Simple Barcode System Based on Ionogels for Real Time pH-Sweat Monitoring

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Outlook

• SWEAT, WHY IS IMPORTANT?
• INTRODUCTION: WEARABLE CHEMICAL SENSORS
• IONOGELED: IONIC LIQUIDS (I.L.)
• BARCODE AND MICRO-FLUIDIC FABRICATION
• CHARACTERISATION OF THE DEVICE
• RESULTS
• CONCLUSIONS
Introduction

SWEAT, WHY IS IMPORTANT?

SWEAT IS NATURALLY GENERATED DURING EXERCISE, THUS THE POSSIBILITY OF MONITORING ITS CONTENTS PROVIDES VERY RICH INFORMATION ABOUT THE PHYSIOLOGICAL CONDITION OF THE INDIVIDUAL.

SWEAT ANALYSIS TO IDENTIFY PATHOLOGICAL DISORDERS:
  * CYSTIC FIBROSIS
  * INFORMATION ON DEHYDRATION
  * CHANGES IN THE CONCENTRATIONS OF BIOMOLECULES AND IONS

HYPONATREMIA (LOW SODIUM CONCENTRATION)

THIS INFORMATION CAN BE USED TO DETERMINE SUITABLE APPROACHES TO REHYDRATION AND RE-MINERALISATION WHICH IMPROVES PERFORMANCE AND GENERAL HEALTH.

*Common hereditary disease which affects the entire body, causing progressive disability and often early death
Introduction

WHY pH IN SWEAT?

\[ \text{pH} \]

- SWEAT RATE
- SODIUM CONCENTRATION
- DEHYDRATION
Introduction

PHYSIOLOGICAL SENSORS
Breath rate, heart rate, activity, posture, skin temperature…

NIKE-APPLE IPOD SPORTS KIT

LIFESHIRT®

TRAINTRAK™

SWEAT INTENSITY
Introduction

CHEMICAL SENSORS

NASA: WEARABLE SENSOR PATCHES

GLUCOWATCH

SWEAT COLLECTION PATCHES
Introduction

PROBLEMS TO OVERCOME WITH CHEMICAL SENSORS?

SAMPLE GENERATION

COLLECTION

DELIVERY

SENSOR CALIBRATION

WEARABILITY

SAFETY ISSUES

SWEAT RATE AND FLUID LOSSES VARY FOR INDIVIDUALS AND ARE GENERALLY DEPENDENT ON BODY SIZE, GENDER, EXERCISE INTENSITY, ENVIRONMENTAL CONDITIONS AND INDIVIDUAL METABOLISM.
Introduction

WHAT DO WE NEED????

DEVICE:

WEARABLE

ROBUST

FLEXIBLE / ADAPTABLE

REUSABLE/ DISPOSABLE → CHEAP

CONTINUOUS REAL TIME ANALYSIS → IMMEDIATE FEEDBACK

MICRO-DEVICES!!
DETECTION:

NOT INVASIVE

WIRELESS

FREEDOM FROM ELECTRICAL NOISE

MINIATURIZATION

NOT PHYSICAL CONTACT

FLEXIBILITY IN INTERROGATION APPROACHES
(HUMAN EYE, LED-SENSORS, CAMERAS, SPECTROMETERS, …)
Introduction

Emitter-detector LED’s $\lambda = 660$ nm

S. Coyle et al., IEEE Transactions on Information Technology in Biomedicine, VOL. 14, No. 2, MARCH 2010
Ionic Liquids

• THE GREEN CHEMISTRY MOVEMENT!

• THEY ARE LOW MELTING POINT SALTS (< 100 °C) THAT REPRESENT A NEW CLASS OF NON-AQUEOUS BUT POLAR SOLVENTS.

• COMPOSED OF IONS: CATIONS AND ANIONS.

• ‘DESIGNER SOLVENTS’ AS THEIR PROPERTIES CAN BE ADJUSTED TO SUIT THE REQUIREMENTS OF A PARTICULAR PROCESS.

• THE NUMBER OF PAPERS PUBLISHED IN 1995 WAS APPROXIMATELY 20 AND ROSE TO 2,500 IN 2006.

Ionic Liquids

Properties of ILs

- Highly polar
- Thermally stable
- Immiscible with many organic solvents
- No measurable vapour pressure
Characterisation

DOPING OF THE IONOGEL WITH THE pH-DYES
Fabrication

BOTTOM LAYER

125 μm  

TOP LAYER (lid)

PMMA

PSA layer (Channels)

CO₂ laser

80 μm

PSA layer

PMMA layer

CO₂ laser

80 μm

ionogel/Dyes

laminator

125 μm
Micro-fluidic: I.L.

1. Methyl Red
2. Bromocresol Green
3. Bromocresol Purple
4. Bromothymol Blue

pH

4.4 - 6.2
3.8 - 5.4
5.2 - 6.8
6.0 - 7.6

pH sensor ionogel
Channels
Adsorbent
Textile (Clothes, sweat band)
Characterisation

- Methyl Red
- Bromocresol green
- Bromocresol purple
- Bromothymol blue
Characterisation

OPTICAL DETECTION TECHNOLOGY

The optical detection set-up consists on:
A) laptop or wireless connection link
B) microcontroller (Lilypad Arduino)
C) black masking tape
D) surface mount $\mu$-LEDs light source
E) Surface mount photodiode: detector
F) barcode system

NOT INTEGRATED YET!!
CALIBRATION OF THE pH DYES

**Characterisation**

- **bromocresol green** (n= 3)
  - $pK_a \text{_lit.} = 4.6$
- **bromothymol blue** (n= 3)
  - $pK_a \text{_lit.} = 7.1$
Characterisation

MICROFLUIDIC SYSTEM PERFORMANCE

pH sensor ionogel

LOADING CAPACITY: 156 ± 3 μL

LIFE-TIME: 34 MINUTES

4.6 ± 0.2 μL min⁻¹

Sweat buffer with dye

Channels

Textile (Clothes, sweat band)

Skin

Adsorbent

Sweat flow direction

t = 0 min

t = 20 min

t = 40 min

t = 60 min
ON-BODY TRIALS

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Colour profile of each of the indicators at different pH’s (pH range: 3-8)

Picture of the back of a trainer with a micro-device (1) and barcode (2) systems (activated at pH 2)
Conclusions

- THE FABRICATION, CHARACTERIZATION AND THE PERFORMANCE OF WEARABLE MICRO-FLUIDIC SYSTEMS BASED ON TEXTILES AND IONIC LIQUID POLYMER GELS (IONOGELS) FOR MONITORING IN REAL TIME MODE THE pH OF THE SWEAT GENERATED DURING AN EXERCISE PERIOD HAS BEEN PRESENTED.

- THE IONOGEL-DYE INTERACTIONS ENSURE NO LEACHING OF THE DYES DURING EXPERIMENTS, PROVIDING LONG DURABILITY OF THE DEVICE AND ACCURACY ON THE pH OF SWEAT MEASUREMENTS OVER TIME.

- THIS APPROACH PROVIDES IMMEDIATE FEEDBACK REGARDING SWEAT COMPOSITION, pH, TO INDIVIDUALS DURING EXERCISE PERIOD.

- THIS CAN BE MEASURED BY EYE, VIDEO ANALYSIS OR BY OPTICAL SENSING COMPONENTS CONTROLLED BY A WIRELESS MICRO-CONTROLLER.
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QUESTIONS???