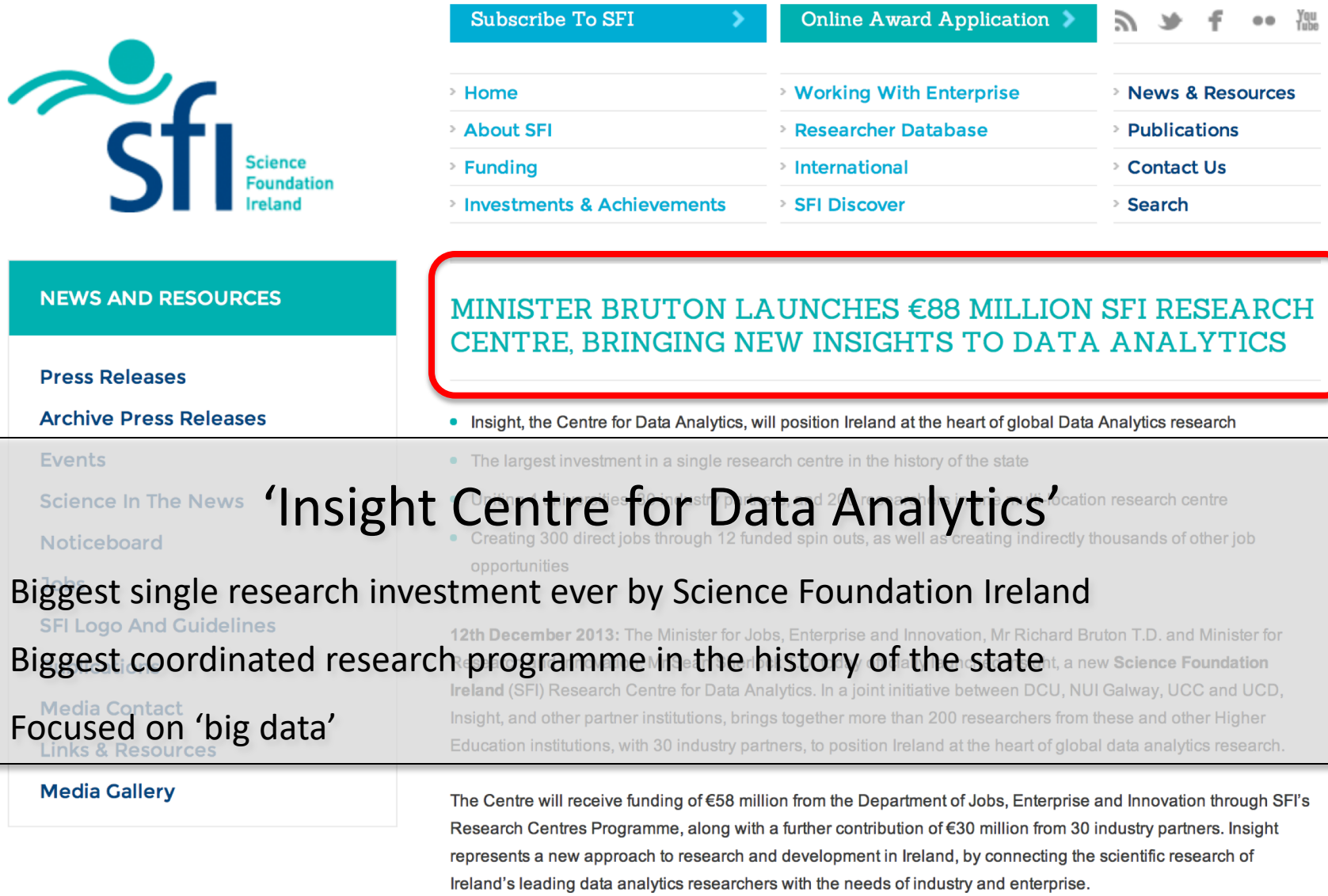
Enterprise Ireland Project ID: IP2016504
'Next Generation Wearable Sensors for Monitoring Sweat Composition in Real-Time'

Insight Centre for Data Analytics



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MINISTER BRUTON LAUNCHES €88 MILLION SFI RESEARCH CENTRE, BRINGING NEW INSIGHTS TO DATA ANALYTICS

- Insight, the Centre for Data Analytics, will position Ireland at the heart of global Data Analytics research
- The largest investment in a single research centre in the history of the state
- Creating 300 direct jobs through 12 funded spin outs, as well as creating indirectly thousands of other job opportunities

12th December 2013: The Minister for Jobs, Enterprise and Innovation, Mr Richard Bruton T.D. and Minister for [illegible], a new **Science Foundation Ireland** (SFI) Research Centre for Data Analytics. In a joint initiative between DCU, NUI Galway, UCC and UCD, Insight, and other partner institutions, brings together more than 200 researchers from these and other Higher Education institutions, with 30 industry partners, to position Ireland at the heart of global data analytics research.

The Centre will receive funding of €58 million from the Department of Jobs, Enterprise and Innovation through SFI's Research Centres Programme, along with a further contribution of €30 million from 30 industry partners. Insight represents a new approach to research and development in Ireland, by connecting the scientific research of Ireland's leading data analytics researchers with the needs of industry and enterprise.

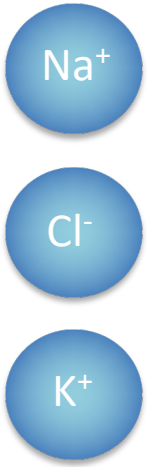
'Insight Centre for Data Analytics'

- Biggest single research investment ever by Science Foundation Ireland
- Biggest coordinated research programme in the history of the state
- Focused on 'big data'

Monitoring in Sweat

Why Monitor Sweat?

