Micro-fluidic Device for Colorimetric Analysis of Sweat

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Outline

- Sweat, Why is it Important?
- Introduction: Wearable Sensors
- Barcode and Micro-fluidic Device Fabrication
- Characterisation of the Device
- Results
- Conclusions

Sweat, why is it 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
- ✧ Hyponatraemia (low sodium concentration)

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

Physiological & Chemical Sensors

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LIFESHIRT®

- ✓ Breath rate,
- ✓ Heart rate,
- ✓ Posture
- ✓ Skin temperature
- ✓ …

Scosche myTrek Sports Kit®

Medtronic Diabetes' Guardian®

Lactate Scout®

Sweat Analysis

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Macroduct sweat collection system

PharmChek Sweat Patch

Whole body sweat collection techniques

S. M. Shirreffs, *et al.*, J Appl Physiol 82 (1997) 336-341

Sweat Analysis

PROBLEMS TO OVERCOME WITH CHEMICAL SENSORS?

SAMPLE GENERATION

COLLECTION

DELIVERY

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.

Real-Time Sweat Analysis

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WHAT DO WE NEED????

DEVICE:

WEARABLE

ROBUST

FLEXIBLE / ADAPTABLE

REUSABLE/ DISPOSABLE (CHEAP)

IMMEDIATE FEEDBACK

MICRO-DEVICES!!

DETECTION:

