MicroBioPatch:

a sweat iodine sensor

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Contents

Introduction

Sweat Analytes

- Electrolytes:
  - Sodium: fluid balance
  - Potassium: nerve and muscle function
  - Chloride: osmotic balance and acid-base equilibrium
- Lactate: fatigue in anaerobic metabolism
- Glucose: blood sugar regulation
- pH: skin health and acidity
- Urea: protein breakdown and kidney function
- Ammonia: metabolic processes and liver function
- Proteins/peptides: inflammation or immune responses
- **Iodine: supports a high energy yielding metabolism**

Our design

Iodine Detection

Our idea is to create a new adhesive device that detects iodine concentration in sweat. This device will follow a similar pattern to devices already created, but will specifically detect for iodine concentration in sweat.

Our device’s goals

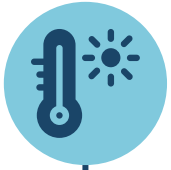
- Help with detection of severe iodine deficiency/excess
  - Hypothyroidism is a result of iodine deficiency
  - Hypothyroidism and thyroid autoimmunity for iodine deficiency
- Help keep track of iodine levels during pregnancy
  - There is a 50% increased need for iodine when pregnant
- Vigorous exercise can lose a considerable amount of iodine in sweat
  - Depending on environmental factors such as temperature and humidity
  - In areas of lower to moderate dietary iodine intake, loss in sweat can equal that in urine

Potential Applications

- Fitness tracking and health monitoring in high-performance sports for athletes
  - Athletes lose a lot of iodine when performing
- Disease diagnosis
- Health monitoring
  - Continuous monitoring
  - Point-of-care device

Device Design

Sweat Stimulation



Sweat Collection

Analyte Isolation

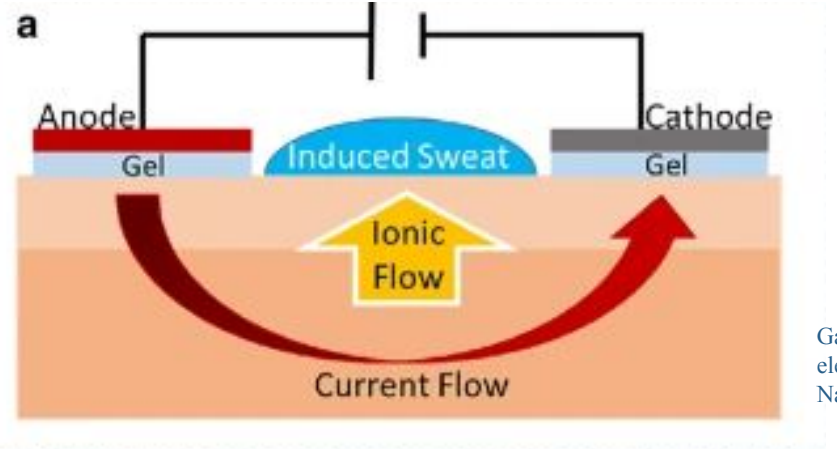
Analyte Sensing

Sweat Stimulation

Passive: user performs intense exercise

Active: electrical stimulation induces sweat secretion

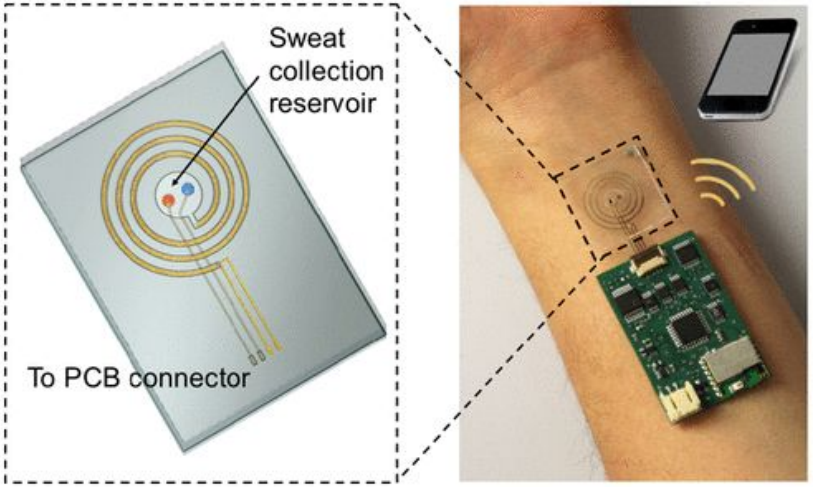
- **Iontophoresis** - electrodes generate current below the skin surface, stimulating the sweat gland



