“My Sweat my Health” Real Time Sweat Analysis Using Wearable Micro-fluidic Devices

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Outlook

- Sweat, Why is Important?
- Introduction: Wearable Chemical Sensors
- SWEAT SENSOR BASED ON IONIC LIQUIDS
  - Fabrication of the device
  - Characterisation of the Device
  - Results
- SWEAT SENSOR BASED ON A TEXTILE
  - Fabrication of the device
  - Characterisation of the Device
  - Results
- Conclusions

Introduction



SWEAT, WHY IS IMPORTANT?

Sweat is naturally generated during exercise.

Monitoring its contents provides very rich information about the physiological condition of the individual.



Rehydration and re-mineralisation

↓

Improve performance and general health



Sweat analysis: identify pathological disorders

* **cystic fibrosis***
* **information on dehydration**
* **changes in the concentration of biomolecules and ions.**
  hyponatremia (low sodium concentration)

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

Introduction

PHYSIOLOGICAL SENSORS

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



LIFESHIRT®

TRAINTRAK™

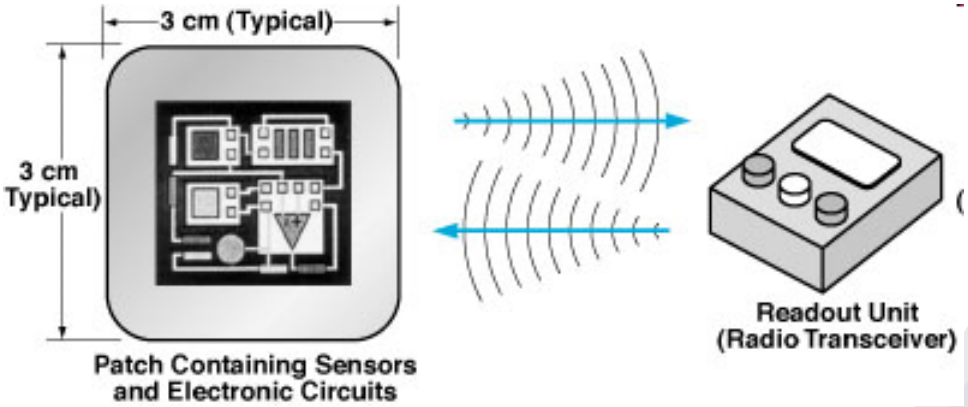




NIKE-APPLE IPOD SPORTS KIT

Introduction

CHEMICAL SENSORS





GLUCOWATCH

NASA: WEARABLE SENSOR PATCHES



PharmChek Sweat Patch

SWEAT COLLECTION PATCHES

NCSR
National Centre for Sensor Research

CLARITY
clarity-centre.org

Current Ways of Sweat Collection and analysis







S. M. Shirreffs and R. J. Maughan, J Appl Physiol 82: 336-341, 1997

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!!

Introduction

DETECTION:

NOT INVASIVE

WIRELESS

FREEDOM FROM ELECTRICAL NOISE

MINIATURIZATION

NOT PHYSICAL CONTACT

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

OPTICAL SENSORS!!

Introduction





NEW GENERATION OF MICROFLUIDIC DEVICES

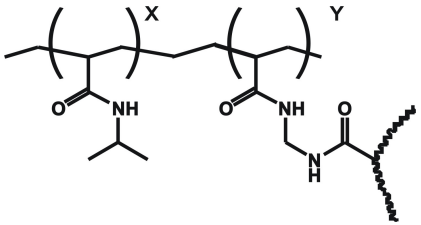
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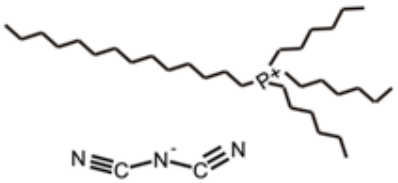
ADVANCES IN FUNDAMENTAL MATERIAL SCIENCE