NOT INVASIVE

WIRELESS

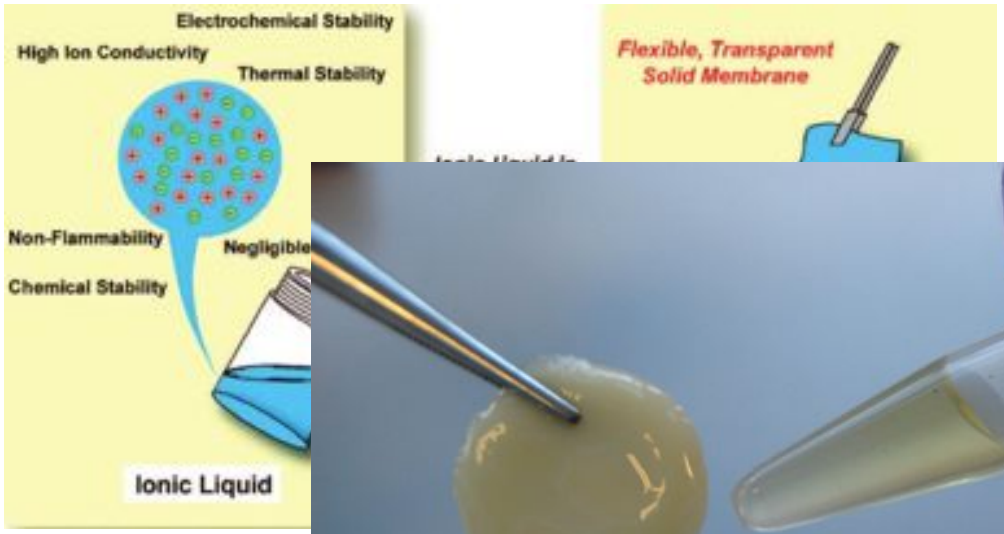
FREEDOM FROM ELECTRONIC NOISE

MINIATURIATION

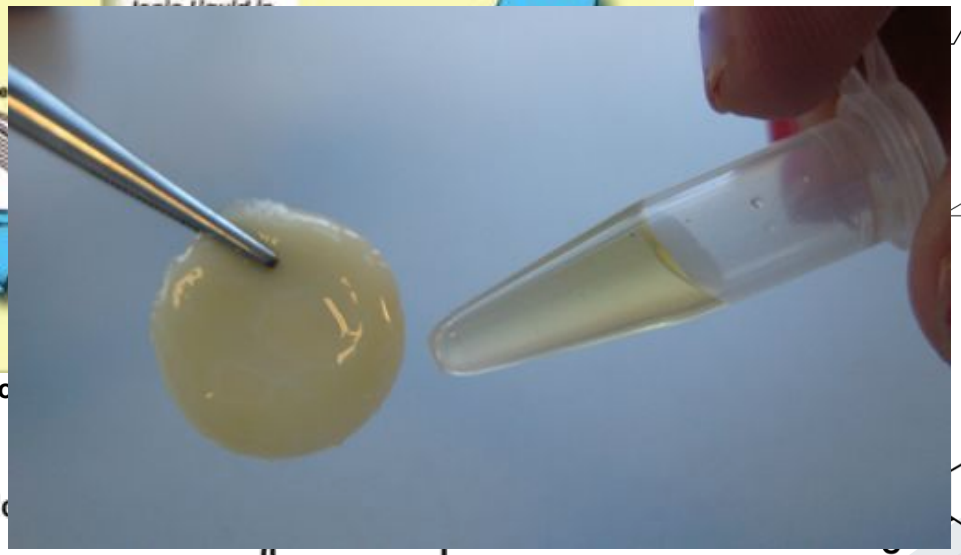
FLEXIBILITY IN INTERROGATION APPROACHES
(human eyes, LED-sensors, cameras, spectrometers, …)

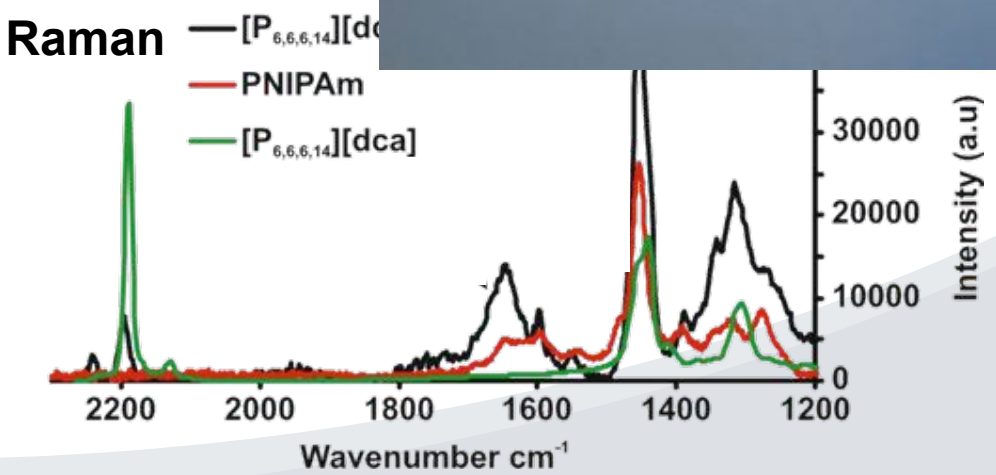
OPTICAL SENSORS!!

NOVEL MATERIAL: Ionogel

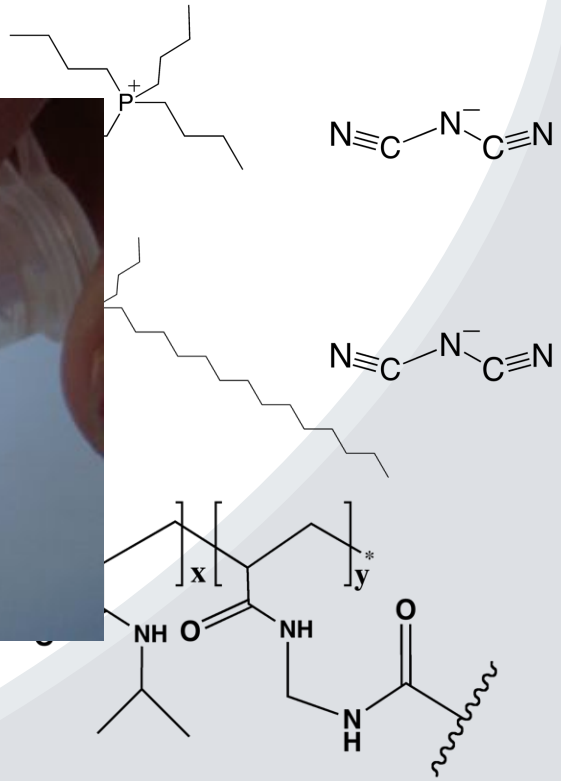


T. Ueki, *et al.*, Macromc





(a)



