

MULTISENSING WEARABLE TECHNOLOGY FOR SWEAT BIOMONITORING

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Wearable Devices

Sweat

State-of-the-art

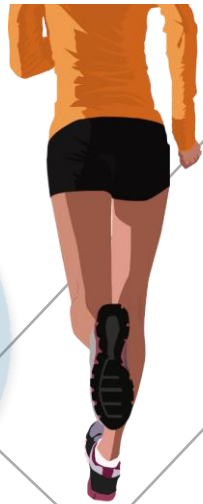
- Sweating leads to the loss of water and electrolytes due to **thermoregulatory** action of sweat during exercise.
- The continuous monitoring of biomarkers in sweat provides useful information about the **physiological state** of a person.

Most of the commercially available wearable devices are capable of just tracking individual's **physical** activity and vital signs like heart rate and body temperature.



By now, only few patches that can continuously measure biochemical markers in sweat have been launched.

Na⁺
Cl⁻ Ca²⁺
K⁺ Mg⁺ HPO₄²⁻
Glucose Lactate
Creatinine



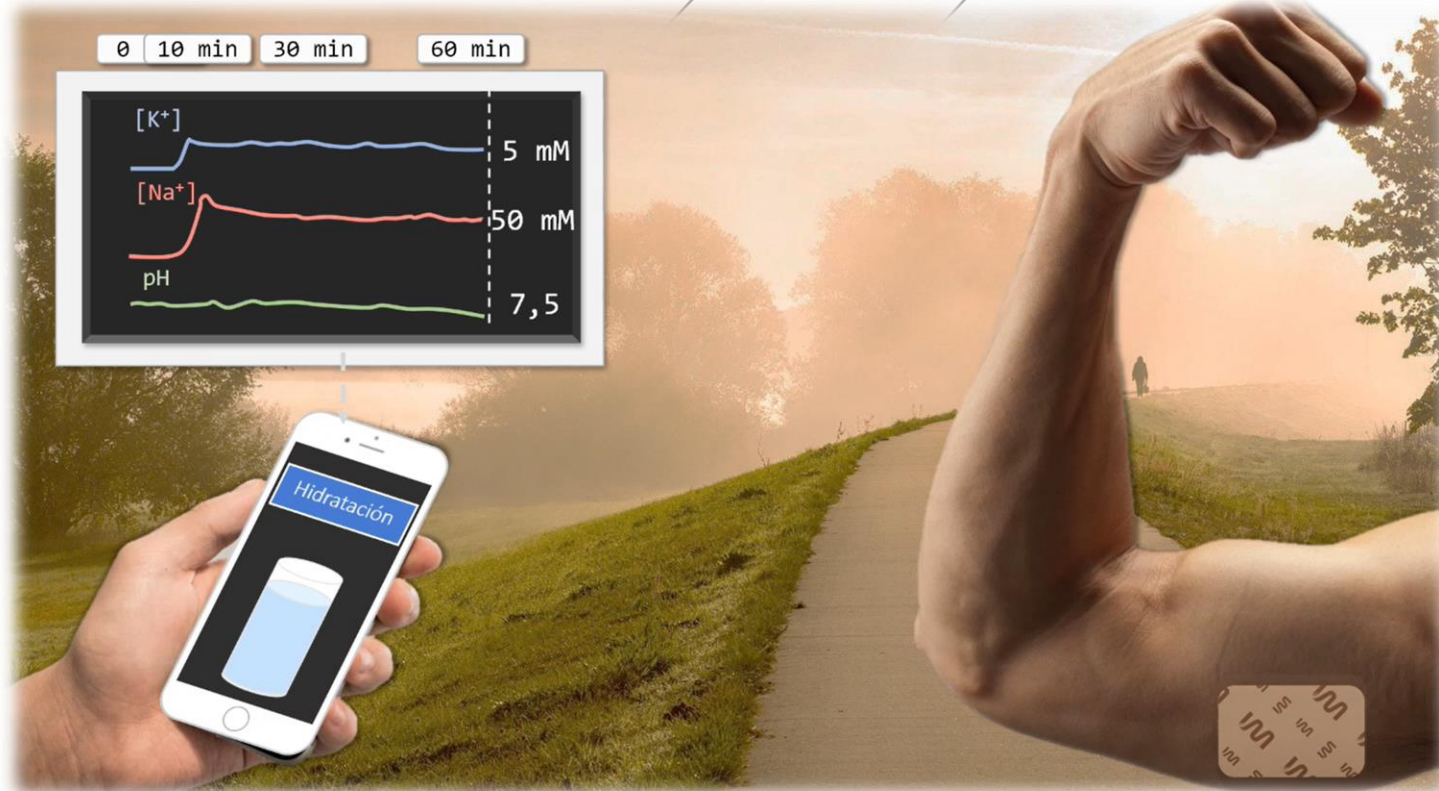
- Cardiac arrhythmia*
- Muscle ramps*
- Fatigue*
- Headaches*
- Dehydration*
- Hyponatremia*
- Vomiting*
- Weakness*
- Tremor*