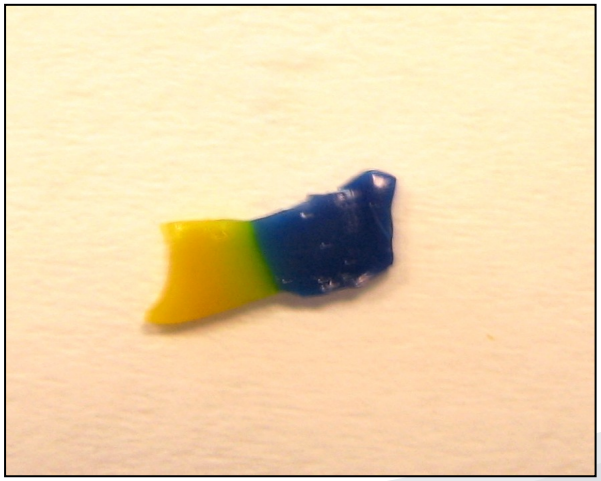




Chemical Sensor







Stable after 20 cycles



BASE

ACID

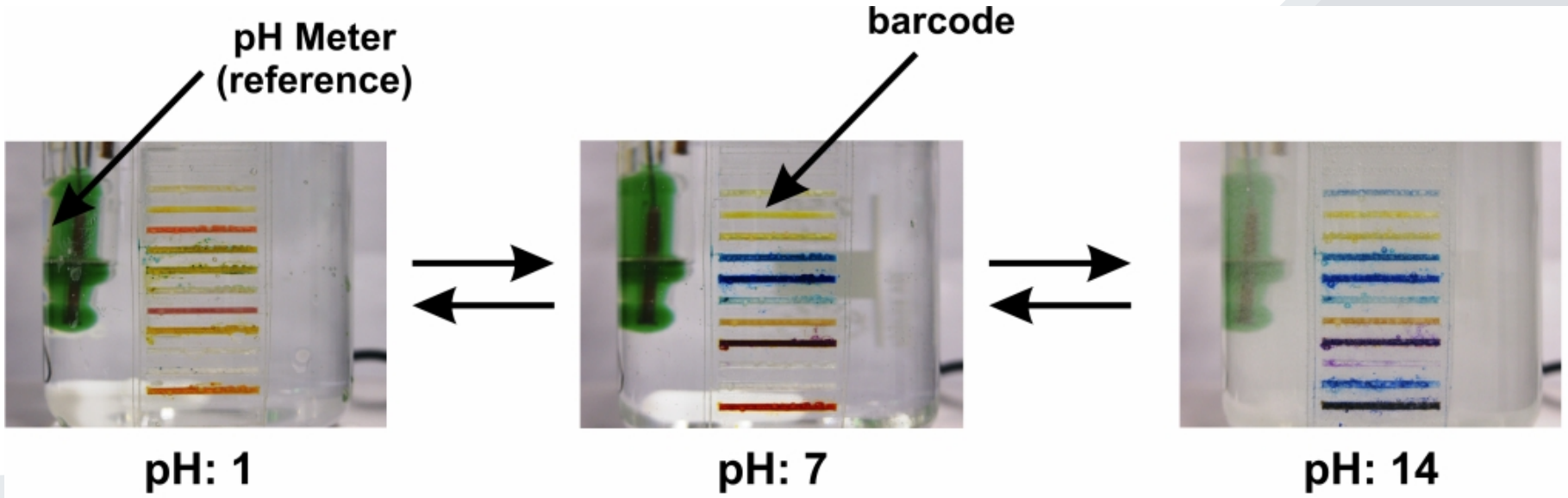


F. Benito-Lopez, et al. Pittcon Conference-2010, Orlando, Florida, USA, 28 March - 5 March, 2010. 610-3P.

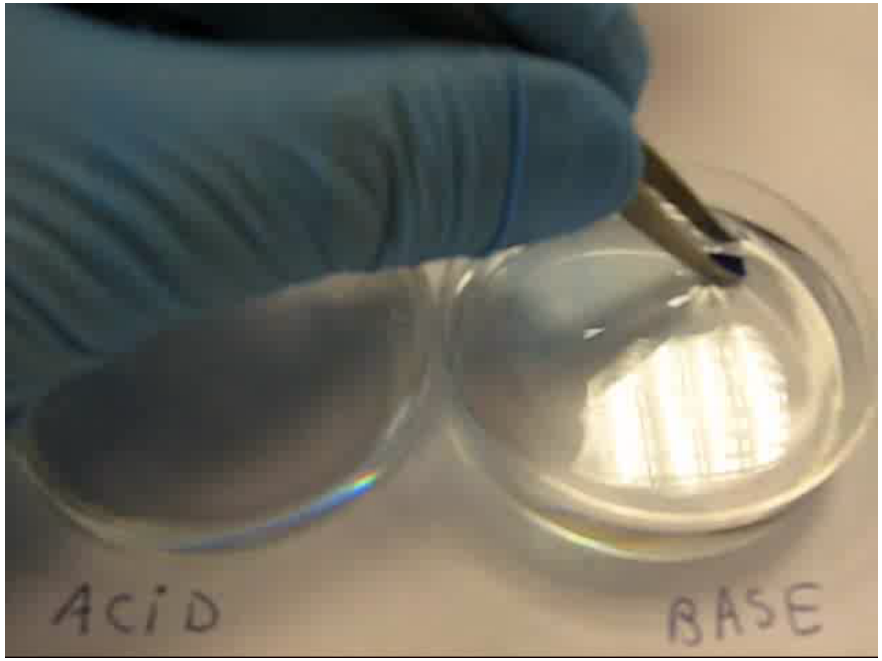
Chemical Sensor

CHEAP
EASY TO FABRICATE
NO CHEMICAL MODIFICATION
NO LEACHING

→ **UNIVERSAL**
REUSABLE