Gao, F., Liu, C., Zhang, L. et al. Wearable and flexible electrochemical sensors for sweat analysis: a review. Microsyst Nanoeng 9, 1 (2023). https://doi.org/10.1038/s41378-022-00443-6

Sweat Collection

- Use **capillary force** to transport sweat through microfluidic channels and collect in **reservoir**

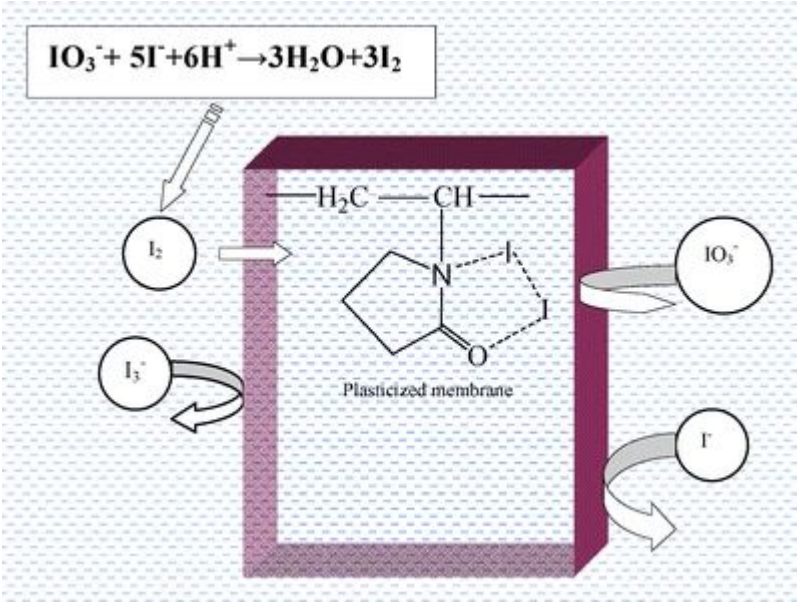


Nyein, H. Y. Y. et al. A wearable microfluidic sensing patch for dynamic sweat secretion analysis. ACS Sens. 3, 944–952 (2018).

Analyte Isolation

Target Analyte: **Iodine**

→ Use selective membrane



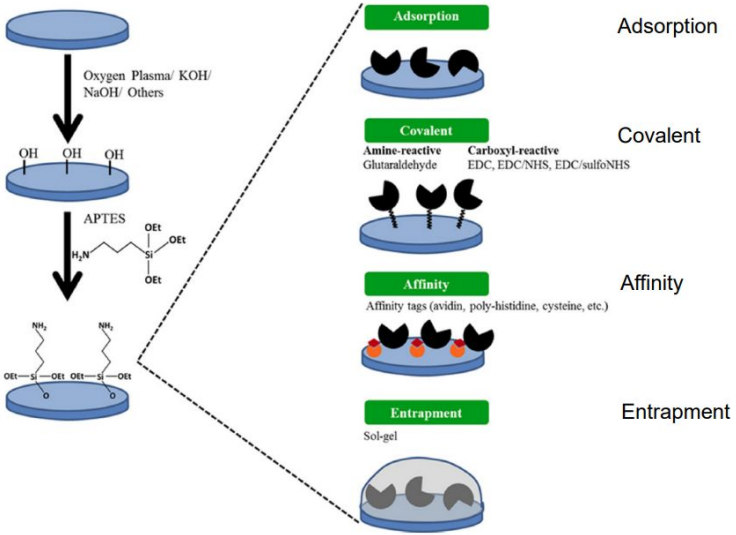
Bhagat, P.R., Pandey, A.K., Acharya, R. et al. Molecular iodine selective membrane for iodate determination in salt samples: chemical amplification and preconcentration. Anal Bioanal Chem 391, 1081–1089 (2008). https://doi.org/10.1007/s00216-008-2057-1