- Non Invasive
- Easily Accessible Bio Fluid
- Contains electrolytes (Sodium, Pottassium, Chloride)



[2] Henry Browne/Action Images. Accessed September 2017 http://www.theguardian.com/lifeandstyle/2009/apr/02/project-marathon-running-injuries

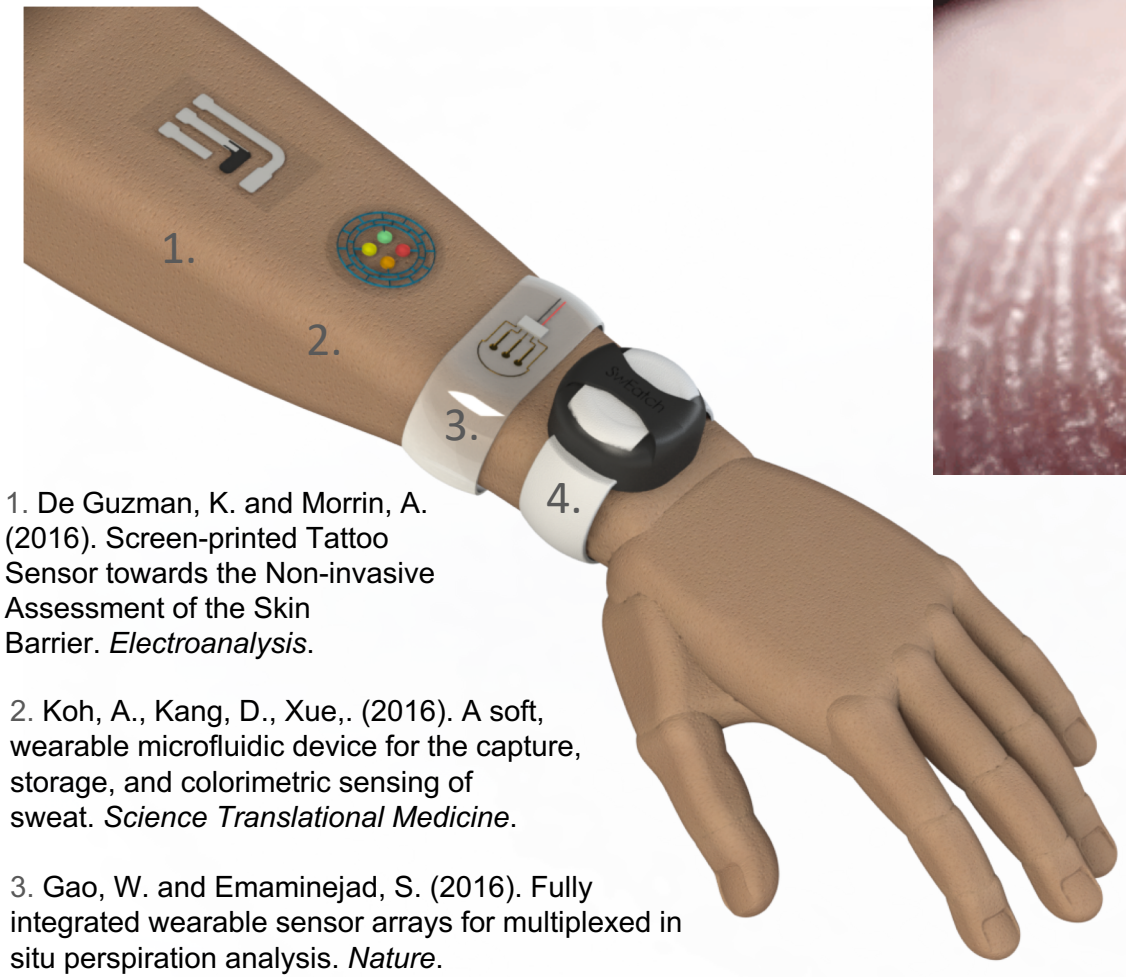
What can sodium levels alert to in individuals?

- Dehydration
- Exercise associated hyponatremia (overhydration) in long distance athletes
- Cystic fibrosis (Abnormal levels of 90-120 mM compared to the standard 10-70mM) [1]

2]. Accessed August 2017 https://www.wsj.com/articles/ease-up-on-the-water-during-that-marathon-1424715632

[1] Ferner, S., et al. "[Reference values of Na (+) and Cl (-) concentrations in adult sweat]." Zeitschrift fur Erkrankungen der Atmungsorgane 175.2 (1989): 70-75.

Recent Advances in Wearable Sensing

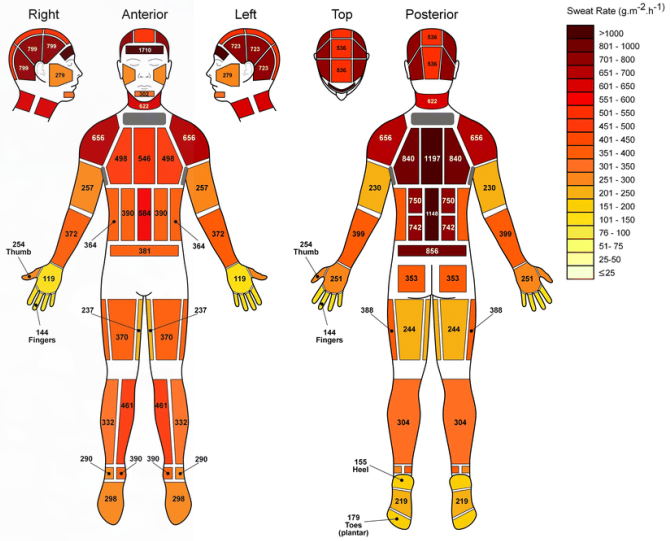


1. De Guzman, K. and Morrin, A. (2016). Screen-printed Tattoo Sensor towards the Non-invasive Assessment of the Skin Barrier. *Electroanalysis*.