LONG TERM DURATION
MASS PRODUCTION



Chemical Sensor





HOSPITAL TRIALS

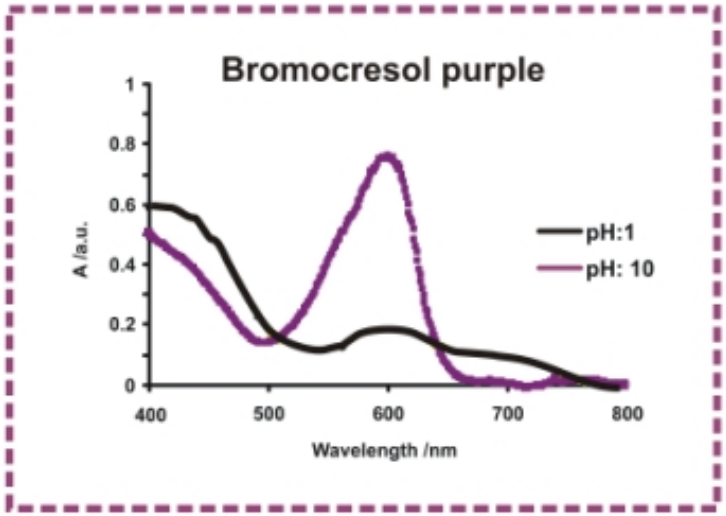
SPORTS APPLICATIONS

Sensor Characterisation

DOPE THE IONOGEL WITH A pH-DYE

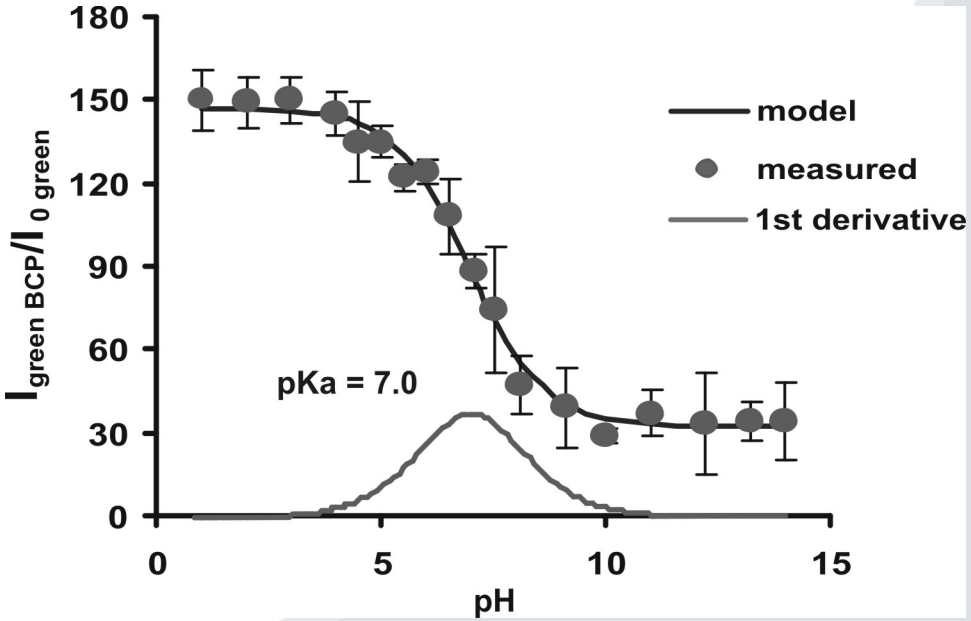
Sweat pH: 4.5-7.5

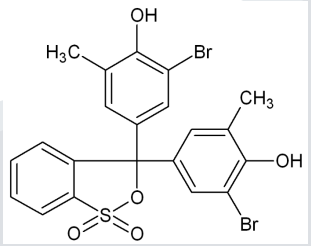
	pH
1- METHYL RED	4.4 - 6.2
2- BROMOCRESOL GREEN	3.8 - 5.4
3- BROMOCRESOL PURPLE	5.2 - 6.8
4- BROMOTHYMOL BLUE	6.0 - 7.6