Analyte Sensing

Enzyme-based biosensing using **thyroid peroxidase**

- **Thyroid peroxidase** is a membrane-bound enzyme responsible for iodine oxidation.

→ Use **enzyme immobilization**



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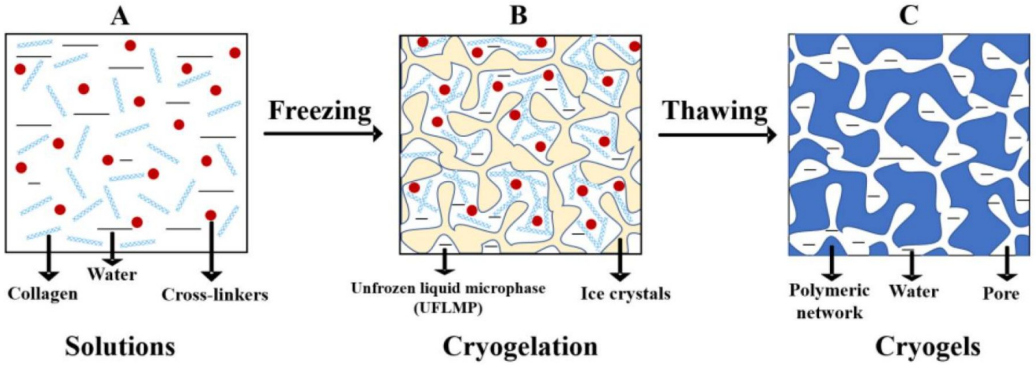
BioMEMS Concepts

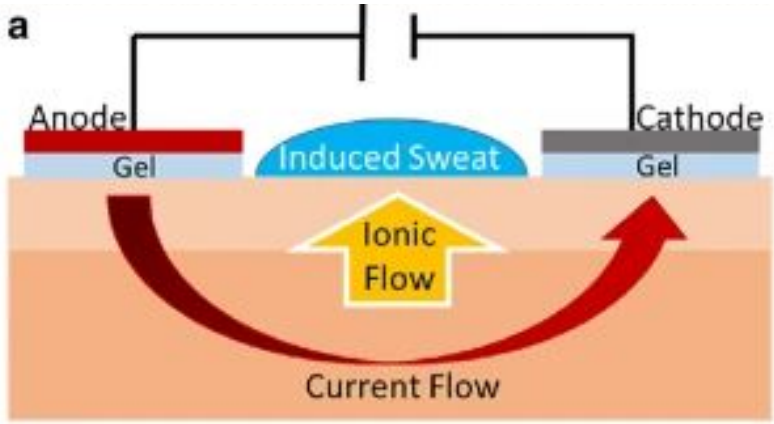
- Biosensors
  - Enzymes as biological recognition element
  - Ion-selective FET
  - Optimizing sensor selectivity and specificity
- Electrokinetics
  - Iontophoresis
- Microfabrication
  - Silicon processing
  - Reducing size for patient convenience

Fabrication

Cryogel Fabrication

- **Gelatin** used as precursor due to biocompatibility
- **Methacrylic anhydride** used as cross-linker