2. Koh, A., Kang, D., Xue,. (2016). A soft, wearable microfluidic device for the capture, storage, and colorimetric sensing of sweat. *Science Translational Medicine*.

3. Gao, W. and Emaminejad, S. (2016). Fully integrated wearable sensor arrays for multiplexed in situ perspiration analysis. *Nature*.

4. Glennon, T., O'Quigley, C., McCaul, M., Wallace, White, P. and Diamond, D. (2016). 'SWEATCH': A Wearable Platform for Harvesting and Analysing Sweat Sodium Content. *Electroanalysis*.



[3]Smith, C. and Havenith, G. (2010). Body mapping of sweating patterns in male athletes in mild exercise-induced hyperthermia. *European Journal of Applied Physiology*, 111(7), pp.1391-1404.

SwEatch: Sweat Analysis

- SwEatch: A Wearable Platform for Harvesting and Analysing Sweat Sodium Content [1]
- Enterprise Ireland Funded project
- Na^+ selective potentiometric sensing in a fully integrated platform
- Platform to be further developed to analyze a variety of electrolytes and other relevant analytes.
- Collaboration between
  - Insight Centre of Data Analytics, DCU
  - ARC Centre of Excellence for Electromaterials Science (ACES), Australia
  - Shimmer, DCU Innovation Campus

[1] Glennon, T., O'Quigley, C., McCaul, M., Matzeu, G., Beirne, S., Wallace, G. G., ... & Diamond, D. (2016). 'SWEATCH': A Wearable Platform for Harvesting and Analysing Sweat Sodium Content. Electroanalysis.