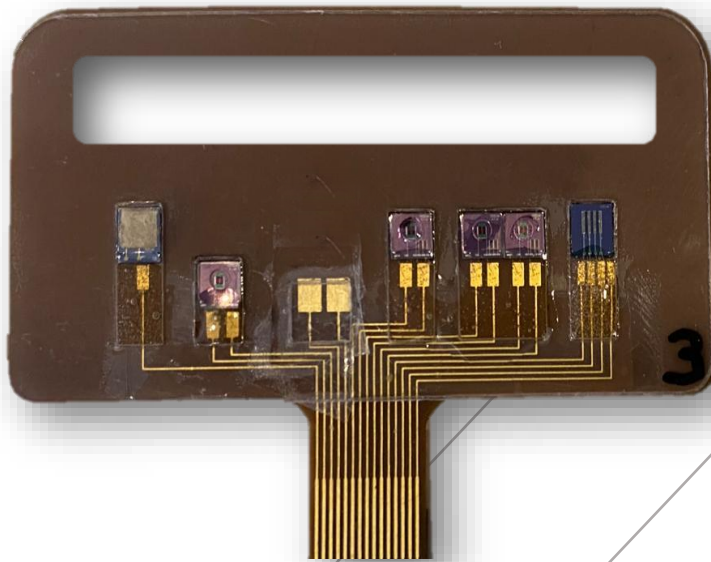
From: <https://www.gatorade.com/gx/sweat-patch-detail>

Objectives

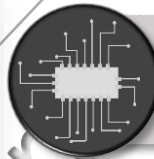
- To validate the measure of **pH, sodium and potassium ISFET** sensors in sweat.
- To develop a **patch** to continuously monitor pH, sodium and potassium concentrations in sweat directly related to hydration status.



