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Microfluidics: New Tools in Sport Science

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25th May 2010

Outlook

- **SWEAT, WHY IS IMPORTANT?**
- **INTRODUCTION: WEARABLE SENSORS**
- **MICRO-FLUIDIC BASED ON TEXTILES**
- **MICRO-FLUIDIC BASED ON IONIC LIQUIDS (*I.L.*)**
- **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.

Introduction

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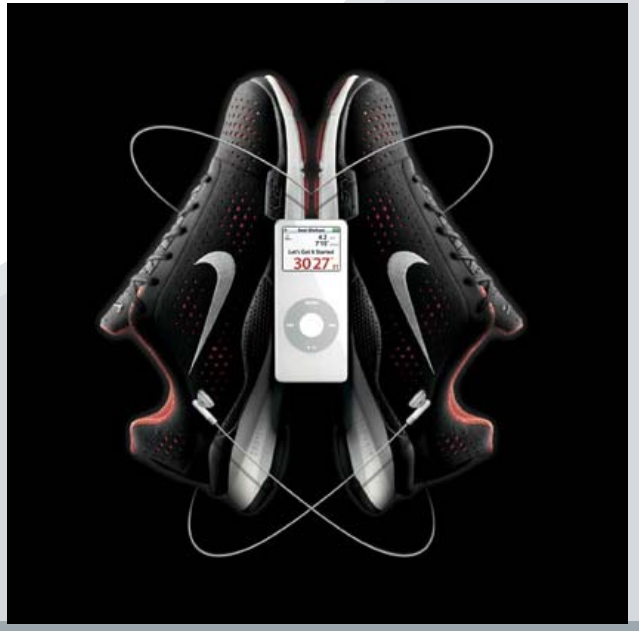
PHYSICAL PROPERTIES

LIFESHIRT®

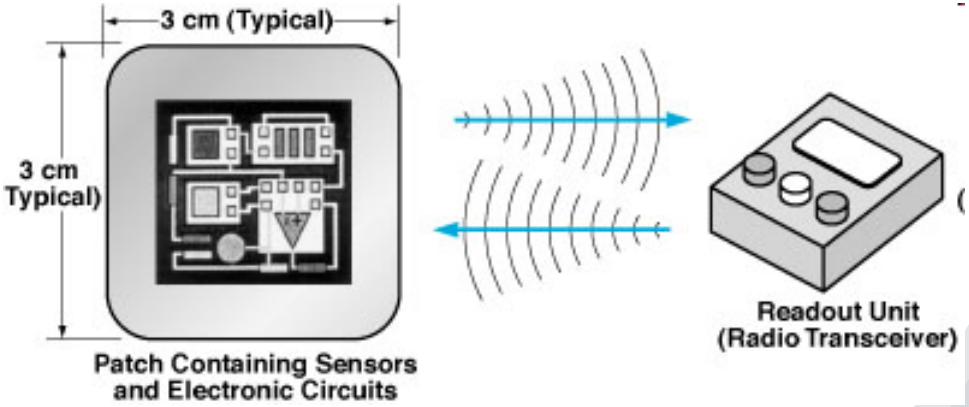
VIVOMETRIX®

NIKE-APPLE IPOD SPORTS KIT

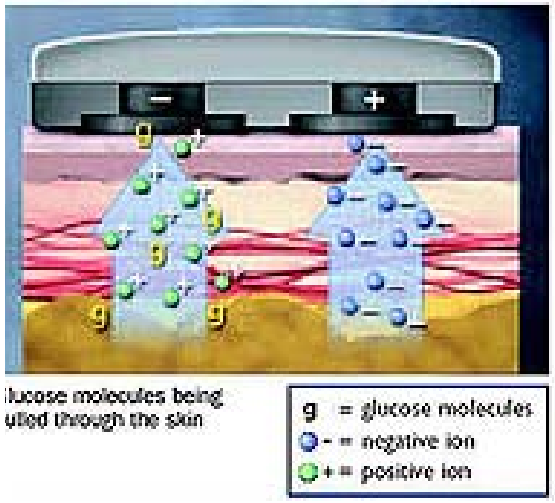


SWEAT INTENSITY

Introduction



NASA: WEARABLE SENSOR PATCHES FOR PHYSIOLOGICAL MONITORING



GLUCOWATCH

SWEAT COLLECTION PATCHES

Introduction

PROBLEMS TO OVERCOME WITH CHEMICAL SENSOR?

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????

<u>DEVICE</u>:

WEARABLE

ROBUST

FLEXIBLE / ADAPTABLE

REUSABLE/ DISPOSABLE → **CHEAP**

CONTINUOUS REAL TIME ANALYSIS → **IMMEDIATE FEEDBACK**

MICRO-DEVICES!!

Introduction

DETECTION:

NOT INVASIVE

OPTICAL SENSORS!!