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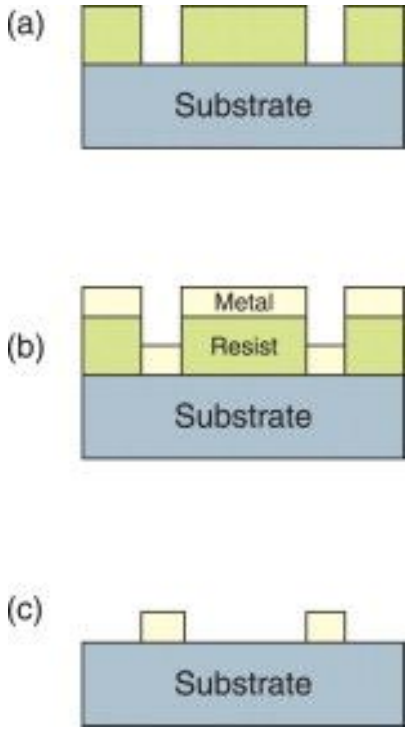
Electrode Fabrication

- Fabricated on **silicon** for flexibility
- Using **photolithography**
  - Negative resist
  - Good adhesion to silicon, lower cost, and a shorter processing time



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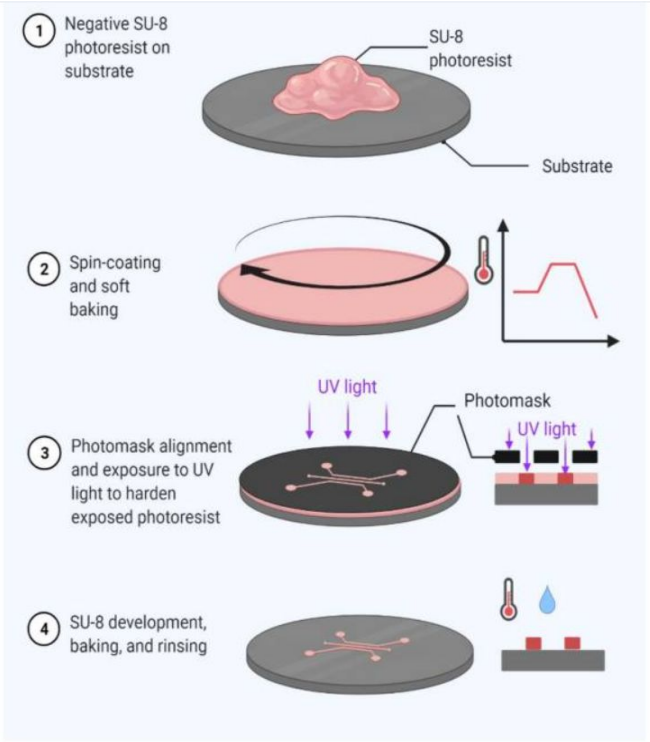
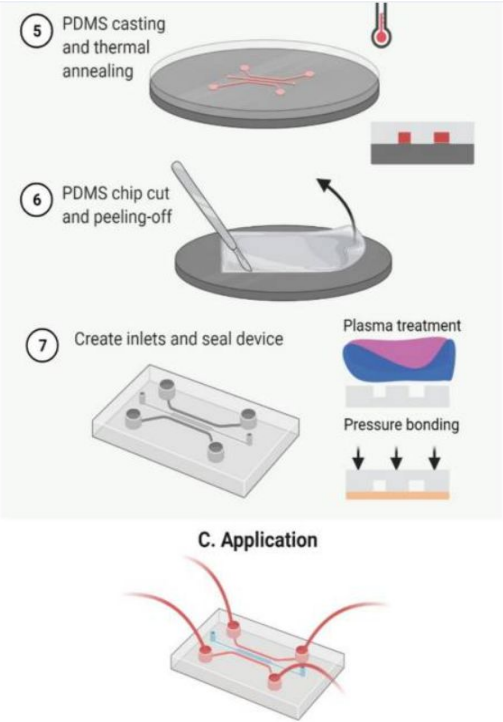
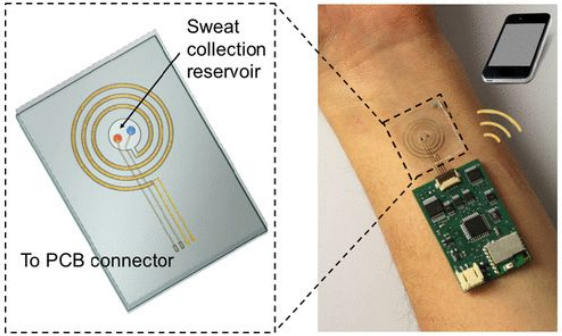
Reservoir Fabrication