Wearable patch



Kapton substrate + copper tracks + gold finish + gold wires

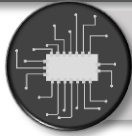


Solid-state sensors

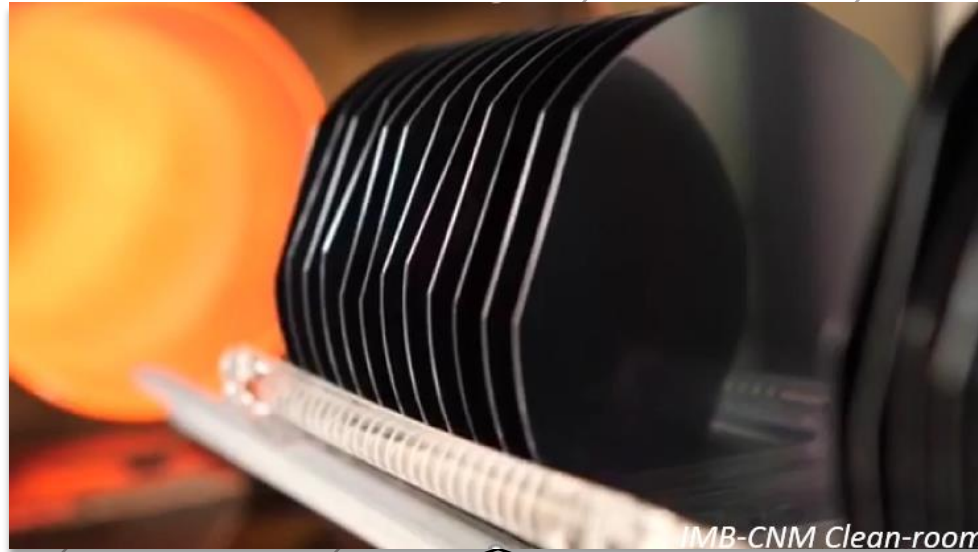


Paper-based microfluidics

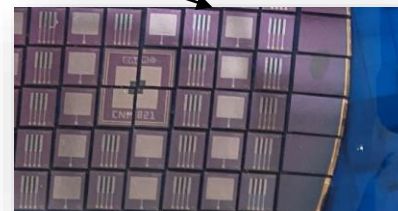
Sensors



Solid-state sensors

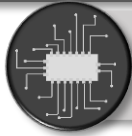


ISFET
(Ion-Sensitive Field-Effect Transistor)



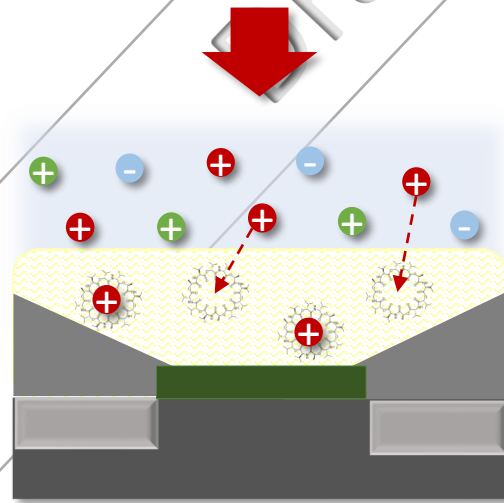
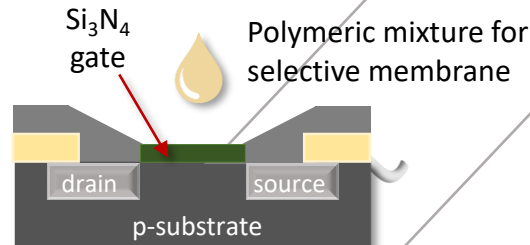
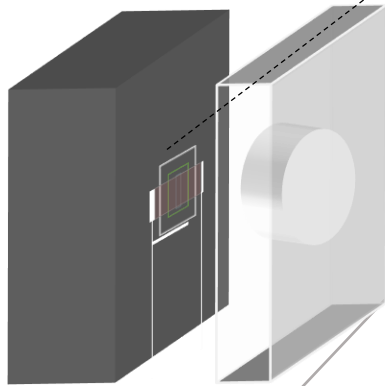
Amperometric and conductivity sensors

Sensors

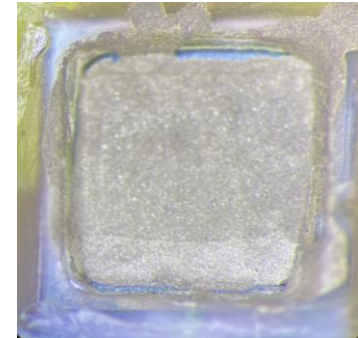


Solid-state sensors

ISFET
(Ion-Sensitive Field-Effect Transistor)

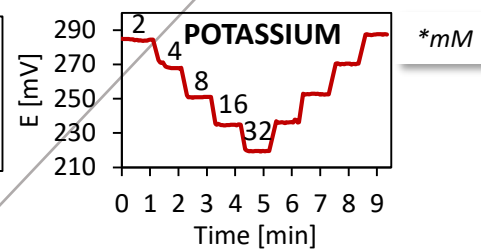
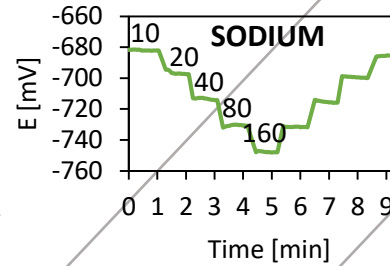
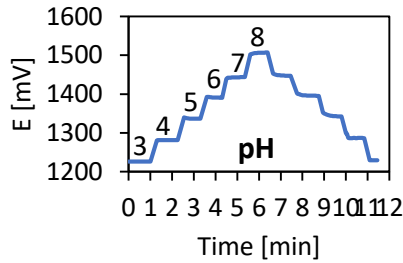