WIRELESS

FREEDOM FROM ELECTRICAL NOISE

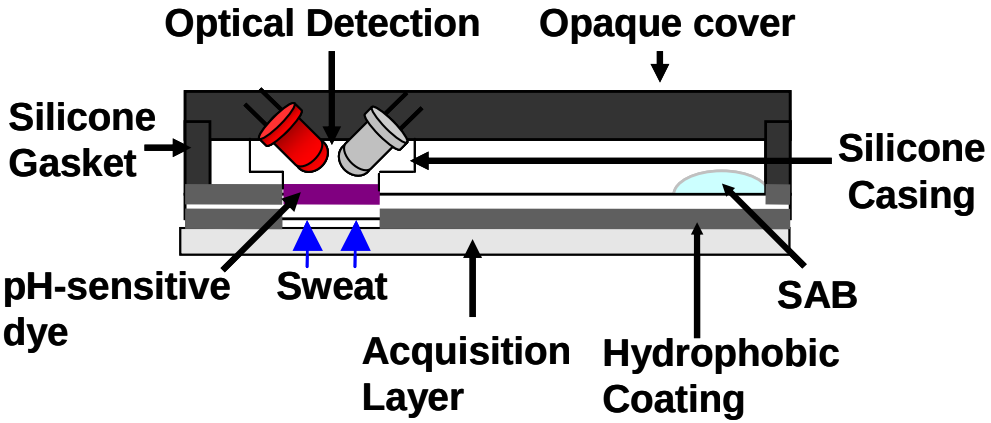
MINIATURIZATION

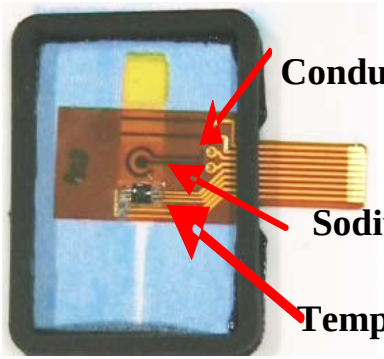
NOT PHYSICAL CONTACT

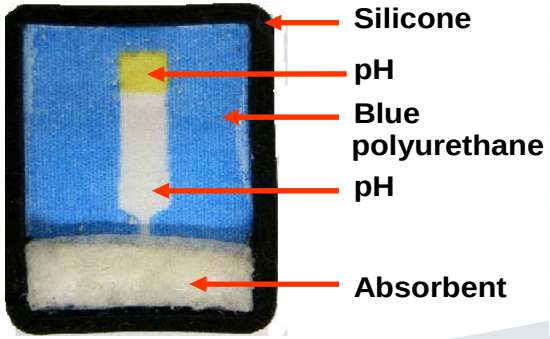
FLEXIBILITY IN INTERROGATION APPROACHES
(HUMAN EYE, LED-SENSORS, CAMERAS, SPECTROMETERS, …)