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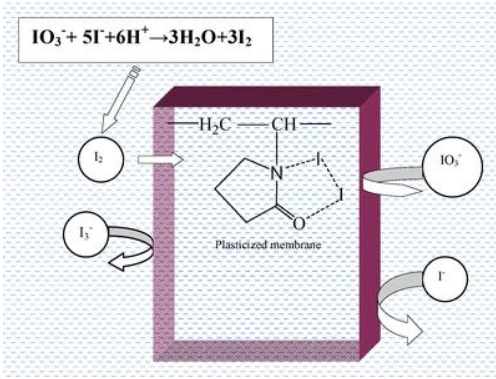
Selective Membrane Fabrication

1. **PVP-containing solution**
   a. Solution of cellulose triacetate (CTA) prepared by dissolving CTA and PVP in dichloromethane
2. **Plasticizer solution**
   a. DOP mixed with chloroform
3. **Casting solution** prepared by mixing the two solutions
4. **Ultrasonication** homogenizes the casting solution
   a. Resulting mixture spread on petri dish
5. **Evaporation** of chloroform and dichloromethane
6. **Membrane** peeled off petri dish and rinsed



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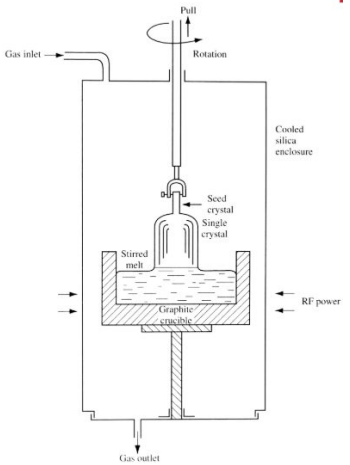
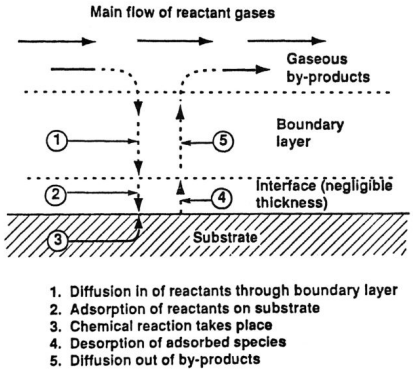
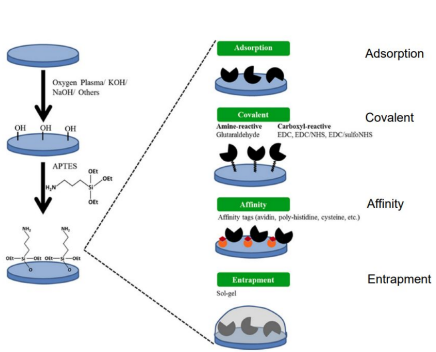
Analyte Biosensor Fabrication

1. **Silicon wafer** fabricated using **Czochralski method**
2. **SiO_2** layer formed on surface of wafer via **Chemical Vapor Deposition**
3. Wafer then soaked in **H_2SO_4** to add **hydroxyl groups** to SiO_2 surface
4. Wafer soaked in **APTES** solution to form **organic monolayer**
5. Organic monolayer tagged with **anti-thyroid antibodies** for binding of **thyroid peroxidase**