Ag/AgCl reference sensor

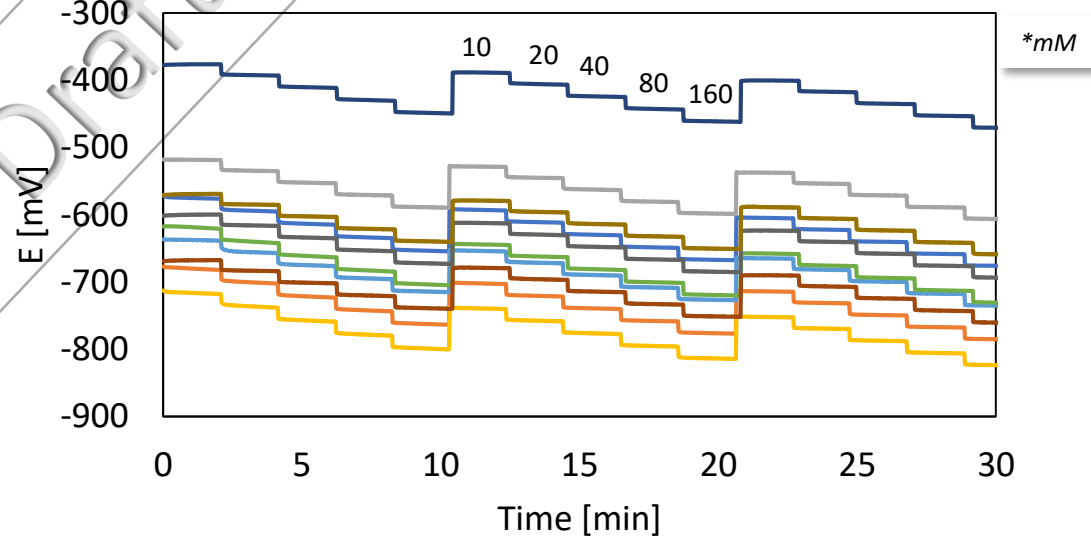


Characterization

Sensibility and hysteresis



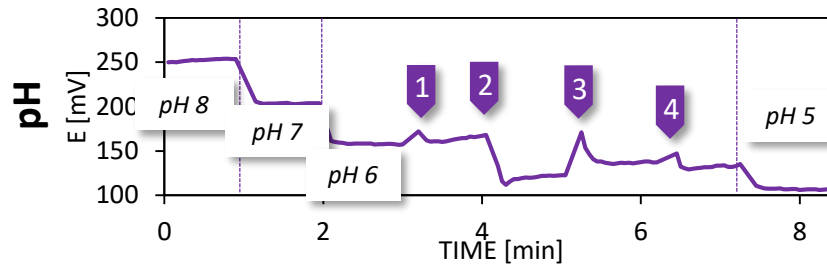
Repeatability and reproducibility among sensors



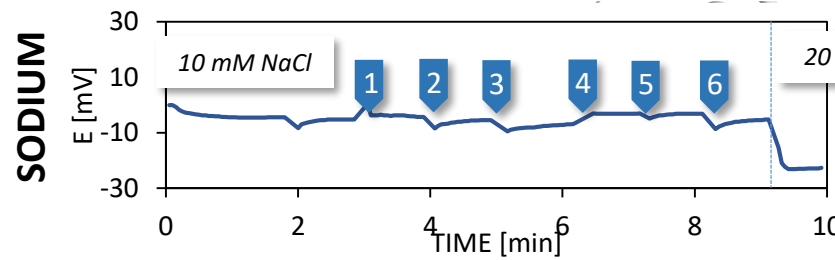
Long term stability 46 days → Deviation of 8 mV/pNa

Characterization

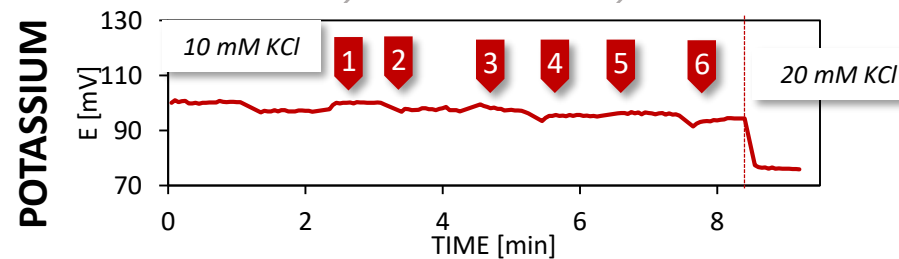
Sweat interferences



1. 100 μ M glucose (pH=5,5)
2. 1 mM CaCl_2 (pH=5,4)
3. 10 mM KCl (pH=5,5)
4. 10 mM NaCl (pH=5,4)