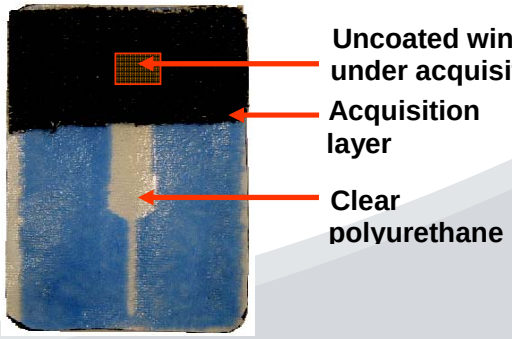
Introduction

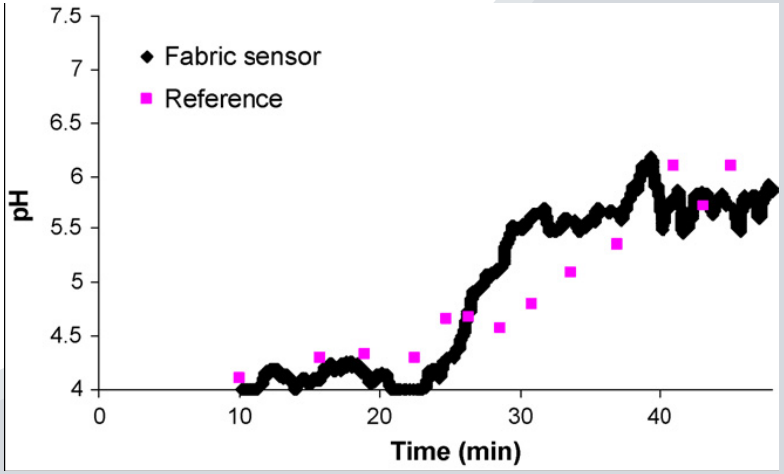
Emitter-detector LED's λ = 660 nm









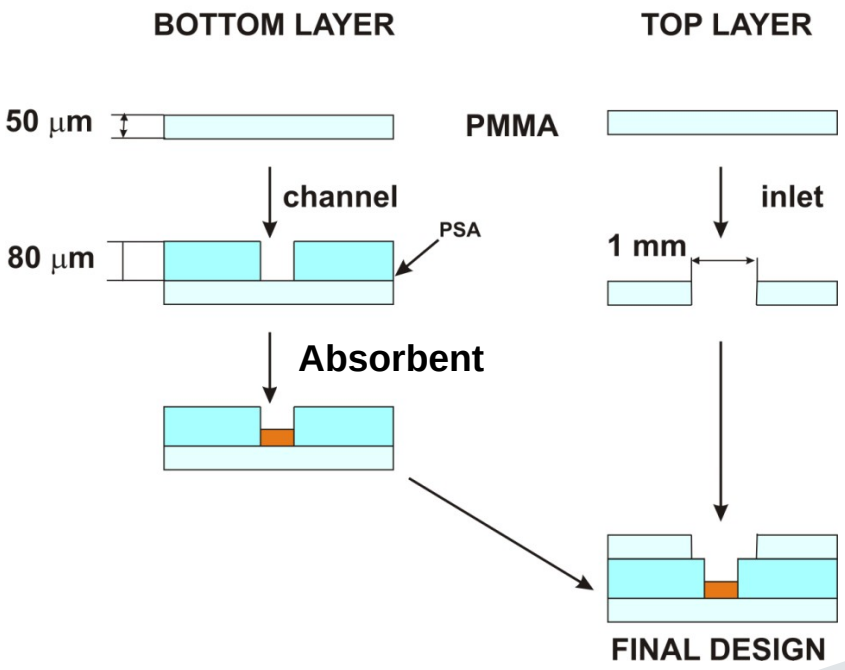


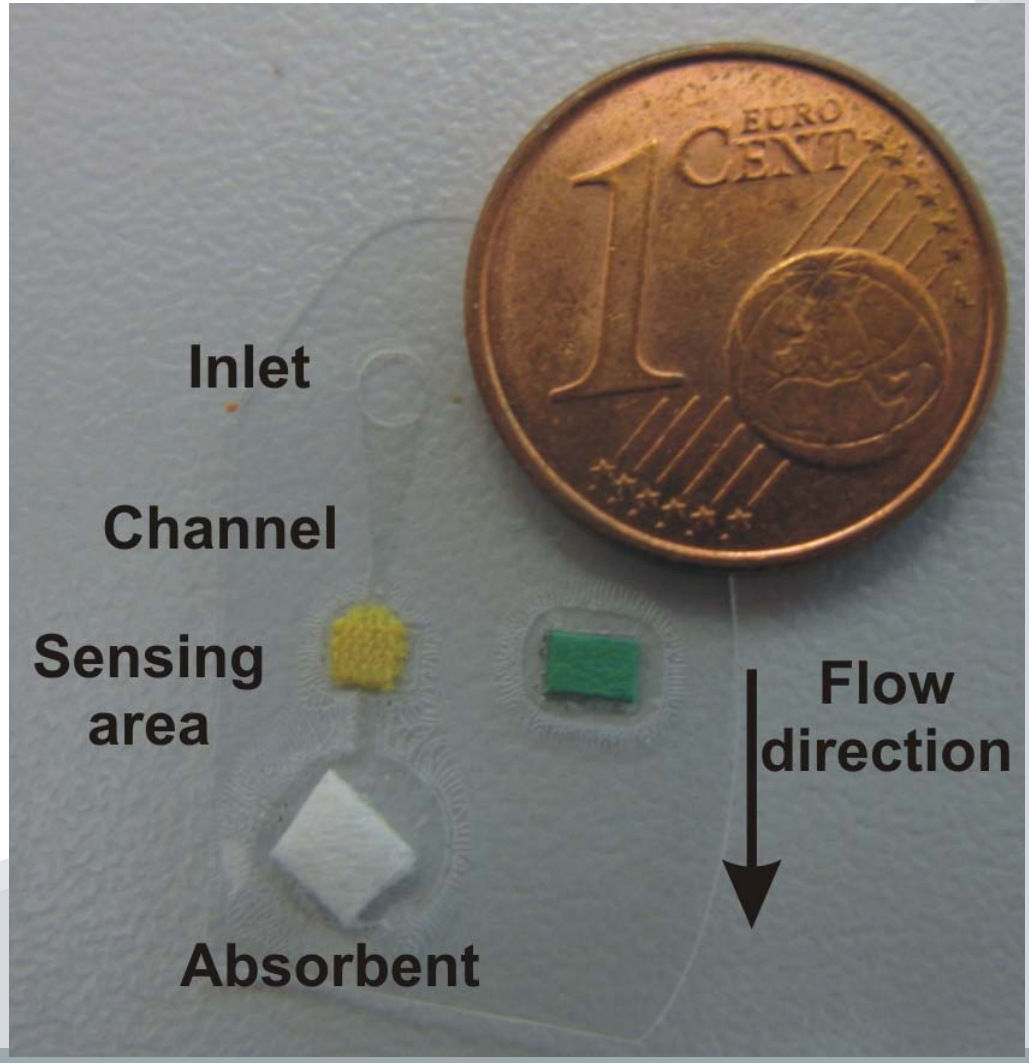
S. Coyle, IEEE Transactions on Information Technology In Biomedicine, VOL. 14, No. 2, MARCH 2010