a) Ionic liquids: tetra-alkyl phosphonium dicyano-amide $[P_{4,4,4,4}][dca]$ and $[P_{6,6,6,14}][dca]$

b) Poly(*N*-isopropylacrylamide-co-*N,N'*-methylenebisacrylamide)

F. Benito-Lopez, *et al.*, Dublin City University, 2009, Patent Application No: GB 0904627-7.

ADAPTIVE MATERIAL: Ionogel/dye

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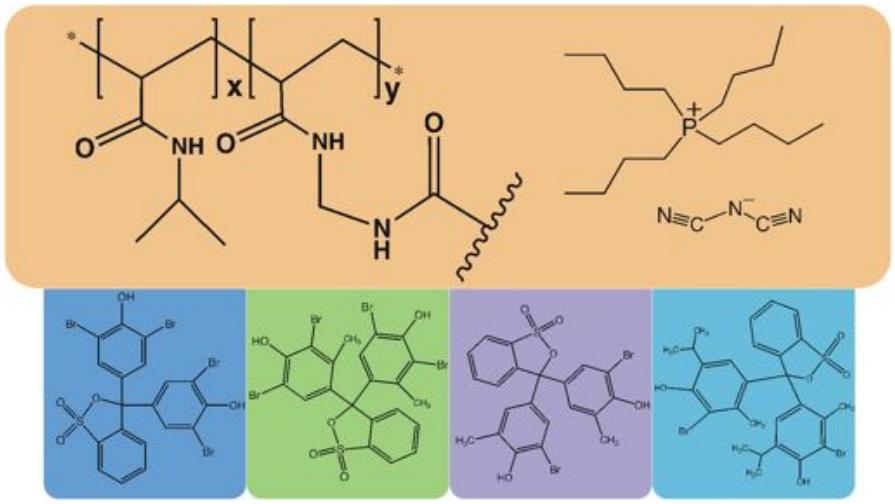
DOPED IONOGEL WITH A pH-DYE