1. 0,08 mM MgCl_2
2. 10 mM KCl
3. Organic ac. and carbohydrates
4. Ammino acids
5. Nitrogenous substances
6. Vitamins

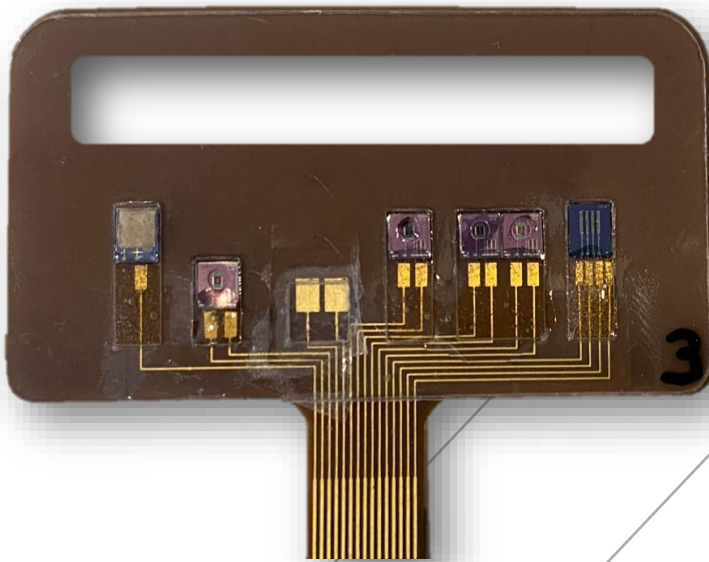


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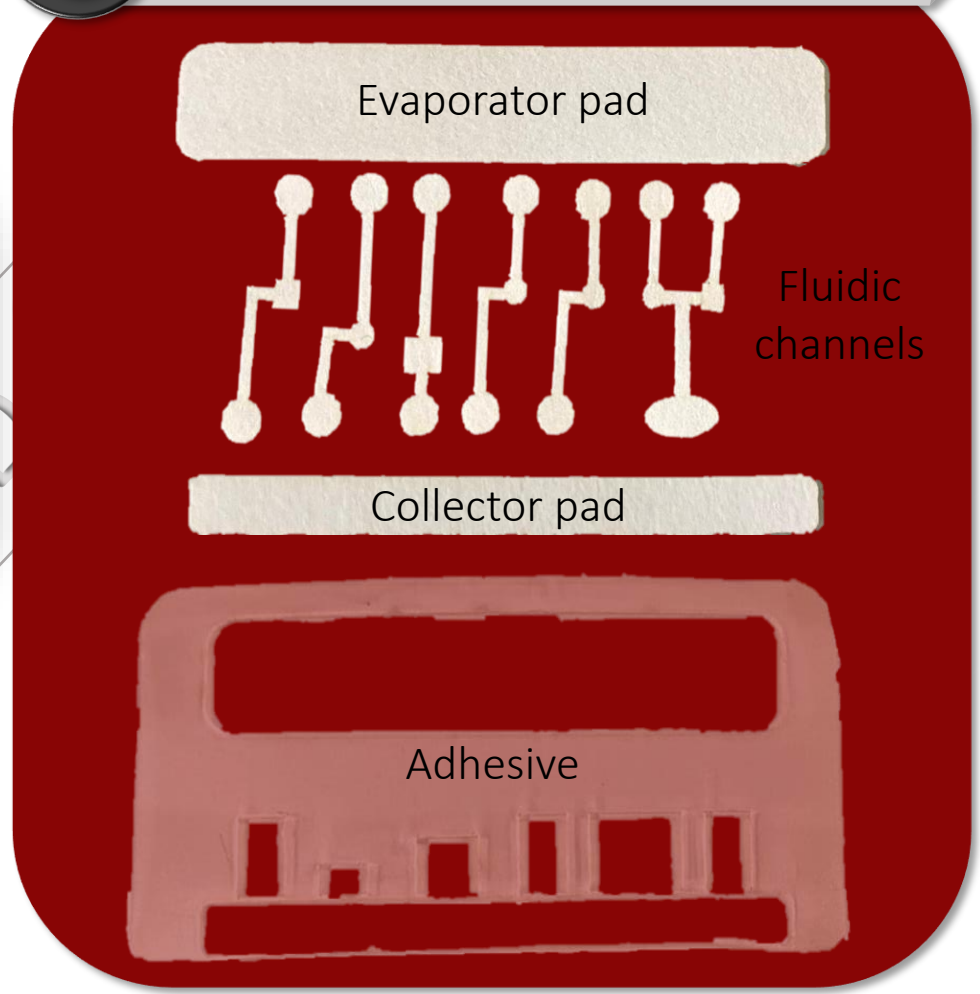
Wearable patch