DYES DO NOT LEACH OUT

DIGITAL CAMERA PHOTO
RGB-MATLAB





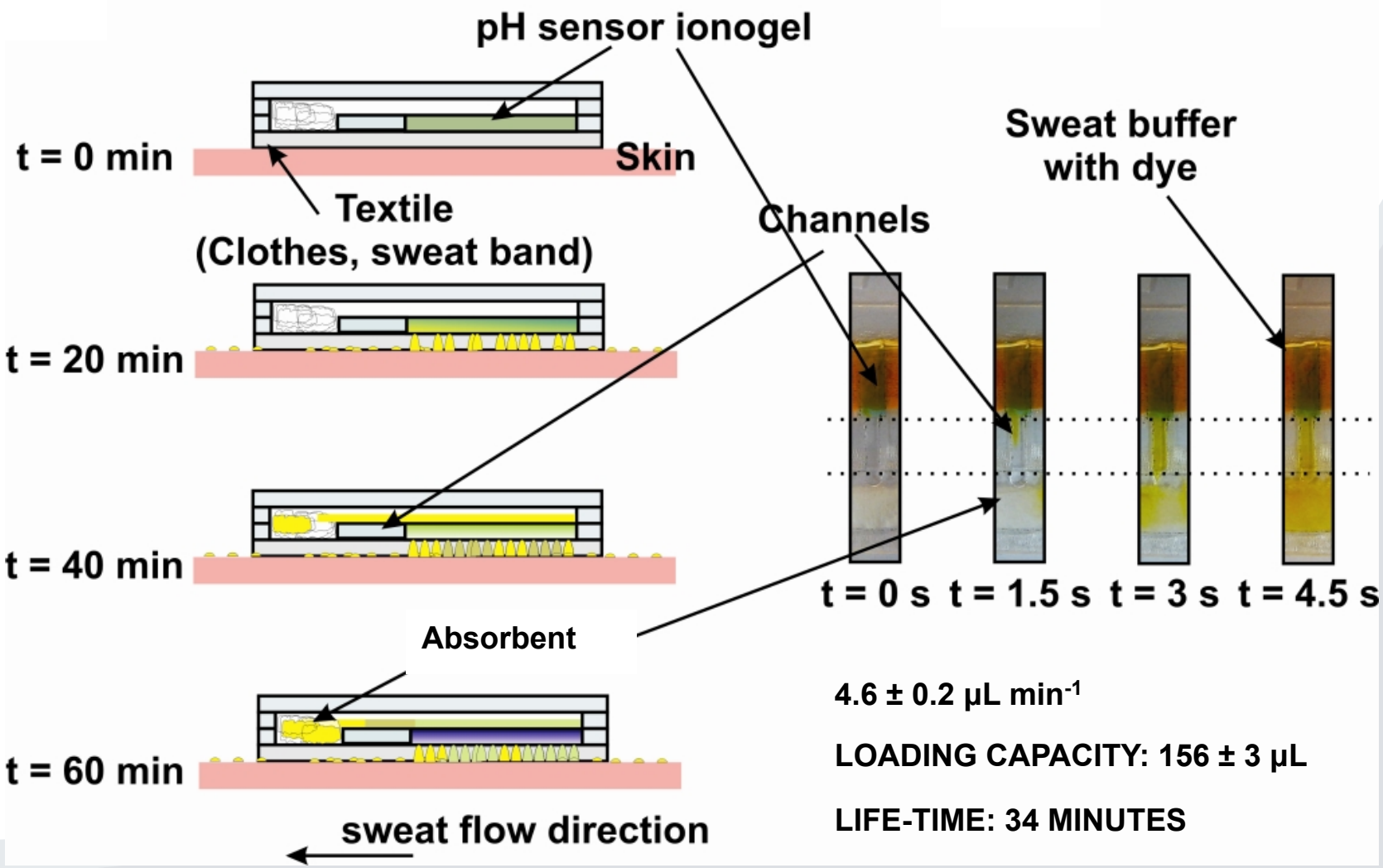
$pKa_{lit.} = 7.1$

OPTICAL DETECTION

F. Benito-Lopez, R. Byrne, D. Diamond, Dublin City University, 2009, Patent Application No: GB 0904627-7.

Chip Characterisation

MICRO-FLUIDIC SYSTEM PERFORMANCE



4.6 ± 0.2 µL min^{-1}

LOADING CAPACITY: 156 ± 3 µL

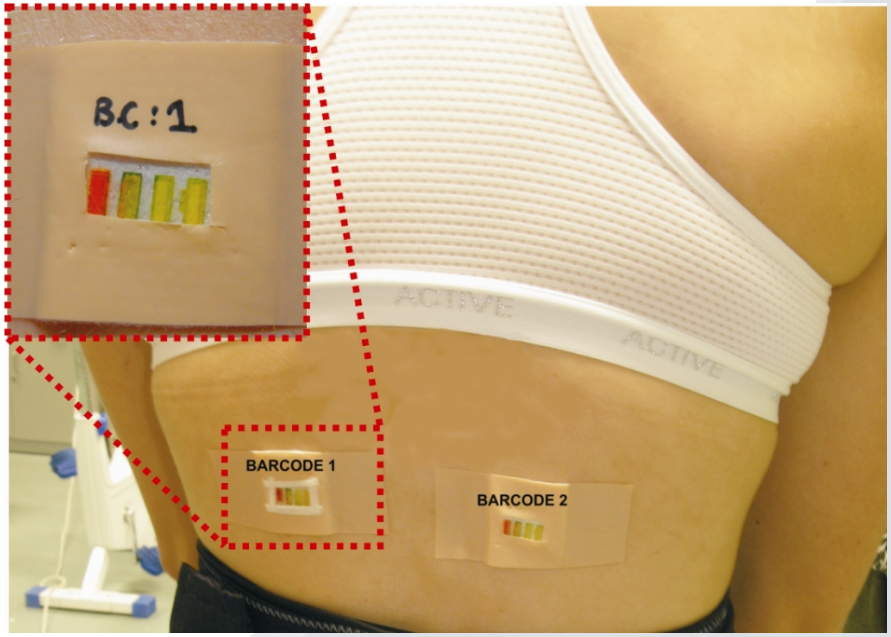
LIFE-TIME: 34 MINUTES

Chip Characterisation

Colour profile of each of the indicators at different pH's (pH range: 1-14)

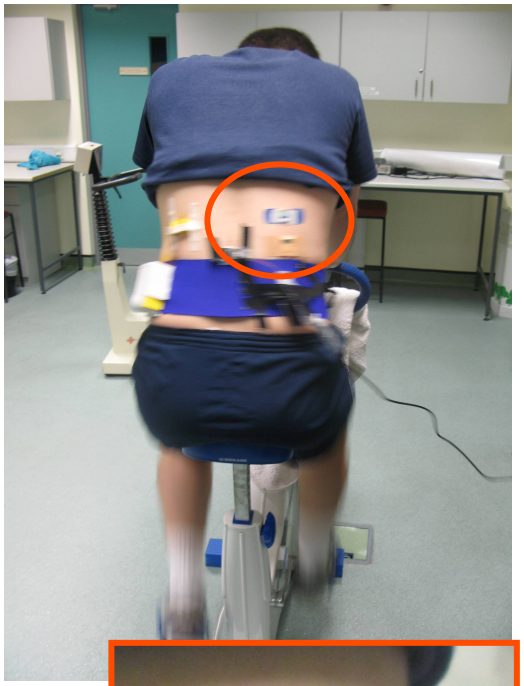


ON-BODY TRIALS

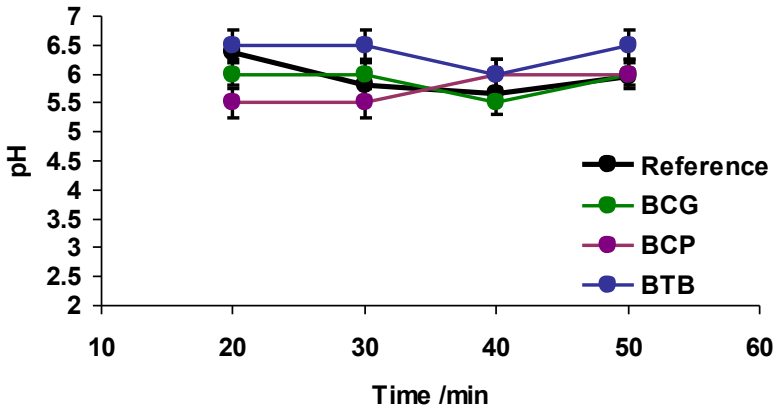


Back of a trainer with a chip (1) and barcode (2) systems (activated at pH 2)