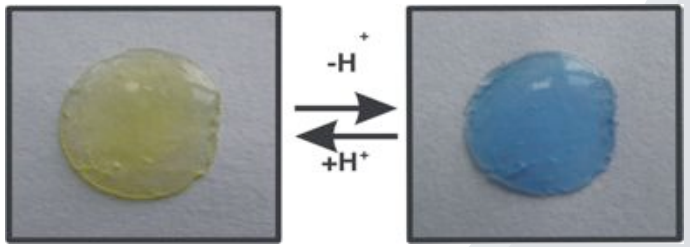
Sweat pH: 5 - 7

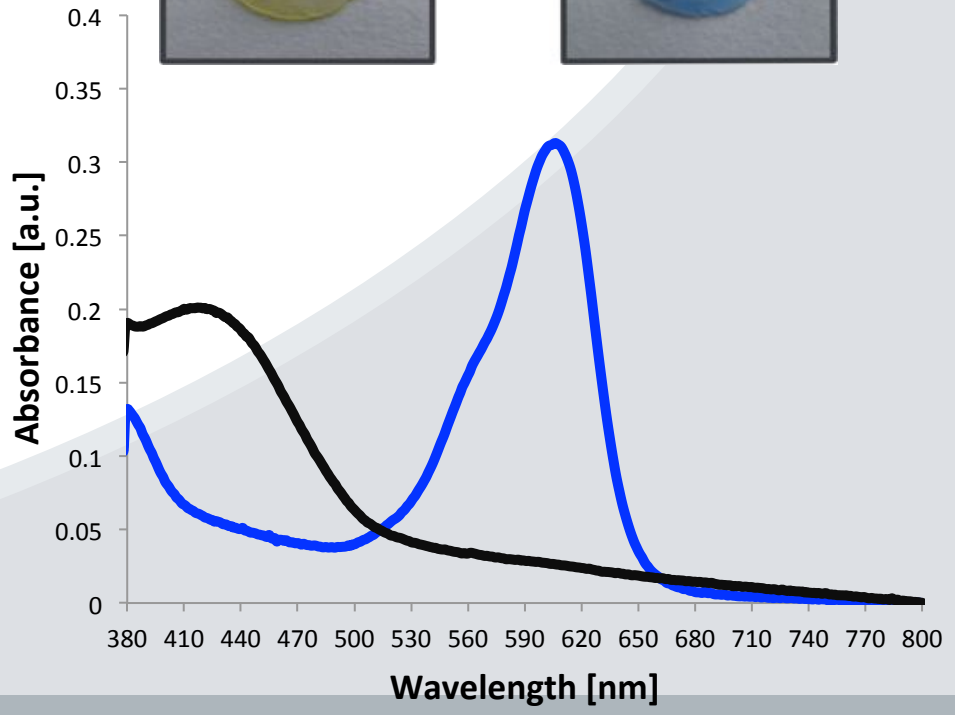


	pH	
1- BROMOPHENOL BLUE	3.0	4.6
2- BROMOCRESOL GREEN	3.8	5.4
3- BROMOCRESOL PURPLE	5.2	6.8
4- BROMOTHYMOL BLUE	6.0	7.6