Paper-based microfluidics



Kapton substrate + copper tracks + gold finish + gold wires

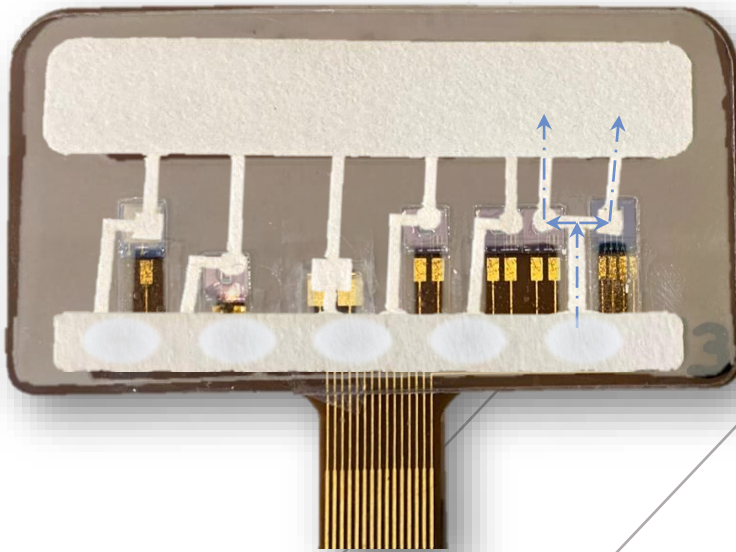


Wearable patch

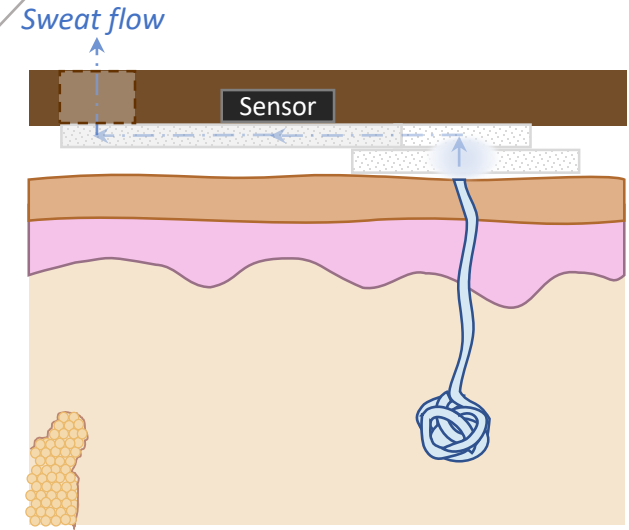


Paper-based microfluidics

Front view



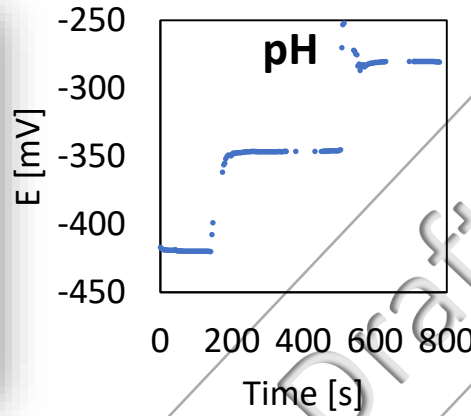
Cross-section view



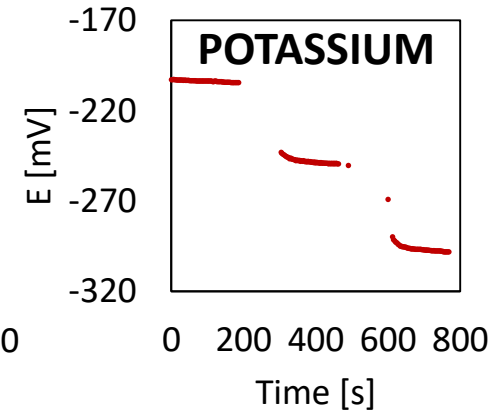
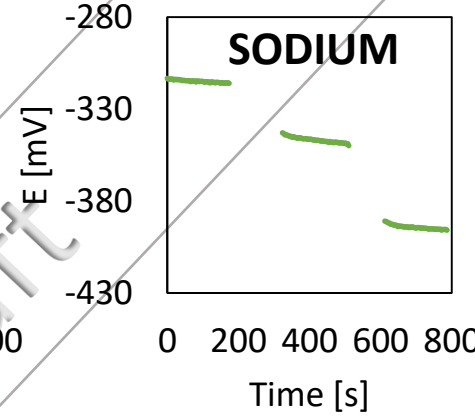
Takes **15 min** to reach all the sensors at the average sweating rate ($1,5 \mu\text{L}/(\text{cm}^2 \cdot \text{min})$)

Tests on patch

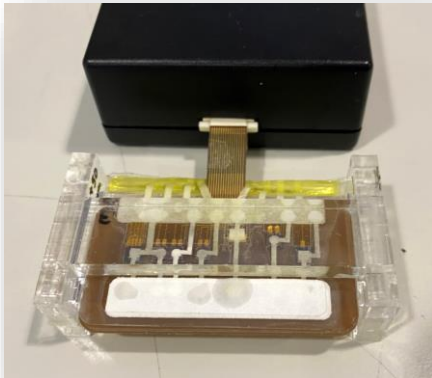
○ Tests on drop



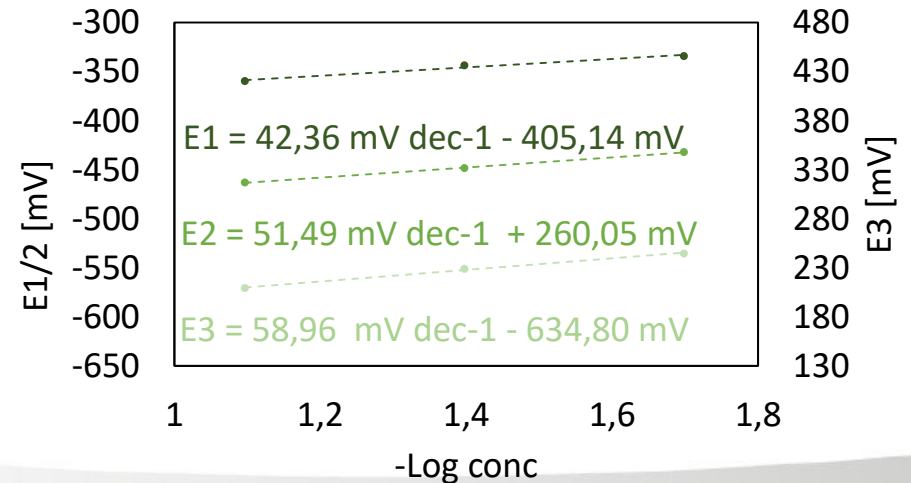
Synthetic sweat matrix



○ Tests with microfluidics



Na ISFETs with increasing concentrations of Na⁺ in a synthetic sweat solution



Conclusions



Time

At sweat flow rate solution contacts the sensors in few minutes



Sensors performance

Good sensitivity, selectivity, stability, repeatability and reproducibility, and no hysteresis effects



Matrix

No components in sweat interfering the sensors response



Compatibility

Good diffusion from paper to silicon sensors





THANK YOU FOR YOUR ATTENTION

This work is performed in the frame of the WeCare project (SNSF, Switzerland). This work used the Spanish ICTS Network MICRONANOFABS supported by the Spanish Ministry of Science and Innovation, Spain.