Results

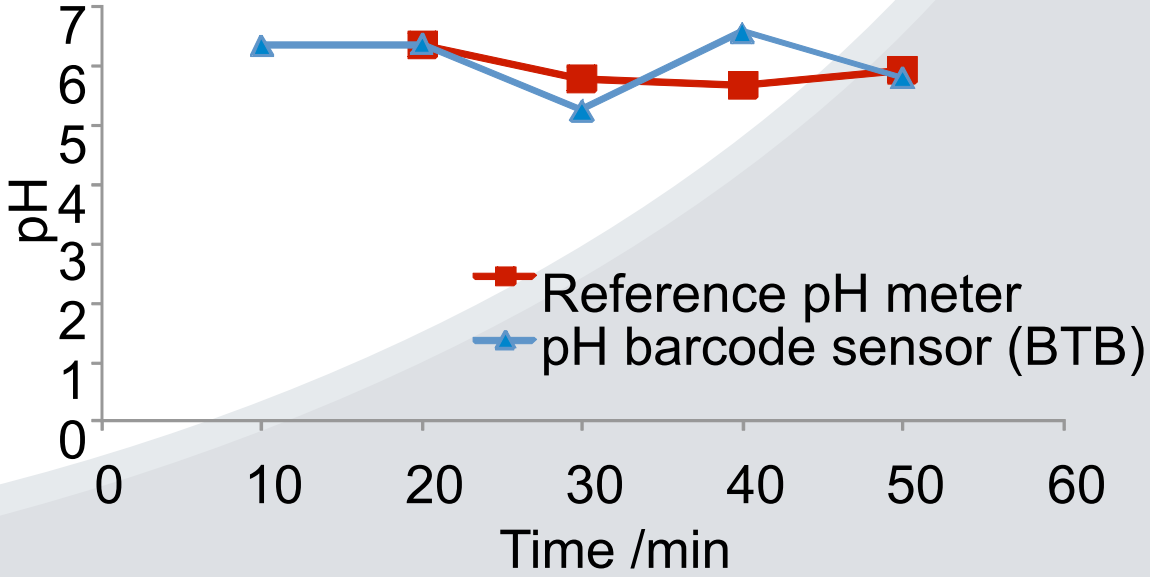






Camera pictures and RGB colour analysis using a reference

Sweat pH determination using the barcode in an athlete during a 50 min training period



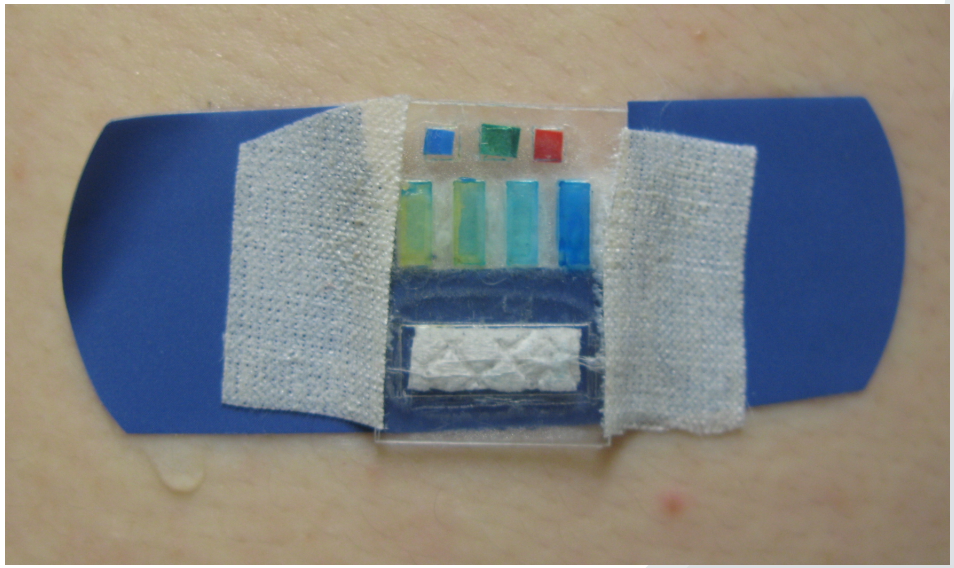
S. Coyle, T. Radu, F. Benito-Lopez, K.-T. Lau, D. Diamond, Res. J. Text. Apparel. 2010. *Accepted.*