Electrode Development

Design and Fabrication Na^+ Electrode

PET Substrate

↓

Screen Printed Conductive Carbon Ink layer

↓

Dielectric insulating Ink

↓

PEDOT Transducing Layer

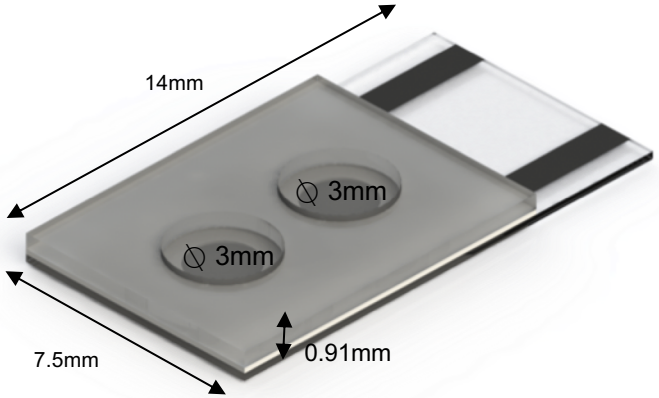
↓

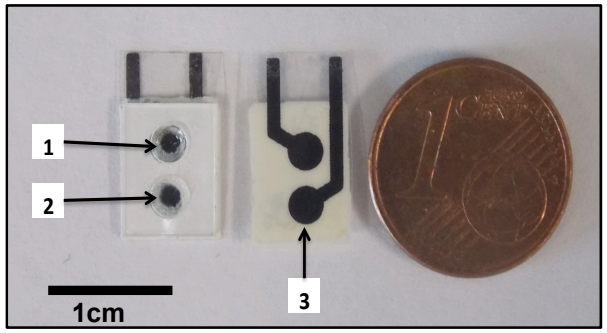
PMMA Gasket

↓

Polymeric Electrode Membrane

Render of the the ISE electrode



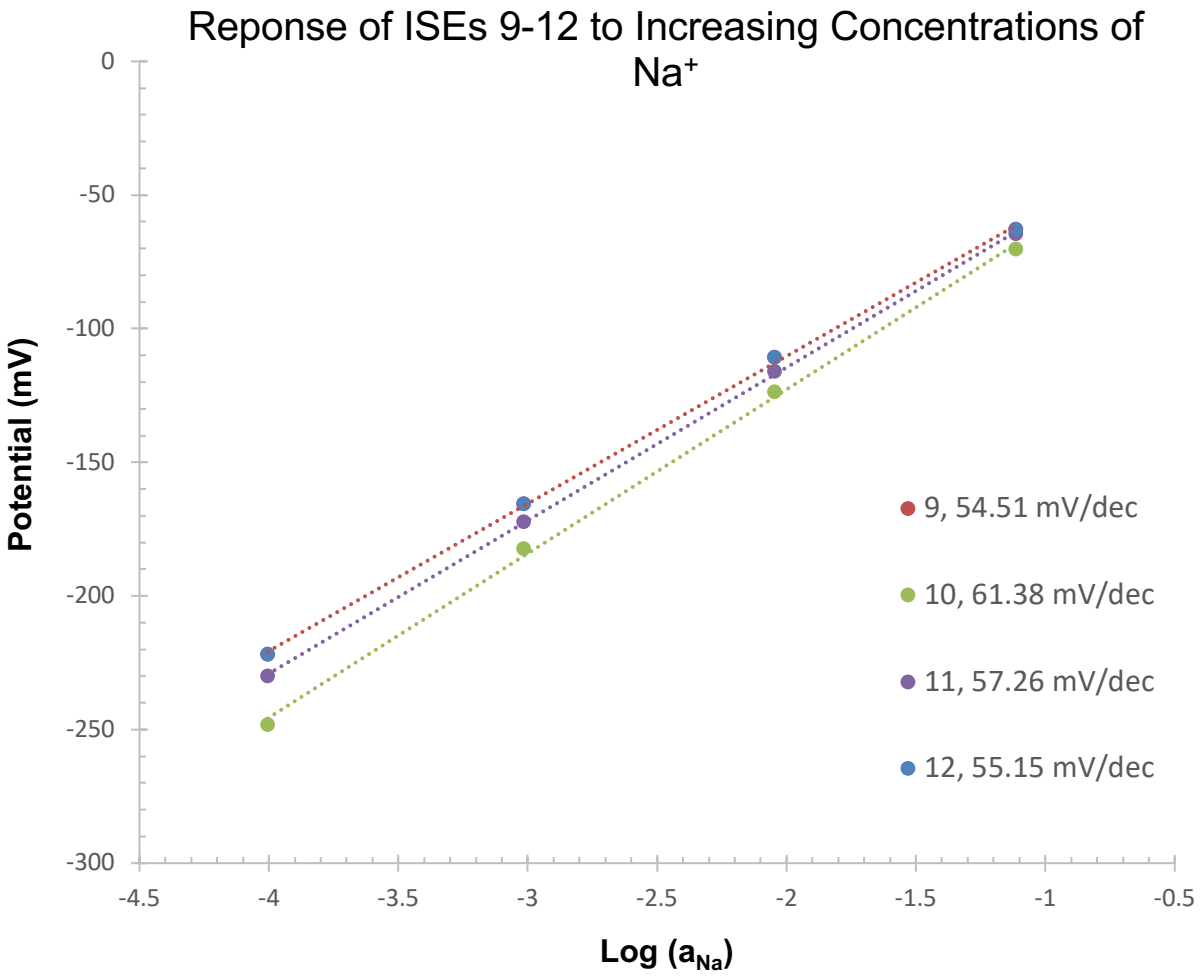


1. The Ion Selective Electrode (ISE)
2. The reference electrode (RE)
3. The screen-printed conductive carbon layer.

Electrode Development

Calibration/Conditioning

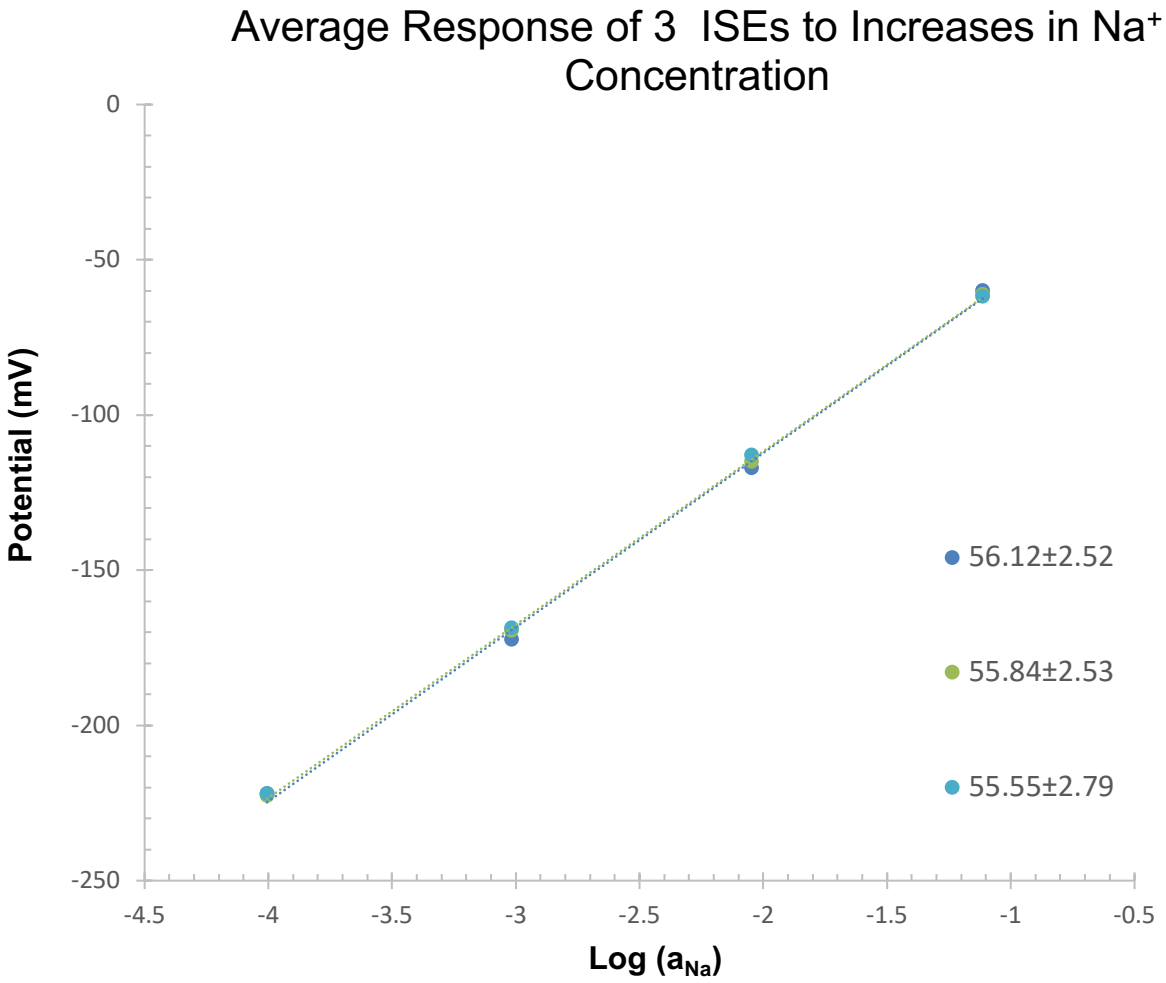
- Comparison of electrochemical response of electrodes
- Four point calibration of 4 ISEs showing ion sensitivity after 2 hour conditioning time in 0.01 M NaCl
- All electrodes display a near Nernstian response to Na^+ in the range $1x10^{-4}$ M – $1x10^{-1}$ M