Micro-fluidic: Textiles

MICRO-FLUIDIC DEVICE

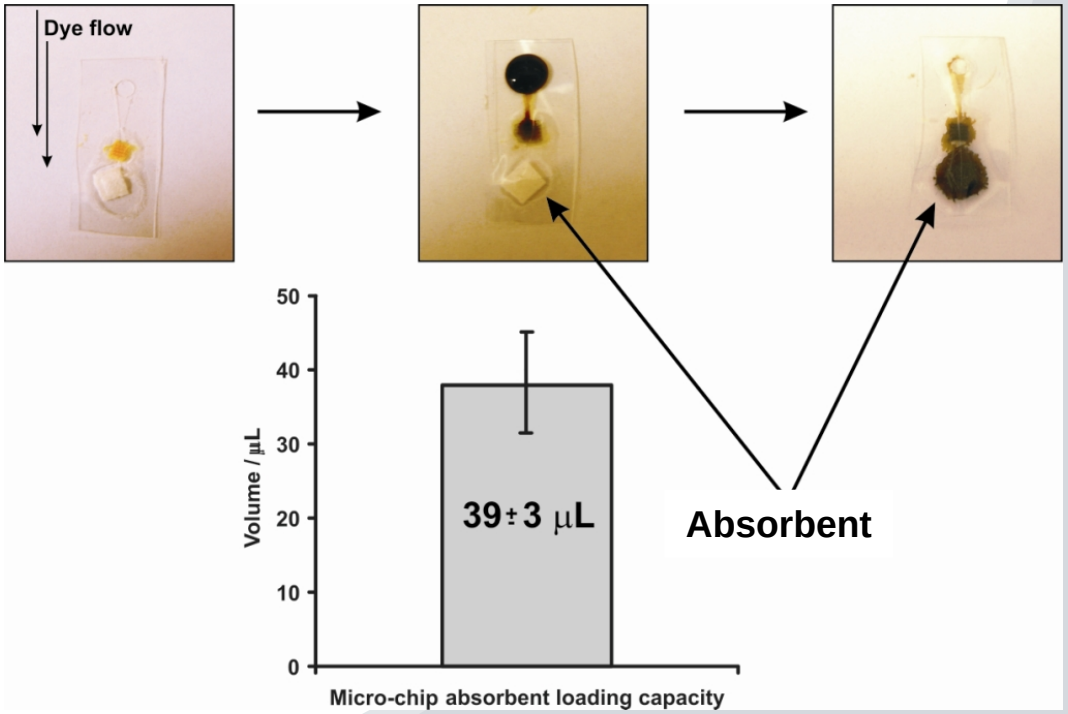
FABRICATION



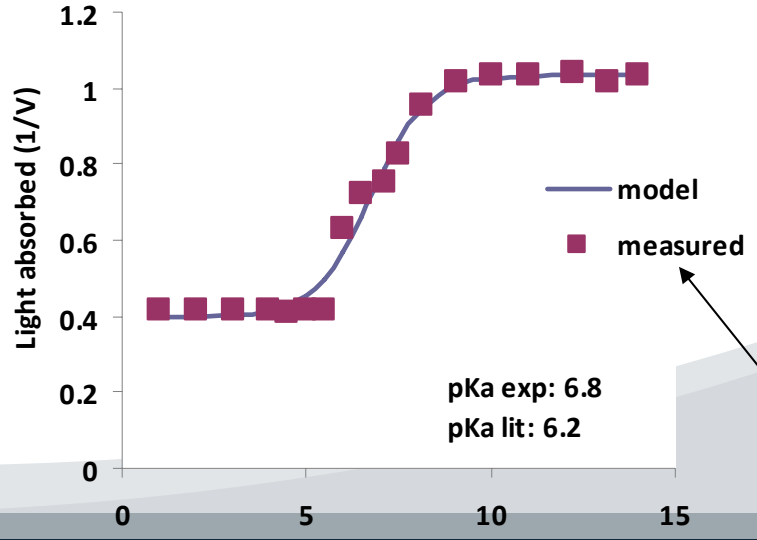


Micro-fluidic: Textiles

CHARACTERISATION



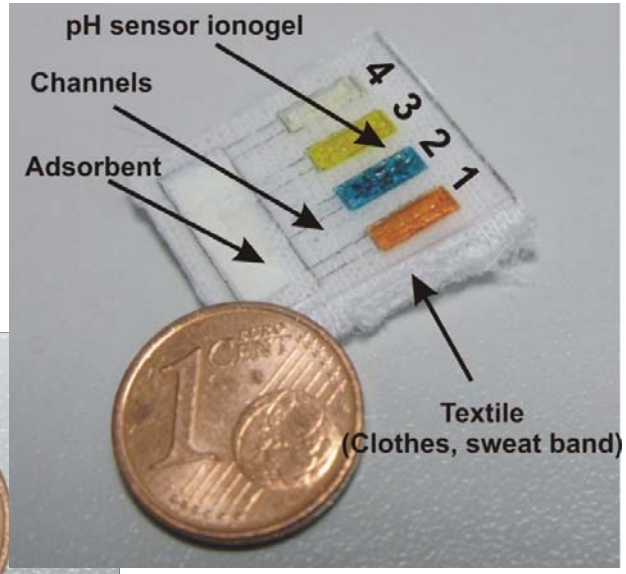
Loading capacity of the absorbent

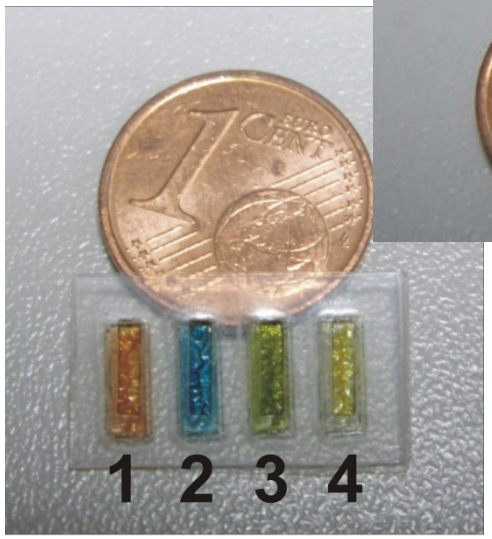


pKa determination of Bromocresol purple in the chip