Integration

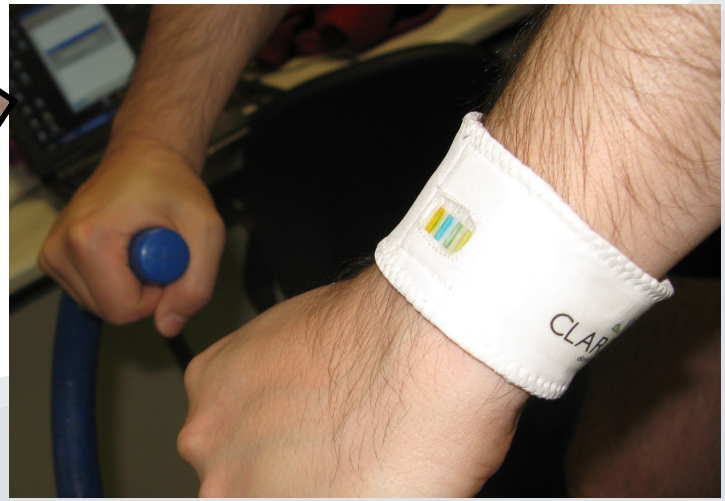




ECG electrode



Adhesive Plaster



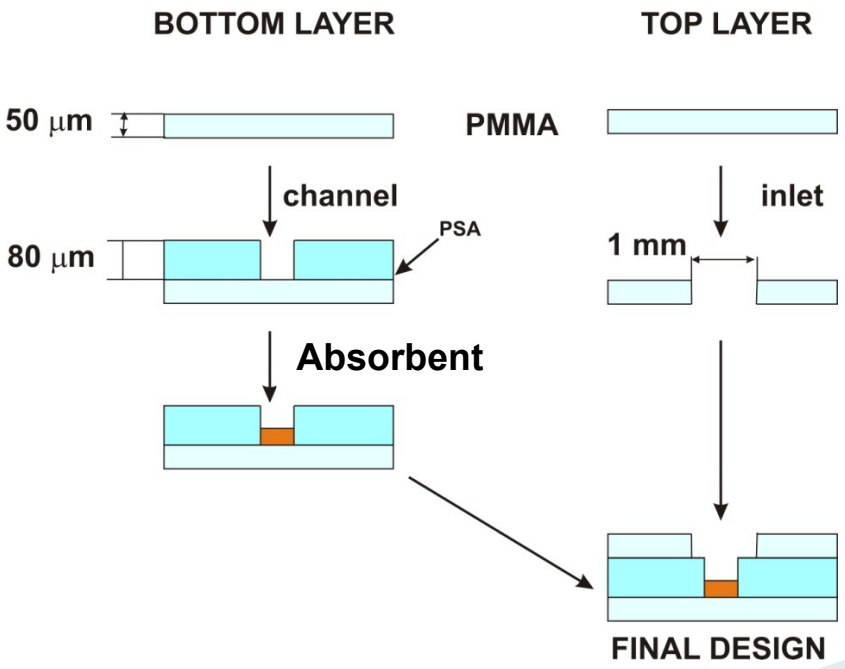
Sweat band

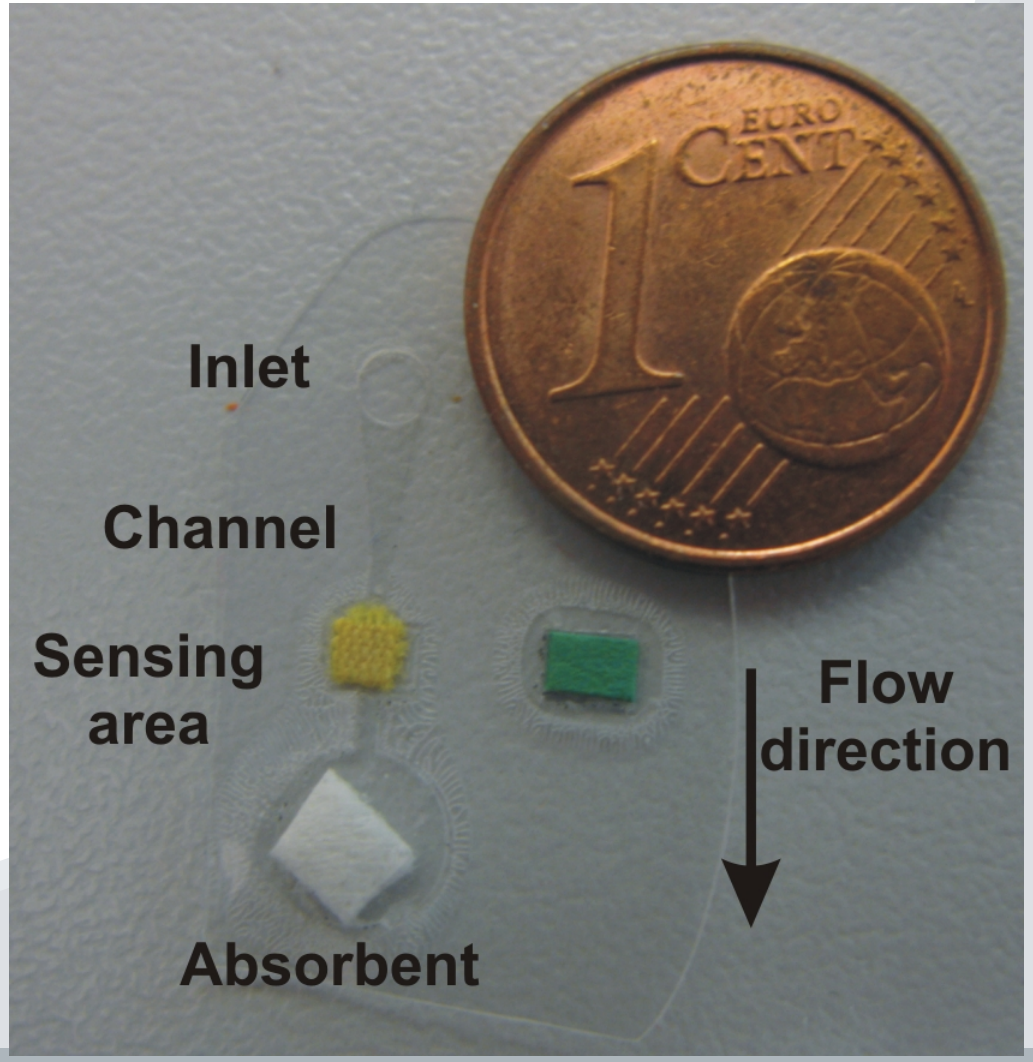
Athletes' Sweat Test Road to Glory. New Scientist, 27 April, 2010.