Electrode Development

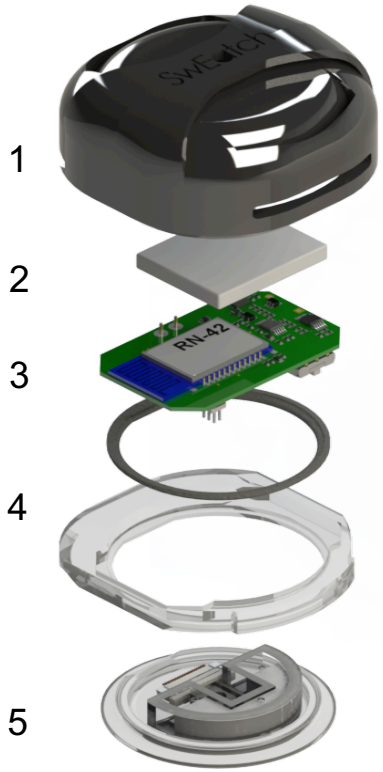
Electrode Reproducibility

- Four point calibration of 3 combination electrodes
- Each calibration carried out in triplicate (n = 3)
- All electrodes display near Nernstian response

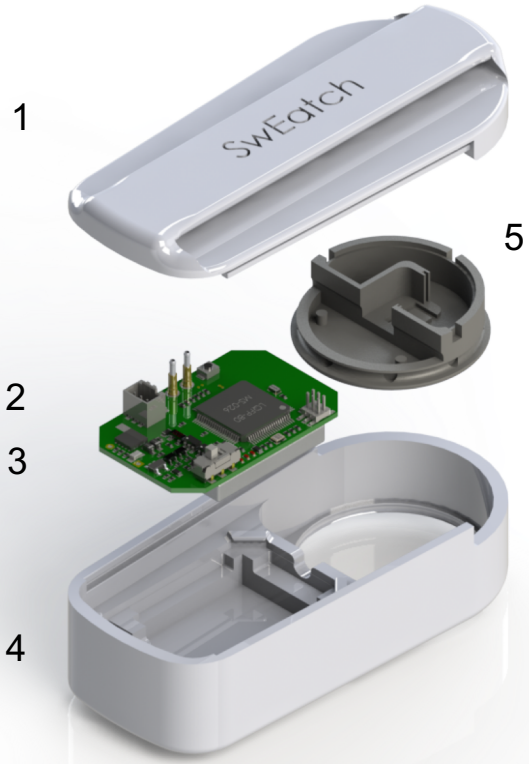


Wearable Platform

Watch Platform



Pod Platform



1. 3D printed housing
2. Lithium battery
3. Custom-built electronics with wireless communication (Shimmer)
4. 3D printed mount with silicon inner seal to house the sweat harvester
5. 3D printed sweat harvesting device and microfluidic chip with integrated sensor