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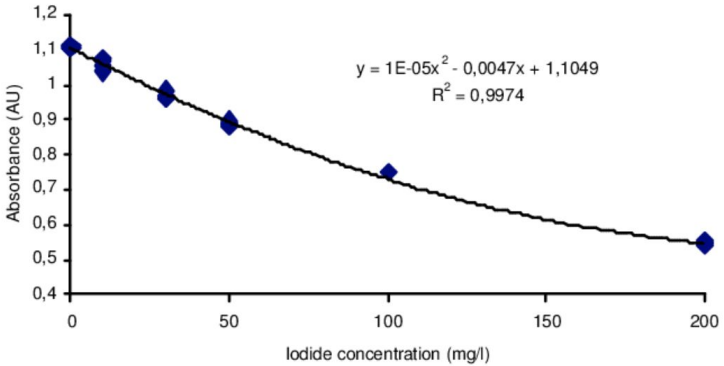
Analysis

Analysis

- Once **thyroid peroxidase** oxidizes iodine it produces an electrical signal
- Using a conventional ion-selective FET changes the gate metal potential
- Signal is transduced and sent via bluetooth to a processor
- Extensive testing to determine calibration curve



Example iodine concentration curve for Spectroscopy[6]

https://www.researchgate.net/figure/Calibration-curve-obtained-plotting-iodide-concentration-against-absorbance_fig4_120100836

Data Analytics

- Signal is analyzed and corresponding iodine concentration is shown in real time.
- Low iodine concentration ranges from **20-49 µg/L**[7]
- High iodine concentration ranges from **100-199 µg/L**[7]
- Overall low concentrations, changes do not need to be major
- To **increase** iodine
  - Consume natural products such as fish, dairy, or eggs[8]
- To **decrease** iodine
  - Avoid foods above

Device Design Benefits of Microbiopatch

- Active sweat stimulation (iontophoresis) provide a more consistent and reliable means of sweat collection for analysis
- Incorporating both active and passive methods enhancing its versatility
- Utilizing capillary force negates the needs for external pumps
- Ion-selective biosensing allows high sensitivity of ion detection

Overall Benefits of Microbiopatch

- Non-invasive, continuous monitoring
- Measure of thyroid function and sequentially metabolic function
- Personalized monitoring for athletes/pregnant women who require more specific regulation
- Integration with other wearable technology
- Compact design

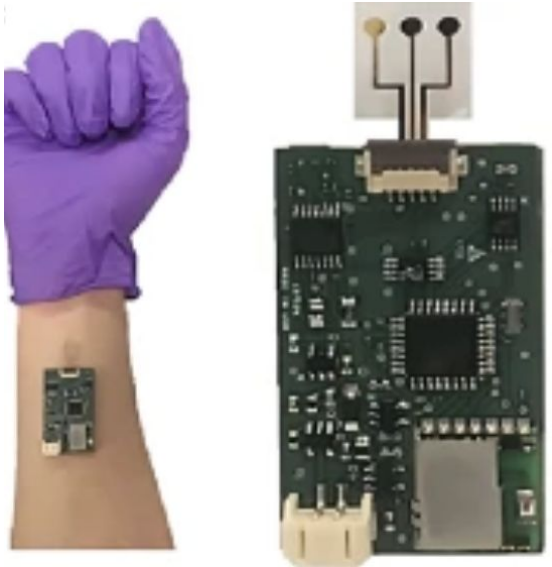


Figure highlighting small device size and noninvasive techniques.[1]

Limitations to Microbiopatch

- Environmental factors influence
- Adhesion issues
- Ion selective membrane durability
- Cost and accessibility
- Reduced clinical applicability for those with certain conditions
- Limited understanding of iodine as a biomarker o metabolism

Example of electrolyte hydration biosensor[9]

Thanks!

Any questions?

Sources

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