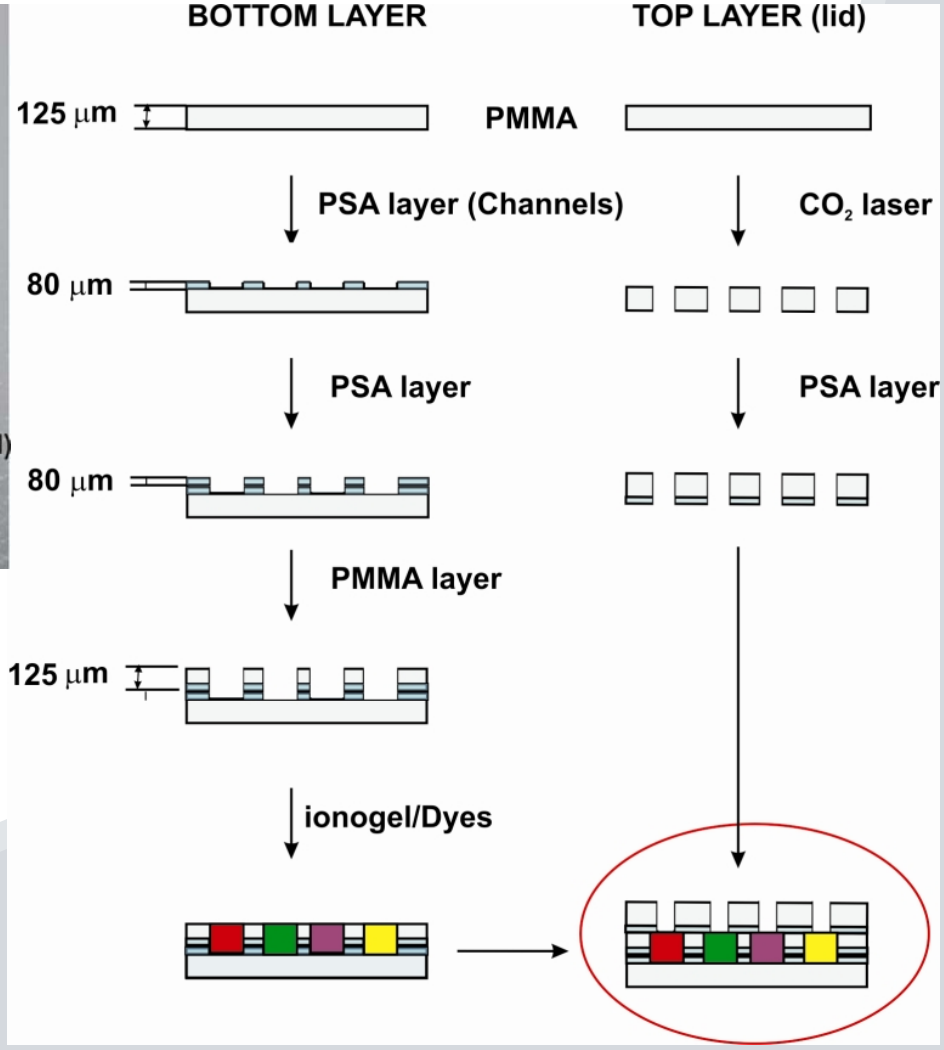
Micro-fluidic: *I.L.*

BARCODE AND MICRO-FLUIDIC FABRICATION

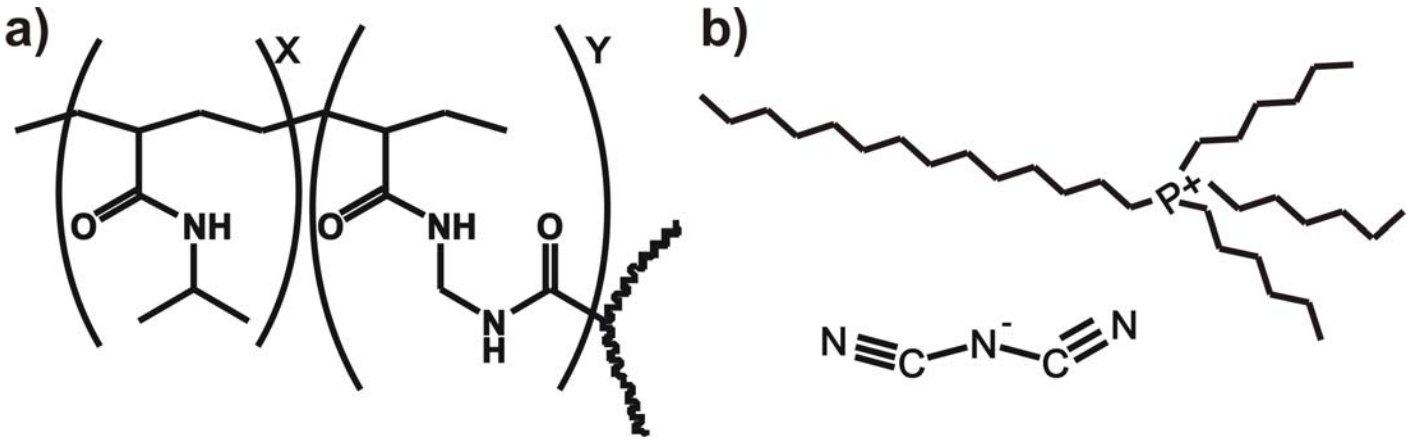




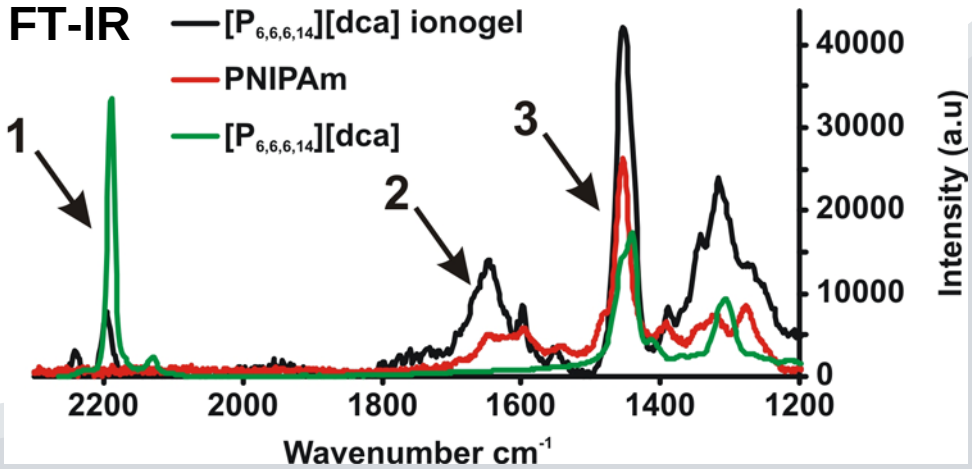
	pH
1- METHYL RED	4.4 - 6.2
2- BROMOCRESOL GREEN	3.8 - 5.4
3- BROMOCRESOL PURPLE	5.2 - 6.8
4- BROMOTHYMOL BLUE	6.0 - 7.6