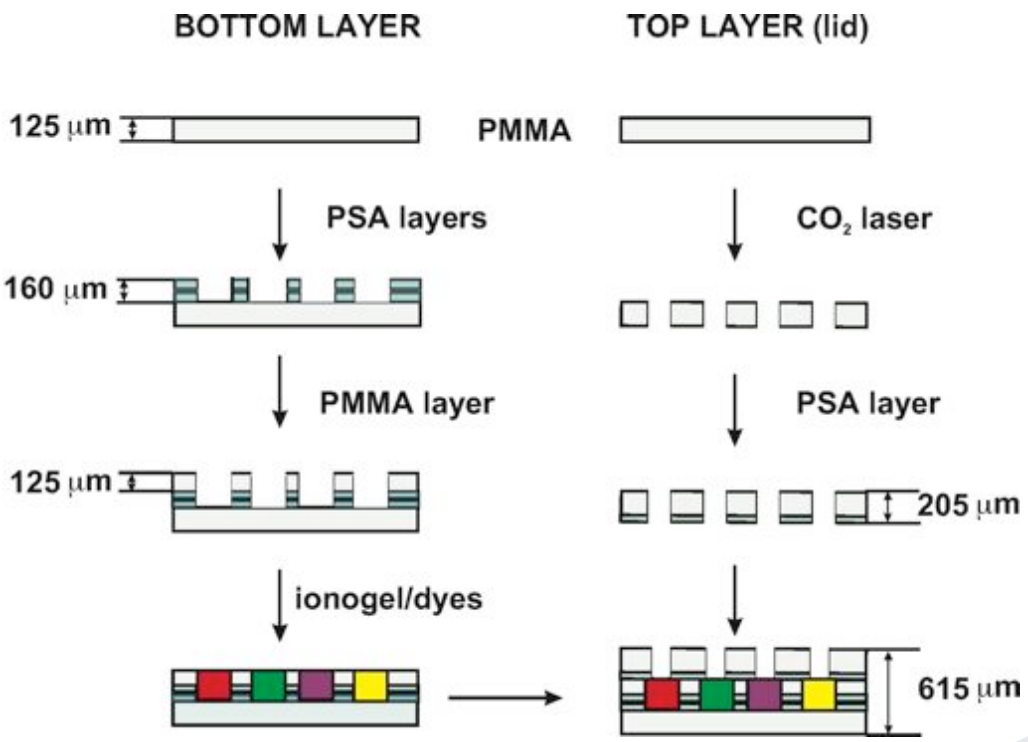
Bromophenol Blue

ionogel /acidic conditions
ionogel /basic conditions





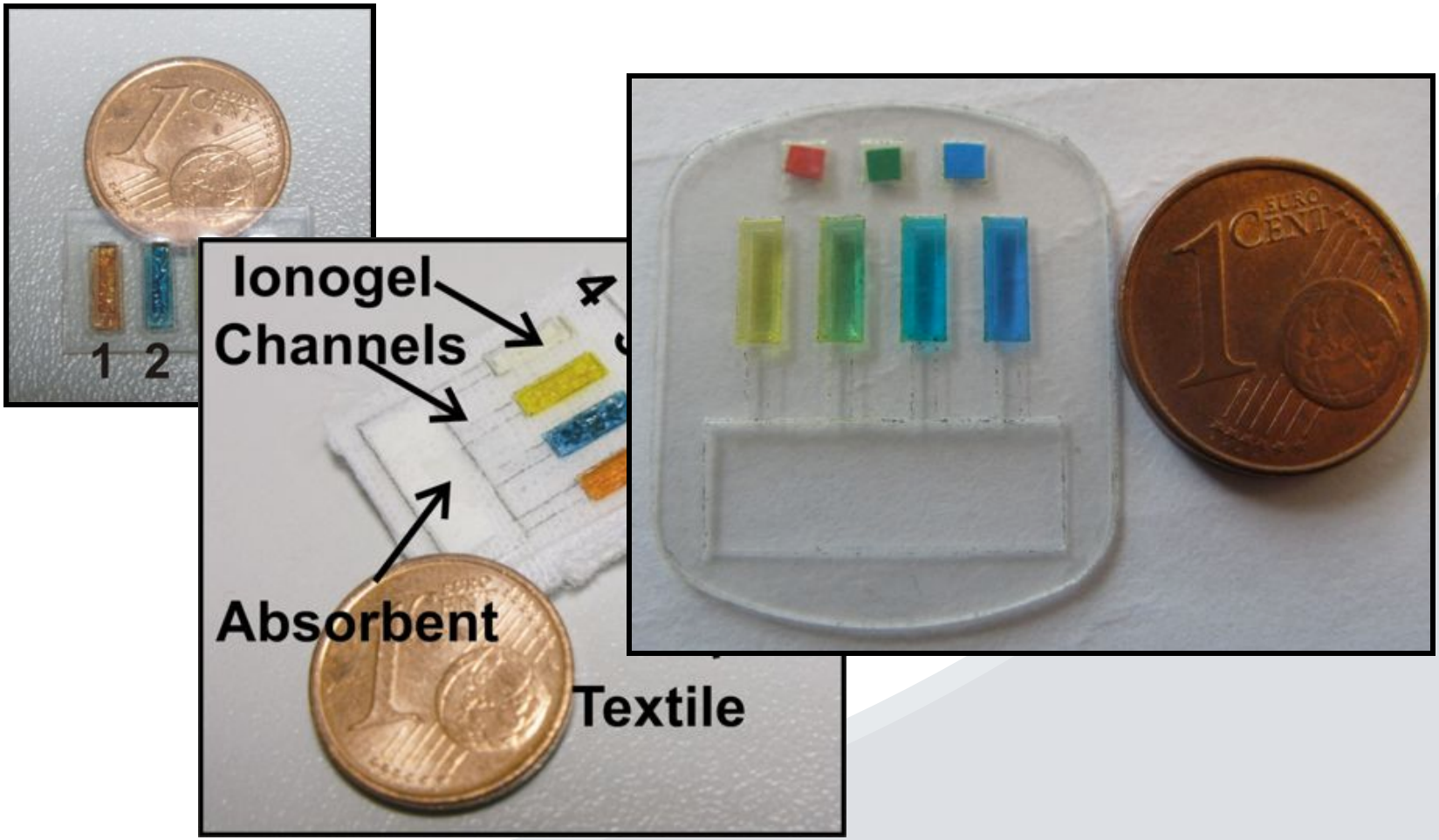
Microfluidic Fabrication



CO_2 laser

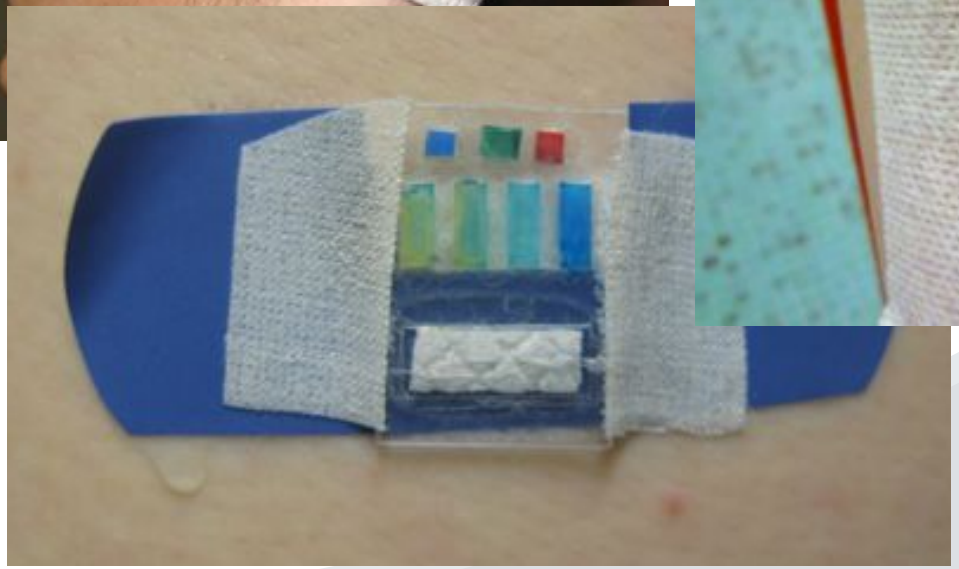