Fluidic Platform

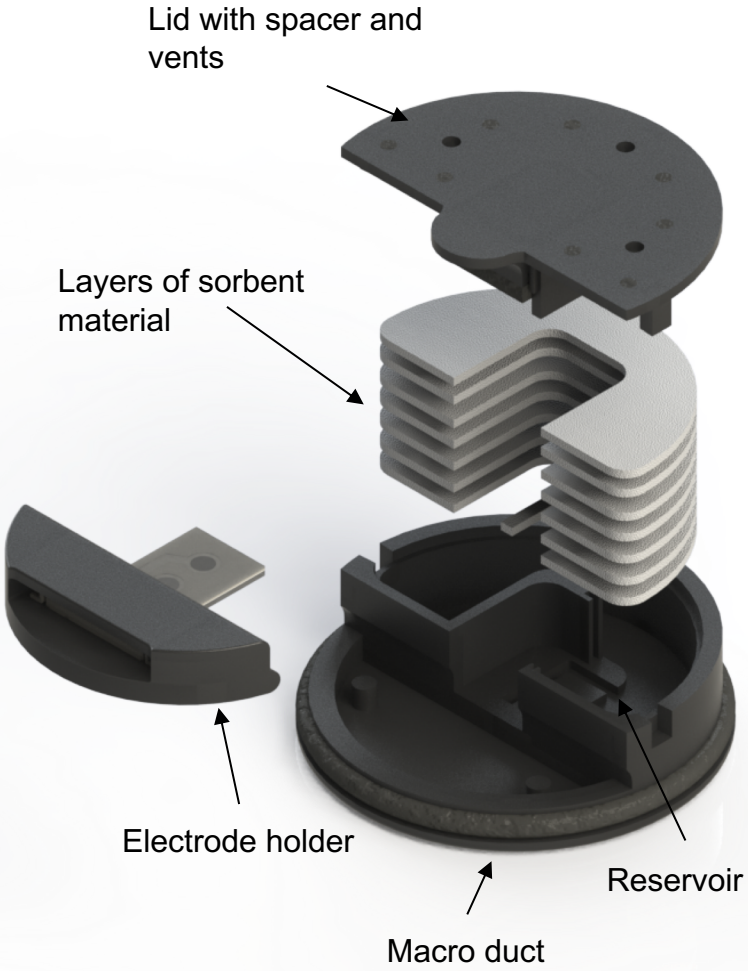
3D Printed Fluidic Platform

Render of Fluidic Platform

Render of reservoir

Picture of Fluidic Platform

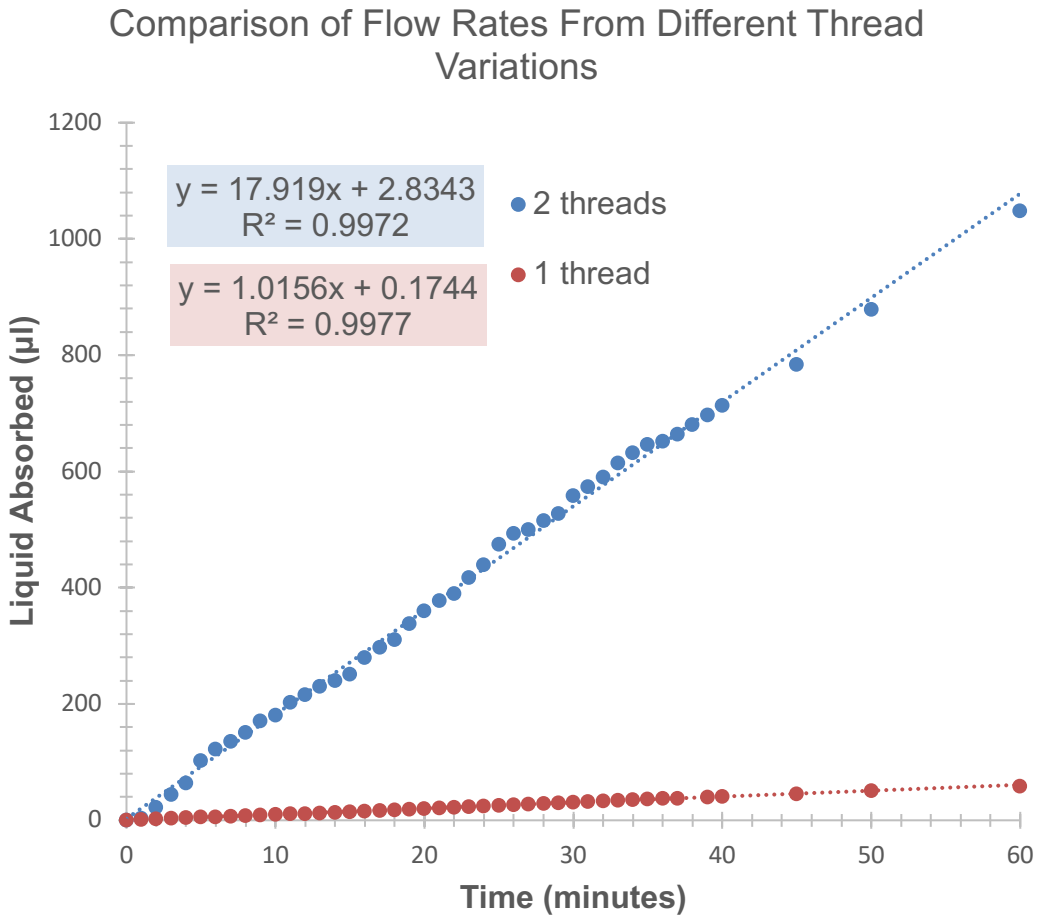
Picture of reservoir



Fluidic Testing

3D Printed Fluidic Platform

- Control Flow Rate by altering thread number
- Flow Rate ~ 1 µl/minute (1 wicking thread)
- Not realistic as flow is too slow to see change in response from electrode
- Flow rate: ~17 µl/minute (2 wicking threads)
- Capacity reached after 2.5 Hours