Micro-fluidic: *I.L.*

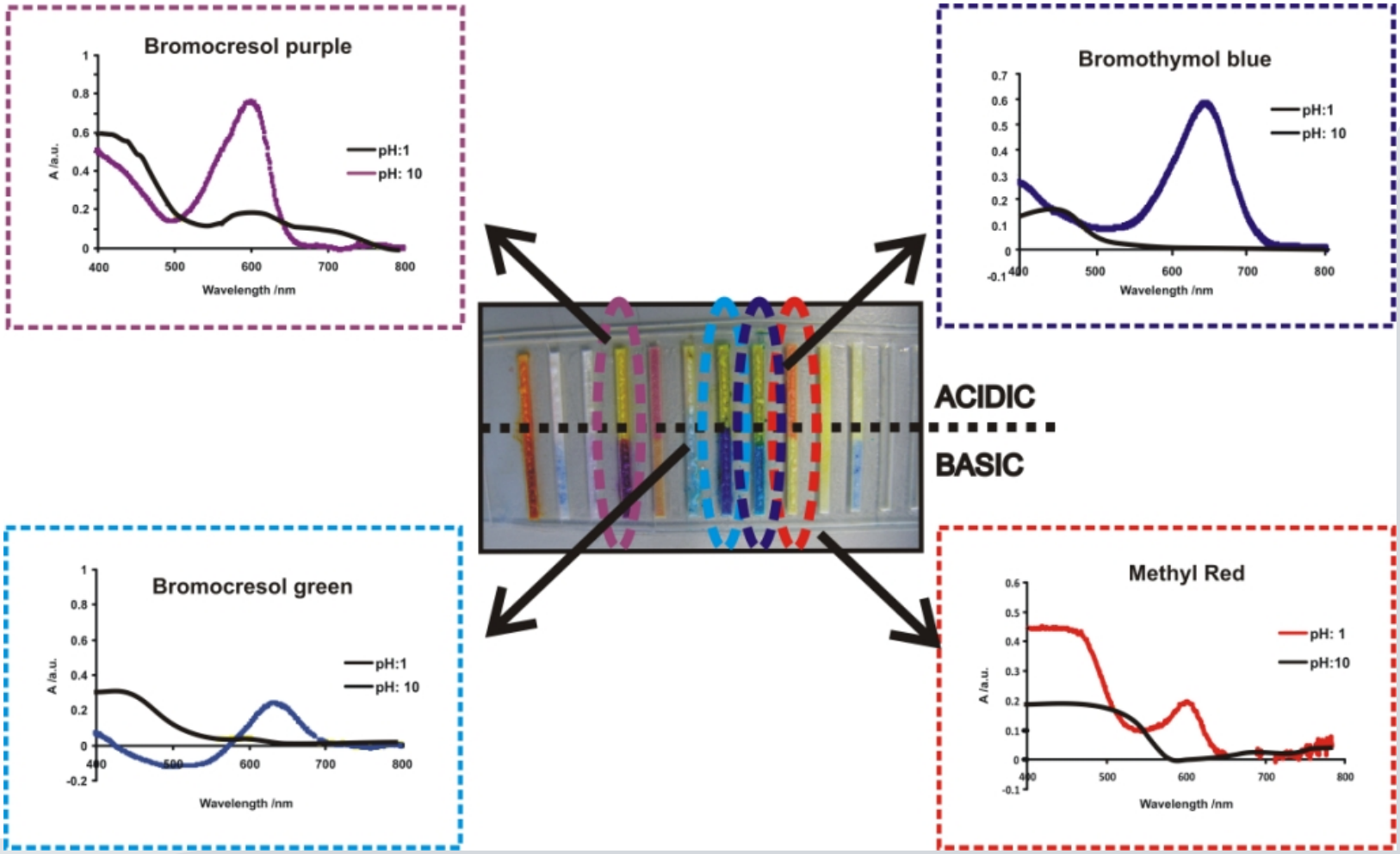


a) Poly(*N*-isopropylacrylamide) & *N*,*N*-methylene-bis(acrylamide)
b) Ionic liquid: trihexyltetradecyl- phosphonium dicyano-amide [$P_{6,6,6,14}$][dca]

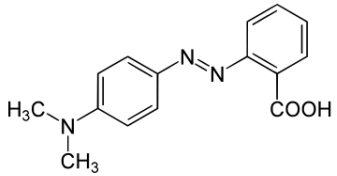


Micro-fluidic: *I.L.*

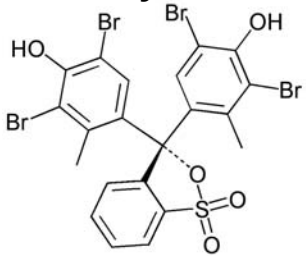
DOPING OF THE IONOGEL WITH THE pH-DYES



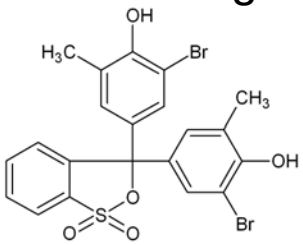
Micro-fluidic: *I.L.*



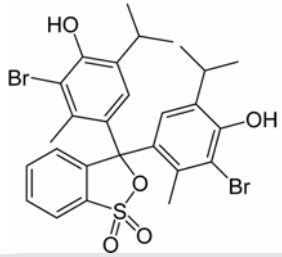
Methyl Red



Bromocresol green



Bromocresol purple



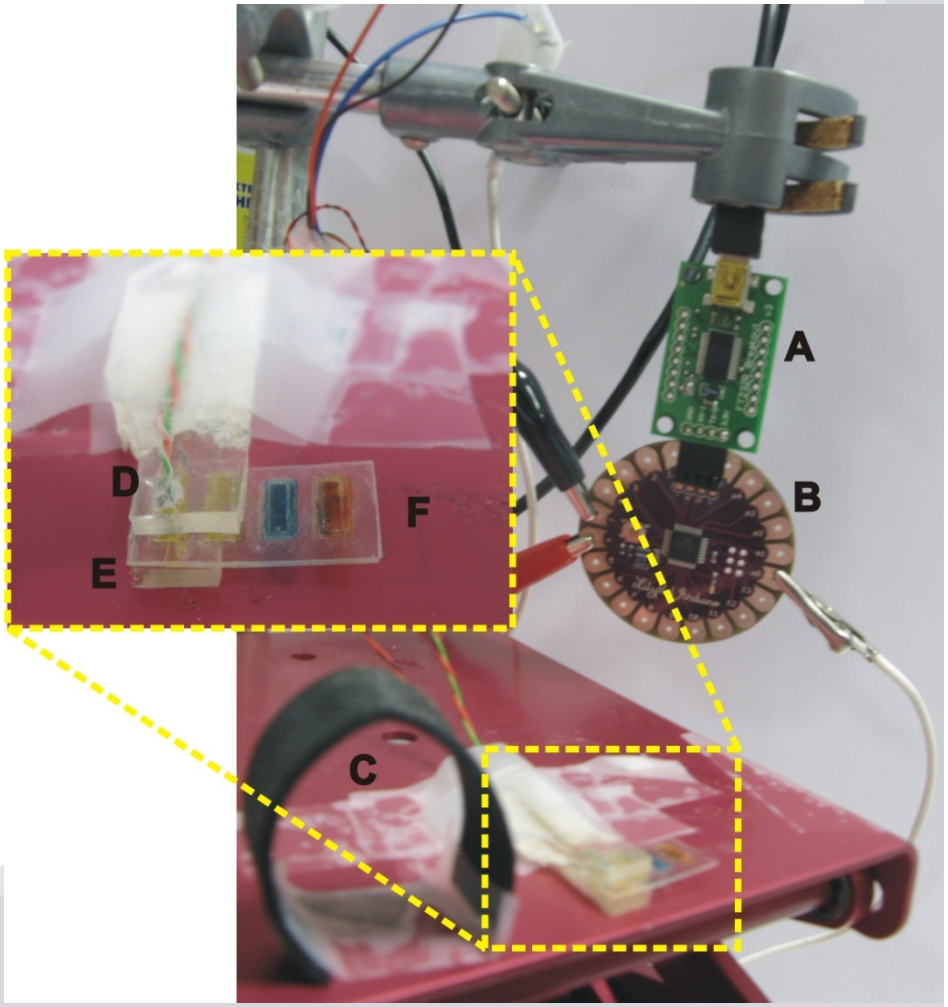
Bromothymol blue

Micro-fluidic: *I.L.*

OPTICAL DETECTION TECHNOLOGY

The optical detection set-up consists on:

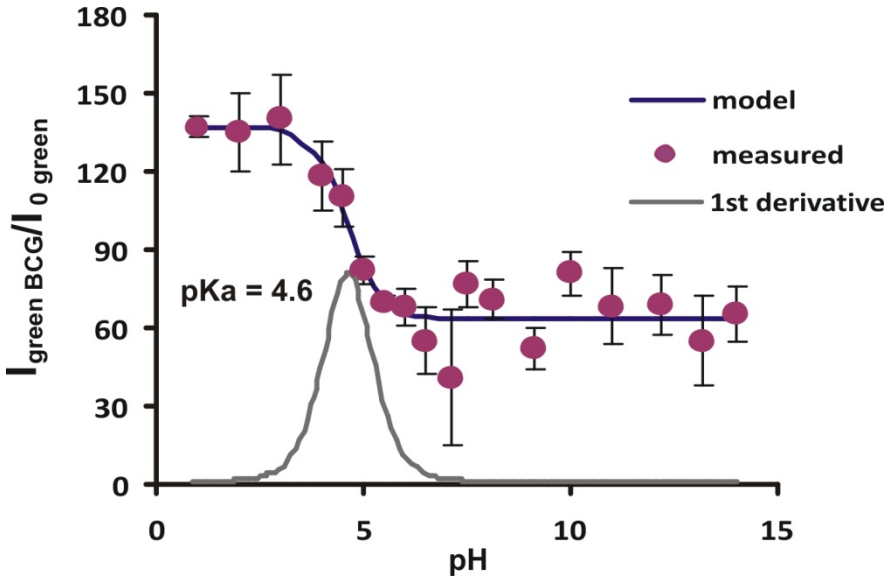
A) laptop or wireless connection link
B) microcontroller (Lilypad Arduino)
C) black masking tape
D) surface mount μ-LEDs light source
E) Surface mount photodiode: detector
F) barcode system

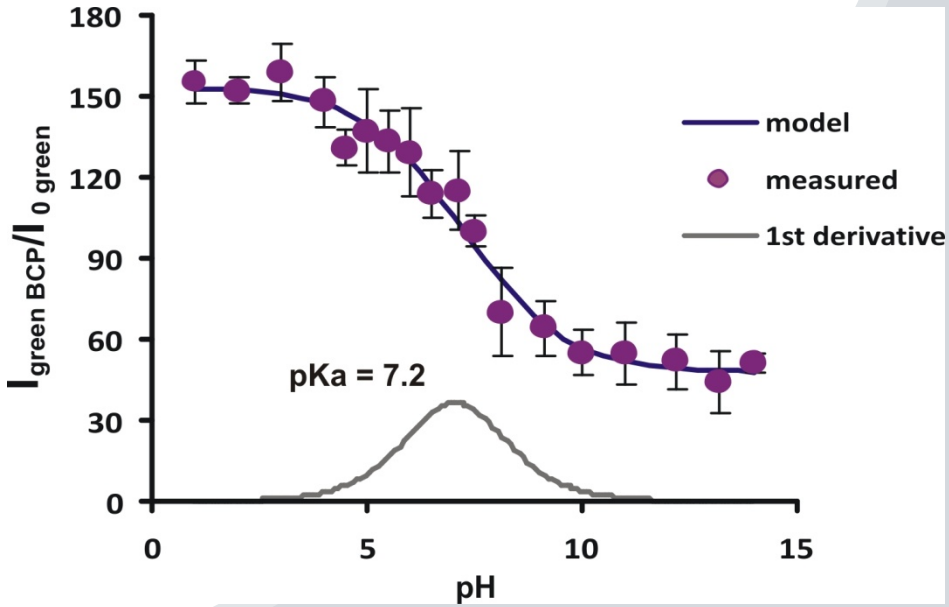


NOT INTEGRATED YET!!