laminator

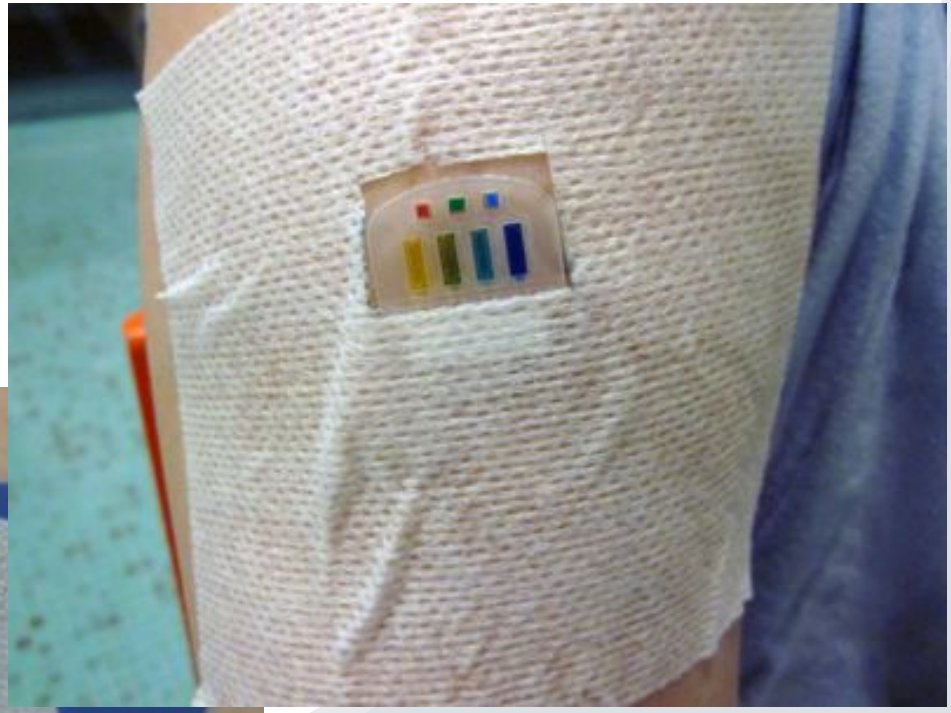
Microfluidic & Barcode



V.F. Curto, *et al.*, (Submitted)
F. Benito-Lopez, *et al.*, 7th International Workshop on Wearable and Implantable Body Sensor Networks-BSN (2010), 291-296