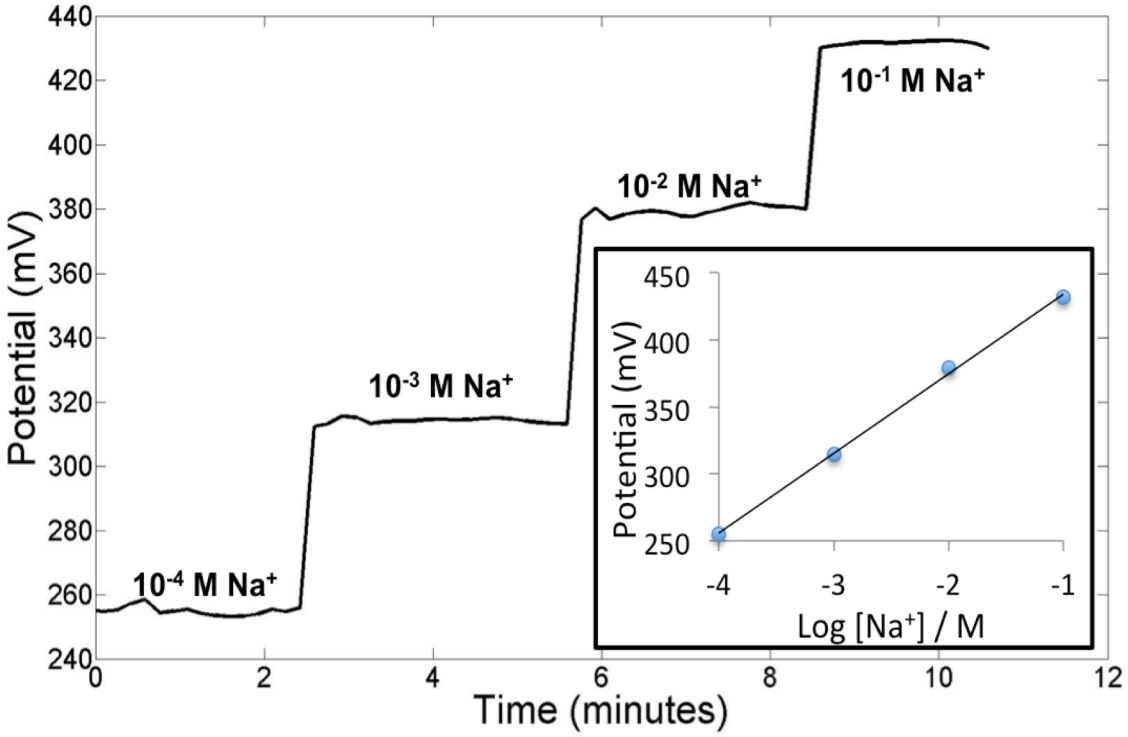


Plot of Liquid Uptake vs. Time for 3D printed platform with changing number of threads, 1cm

Sensor Calibration on Platform

Electrode Integrated

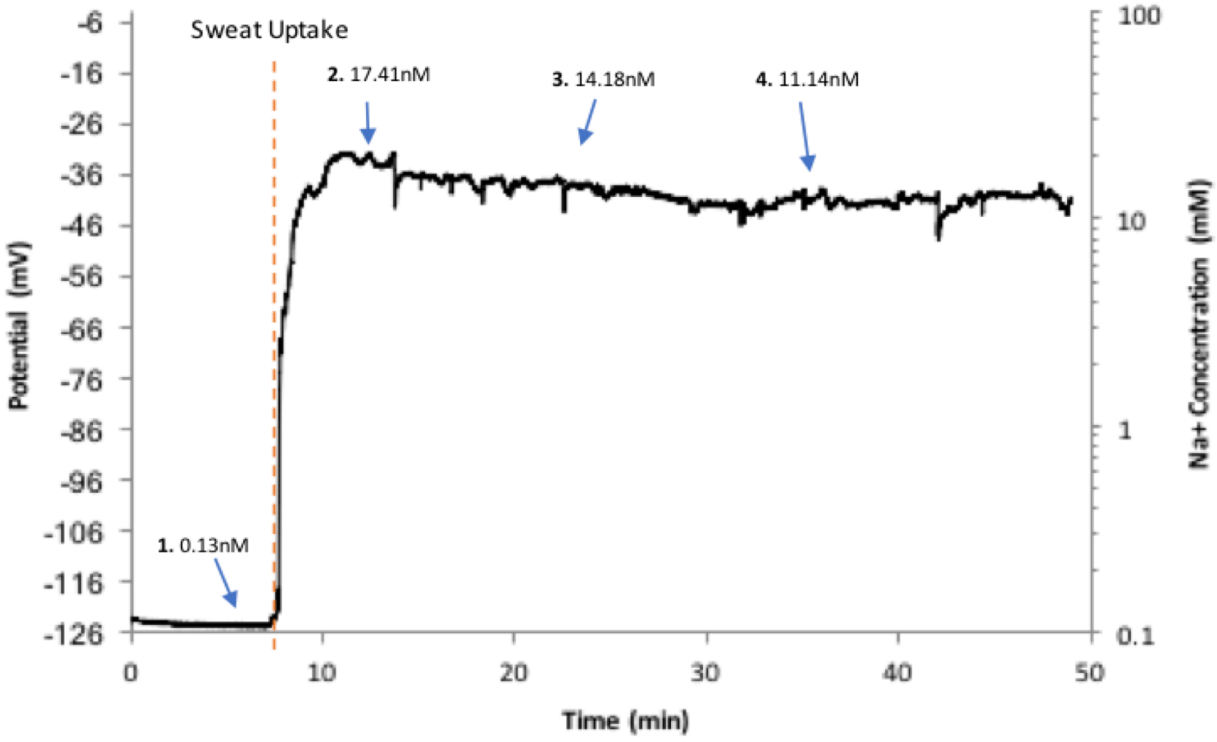
- Calibration of a Na^+ ISE and RE output signal using the Shimmer board, giving a slope of 56.98mV and an R^2 value of 0.99.
- Calibrated in the 3D fluidic Platform



On-Body Trials

- Subject 1: Male
- Age: 26
- Absolute $VO_{2\ Max}$:4.2L/min
- Relative $VO_{2\ Max}$:50.8mL/kg/min