Micro-fluidic: *I.L.*

CALIBRATION OF THE pH DYES



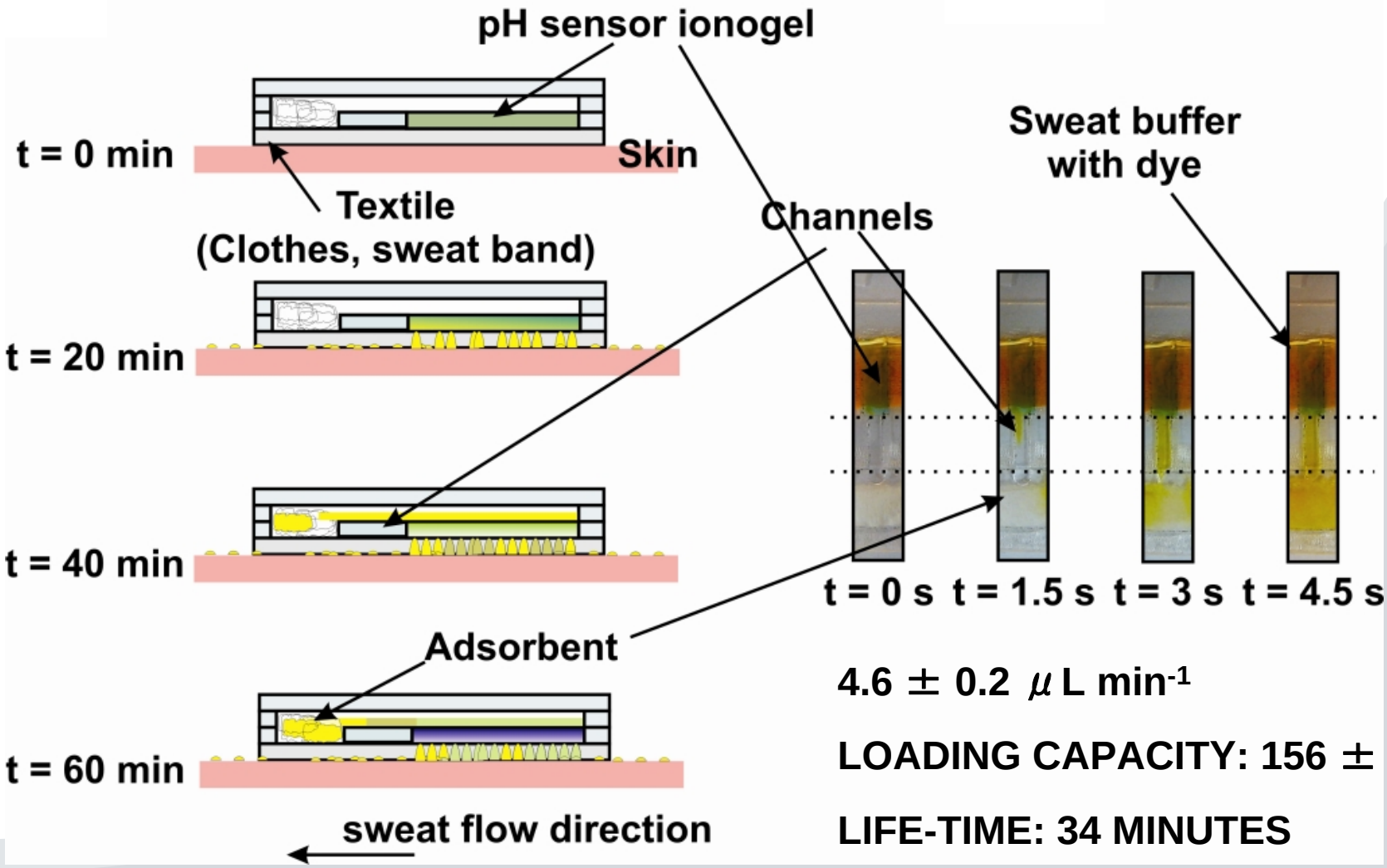


bromocresol green (n= 3)

bromothymol blue (n= 3)

Micro-fluidic: *I.L.*

MICROFLUIDIC SYSTEM PERFORMANCE



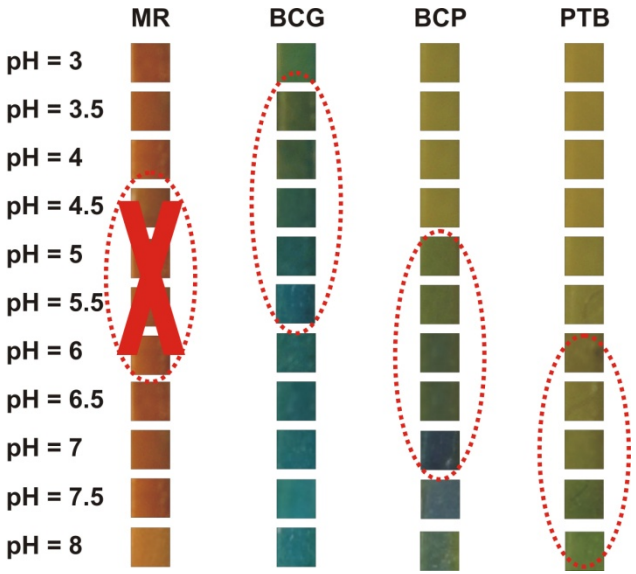
4.6 ± 0.2 μL min^{-1}

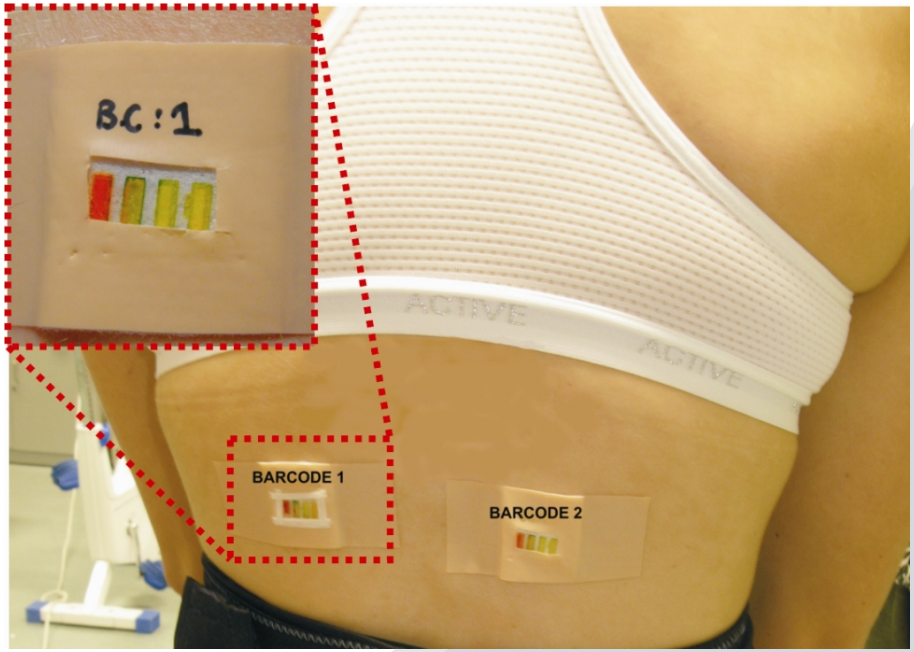
LOADING CAPACITY: 156 ± 3 μL

LIFE-TIME: 34 MINUTES

Micro-fluidic: *I.L.*

ON-BODY TRIALS





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

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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