Integration

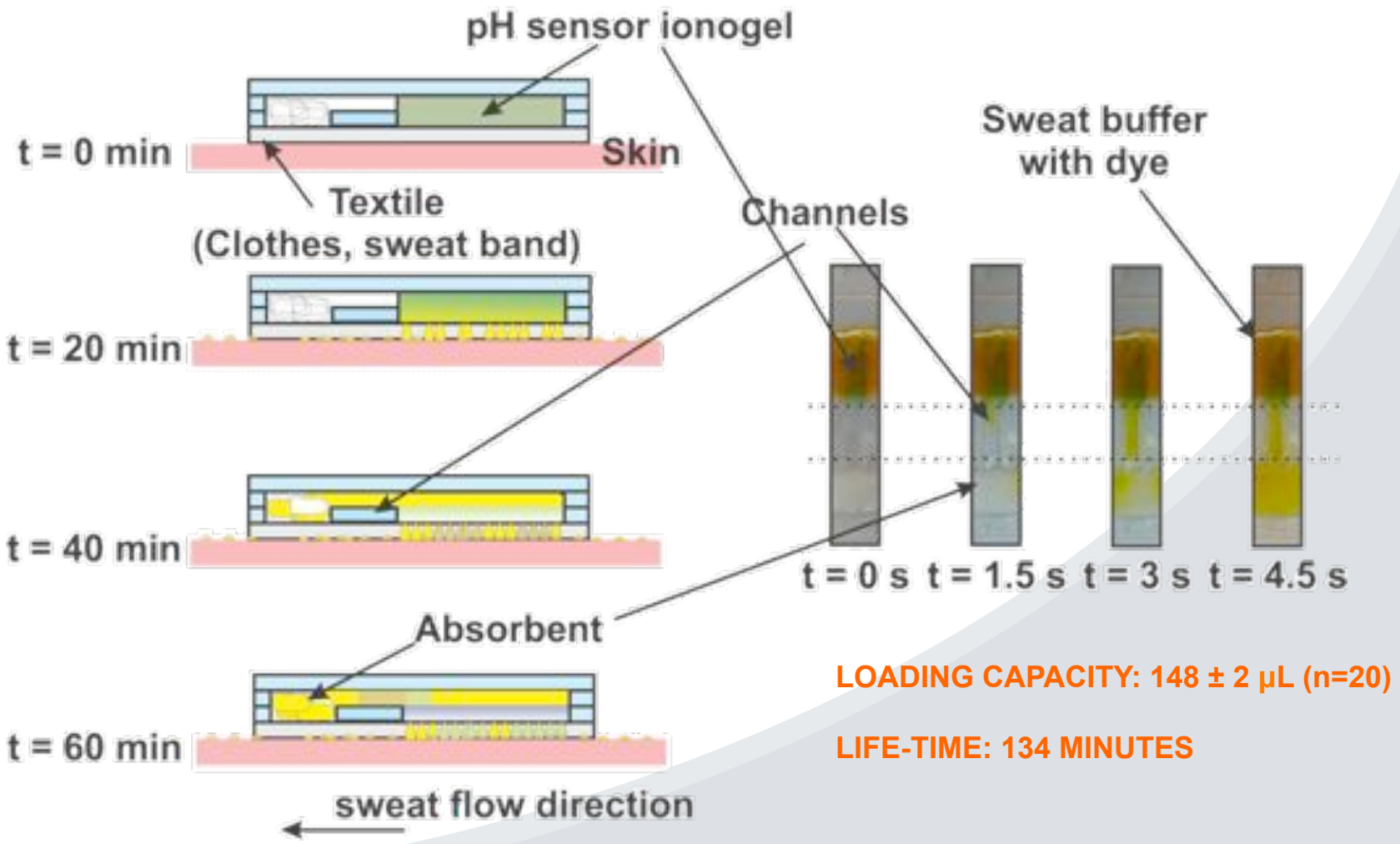




Adhesive Plaster

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

Characterisation: Performance



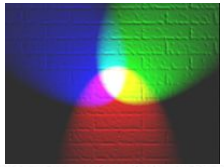
LOADING CAPACITY: 148 ± 2 µL (n=20)