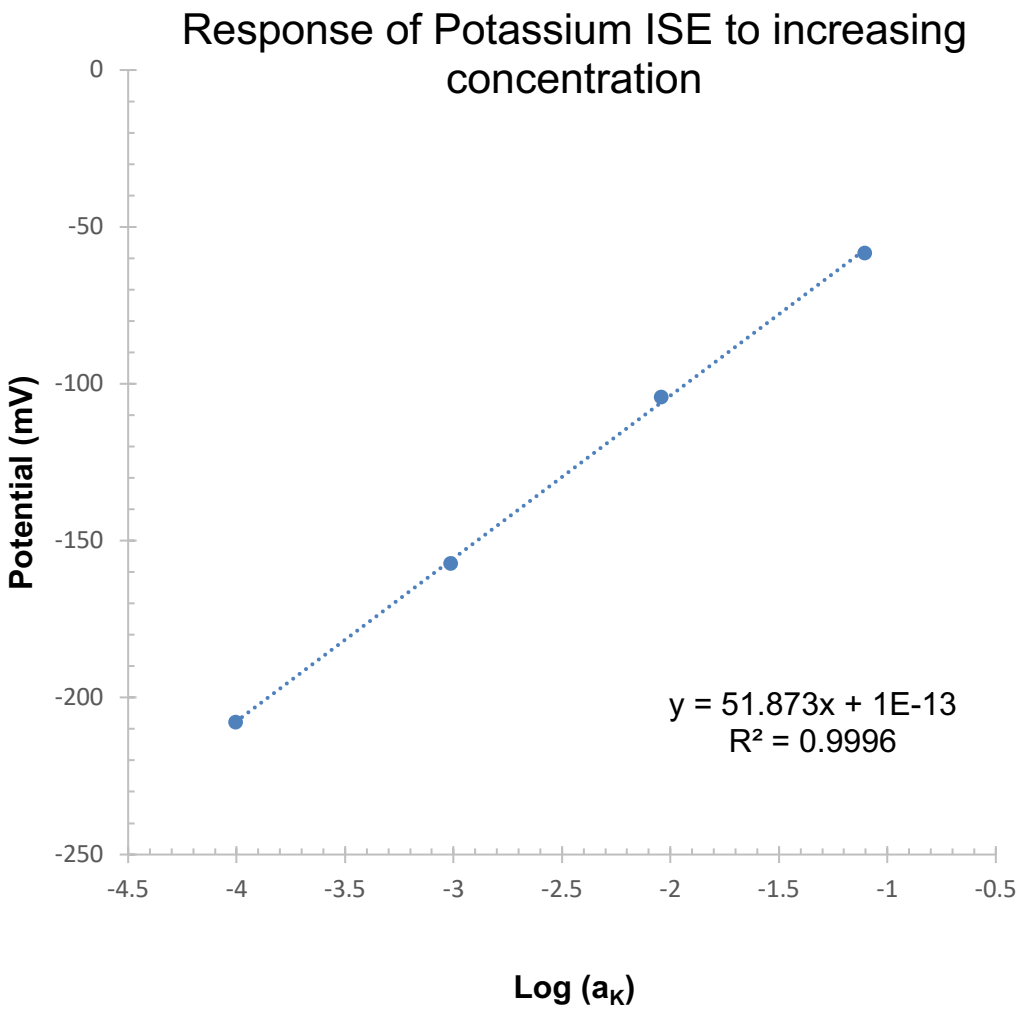
- On body trials carried out with excercised induced perspiration.
- Succesfully monitored Na^+ levels for periods ranging from 7-50 min.



Potassium ISE Development

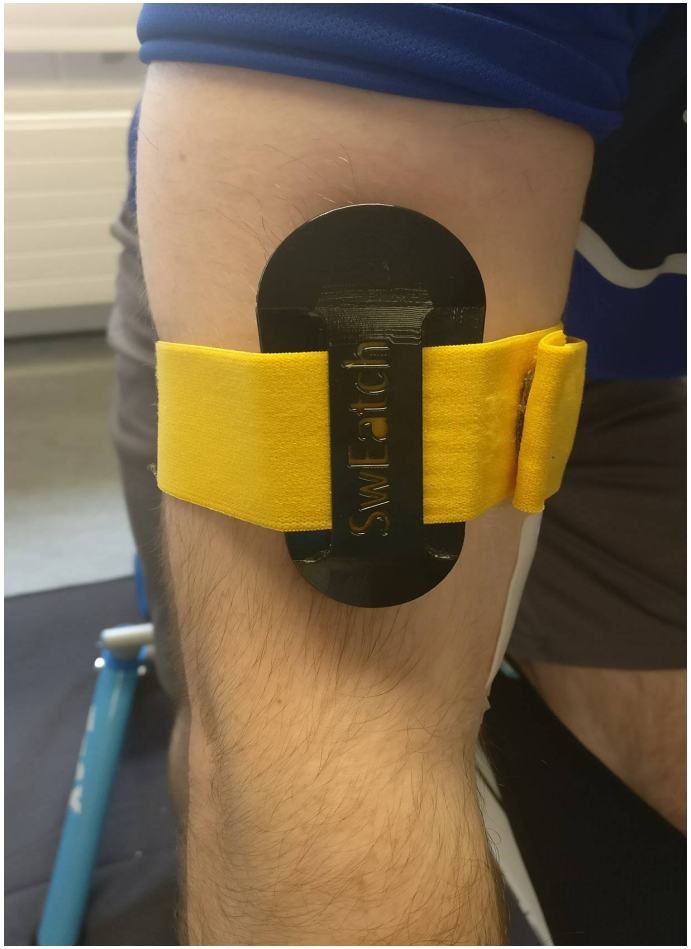
Calibration/Conditioning

- Comparison of electrochemical response of electrode
- Four point calibration of Potassium ISE showing ion sensitivity
- Electrode display's a near Nernstian response to K^+ in the range $1x10^{-4}$ M – $1x10^{-1}$ M
- Each Calibration carried out in triplicate (n=3)



Future Work

- Larger scale trials to fully study Na^+ concentrations in sweat during exercise
- Incorporate detection for other analytes such as K^+
- Improve design to maximise contact with skin and minimise device size



Conclusions

Successfully developed a fully integrated platform which can:

- Harvest sweat from a pre-selected location
- Transport the sweat from the skin to electrodes to measure Na^+ concentration
- Collect the sweat in an in-device storage area for post-trial analysis
- Make the measured data available in real-time using Bluetooth wireless connectivity

Acknowledgements

- Adaptive Sensors Group in particular Dr. Margaret McCaul, Dr. Adam Porter, Ruairi Barrett, Prof. Dermot Diamond
- Prof Gordon Wallace and his group in ACES, IPRI, University of Wollongong
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