Textile Chip Fabrication

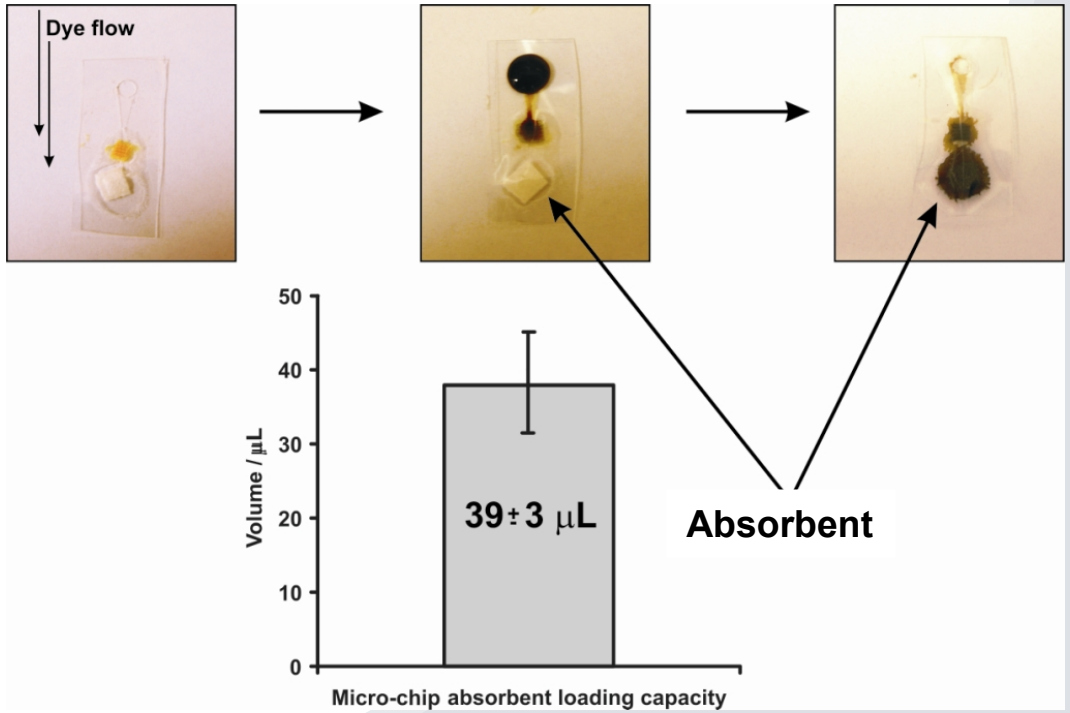
MICRO-FLUIDIC DEVICE

FABRICATION

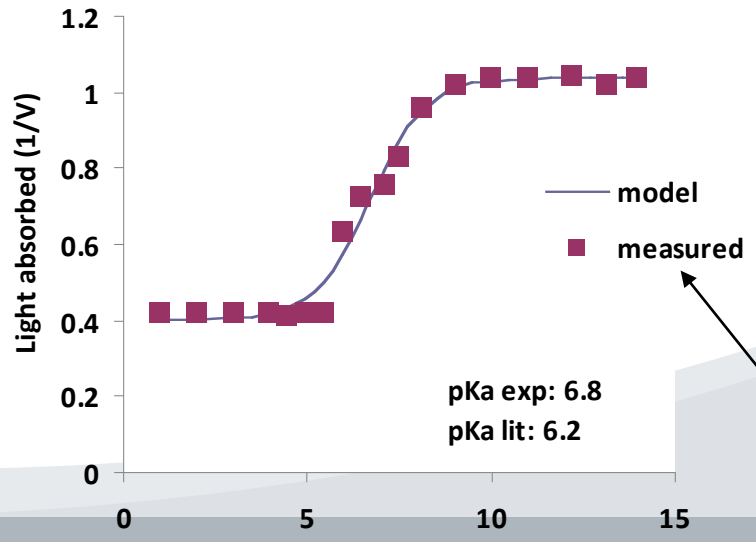




Characterisation



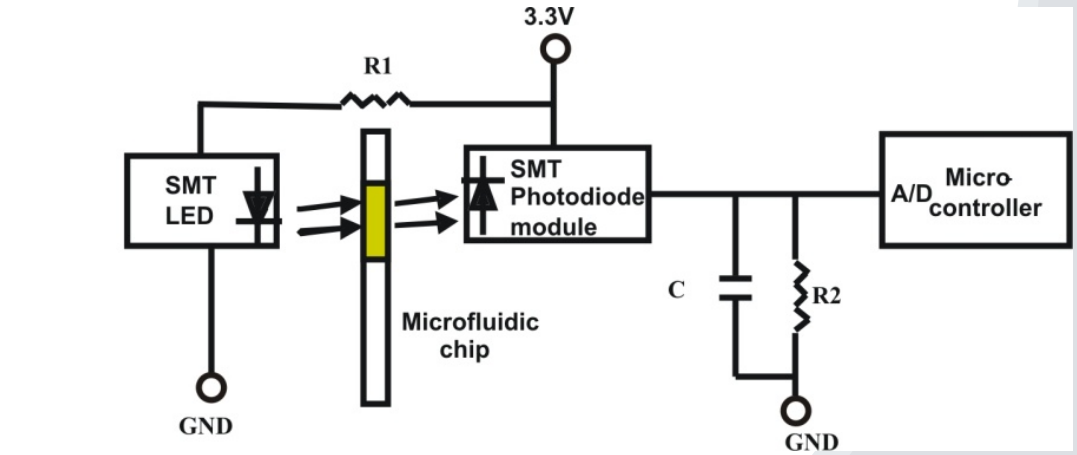
Loading capacity of the absorbent



pKa determination of Bromocresol purple in the chip

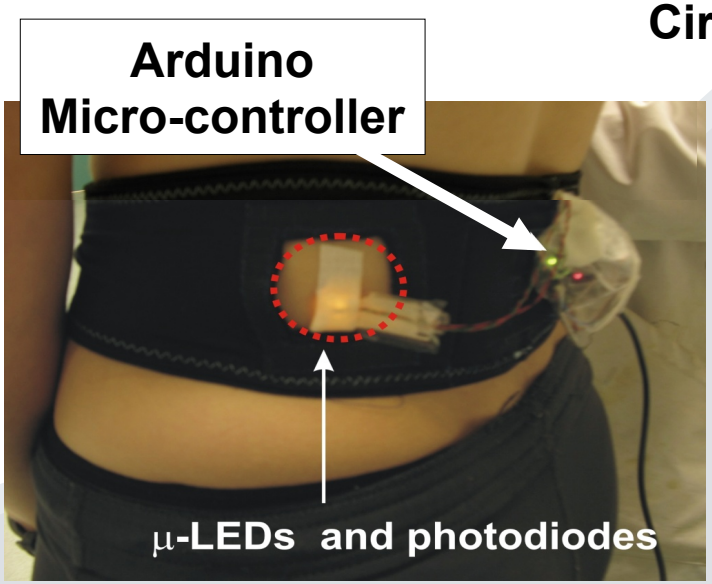
Performance





Yellow LED 590 nm

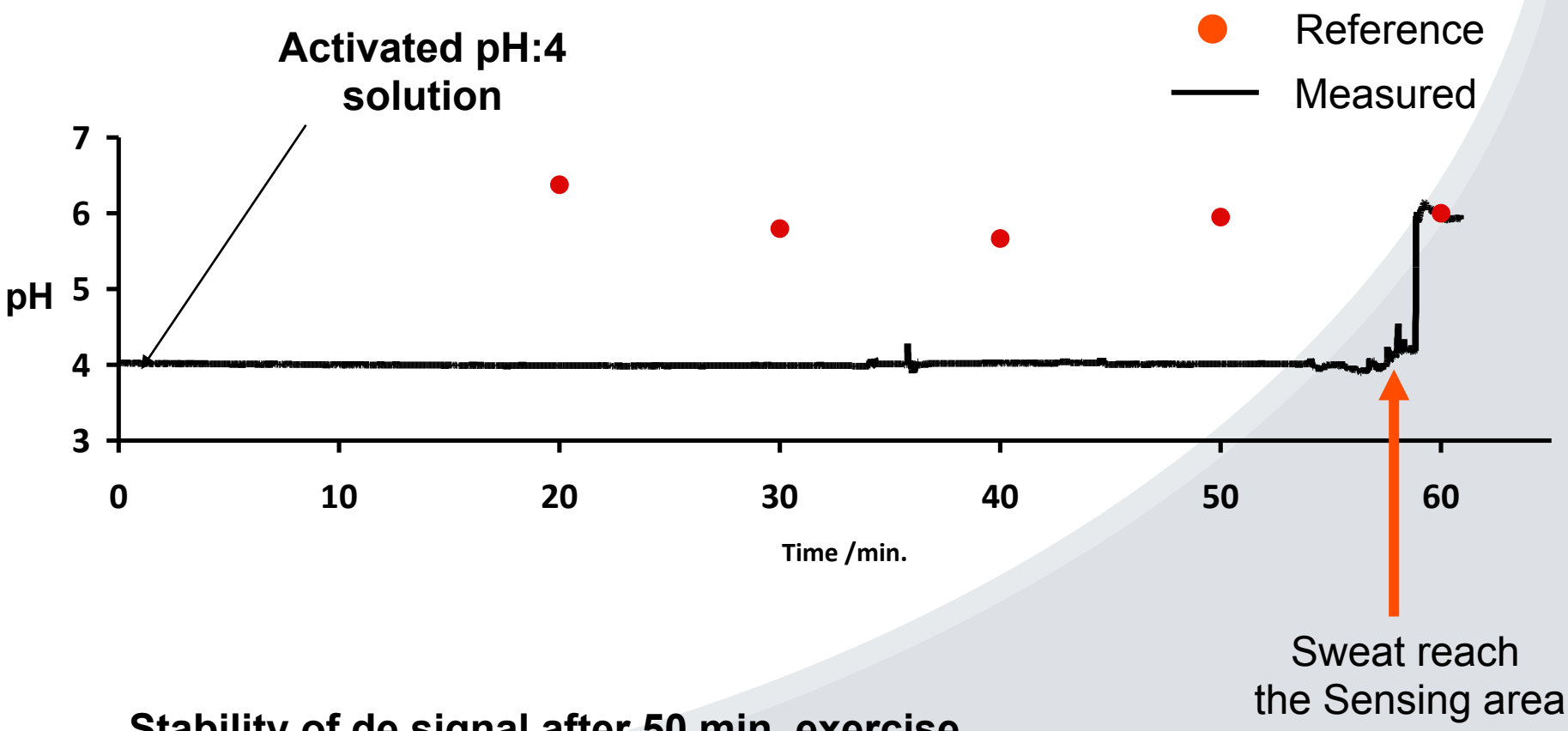
Circuit diagram



Possible wireless connection by attaching a Bluetooth® modem

LEDs stability

RESULTS



Stability of de signal after 50 min. exercise.
LED alignment is not perturbed with athlete movement

Conclusions

- THE FABRICATION, CHARACTERISATION AND THE PERFORMANCE OF WEARABLE MICRO-FLUIDIC SYSTEMS BASED ON IONIC LIQUIDS AND A TEXTILE FABRIS FOR MONITORING IN REAL TIME MODE THE pH OF THE SWEAT GENERATED DURING AN EXERCISE PERIOD HAS BEEN PRESENTED.

- SINGLE USE DEVICES, CHEAP AND EASY FABRICATION PROTOCOLS: MASS PRODUCTION.

- DURABILITY OF THE DEVICE DURING EXCERSICE PERIOD.

- ACCURACY ON THE pH OF SWEAT MEASUREMENTS OVER TIME.

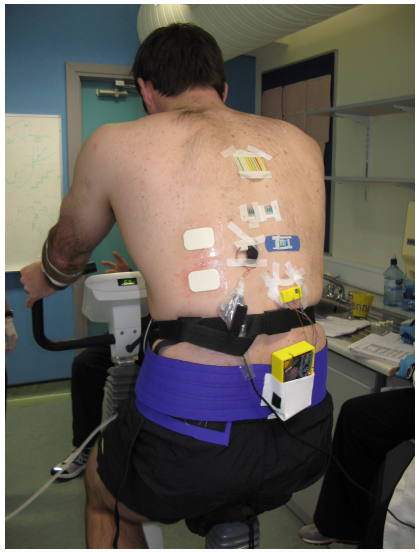
- IMMEDIATE FEEDBACK REGARDING SWEAT COMPOSITION, pH, TO INDIVIDUALS DURING EXERCISE PERIOD.

- INTERROGATION: VISUAL, RGB COLOUR ANALYSIS AND OPTICAL SENSING COMPONENTS CONTROLLED BY A WIRELESS MICRO-CONTROLLER ARE USED.

Thanks to…..

CLARITY
clarity-centre.org

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NCSR
National Centre for Sensor Research

SARAH HUGHES

Prof. NIALL MOYNA

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QUESTIONS?