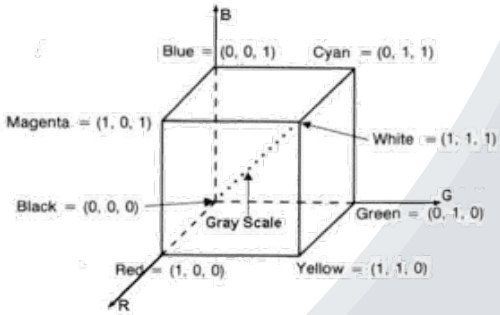
LIFE-TIME: 134 MINUTES

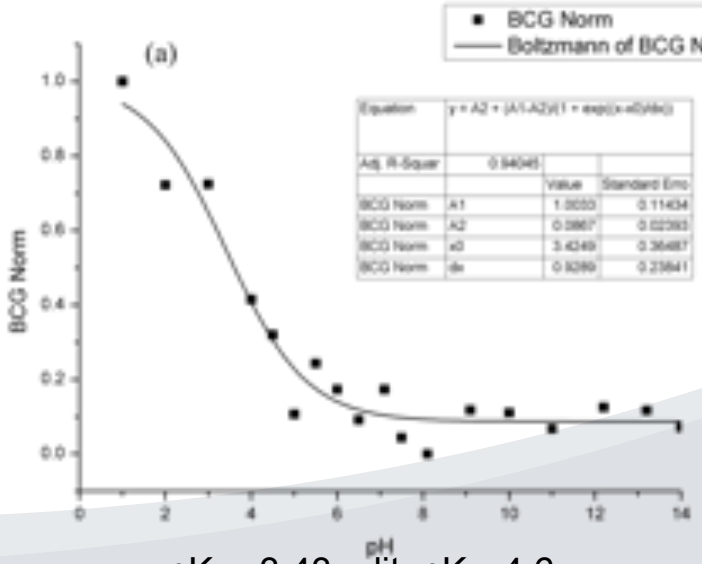
V.F. Curto, *et al.,* (Submitted)

Characterisation: Calibration

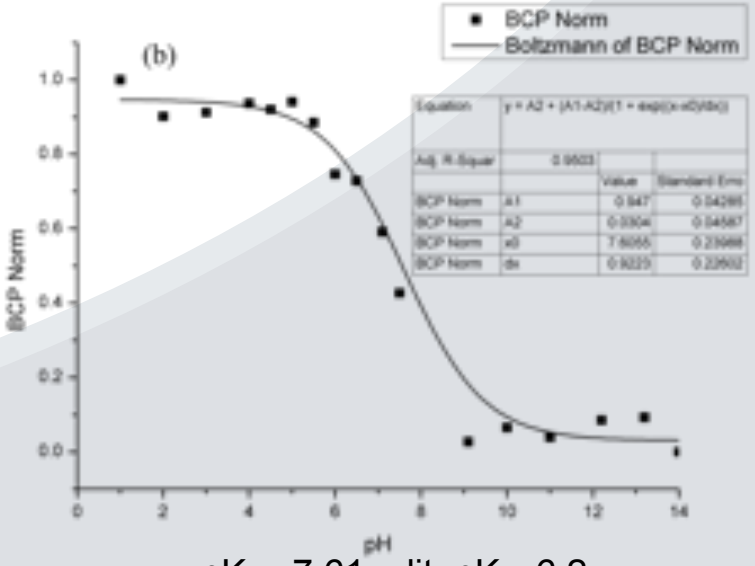
RGB Color Space







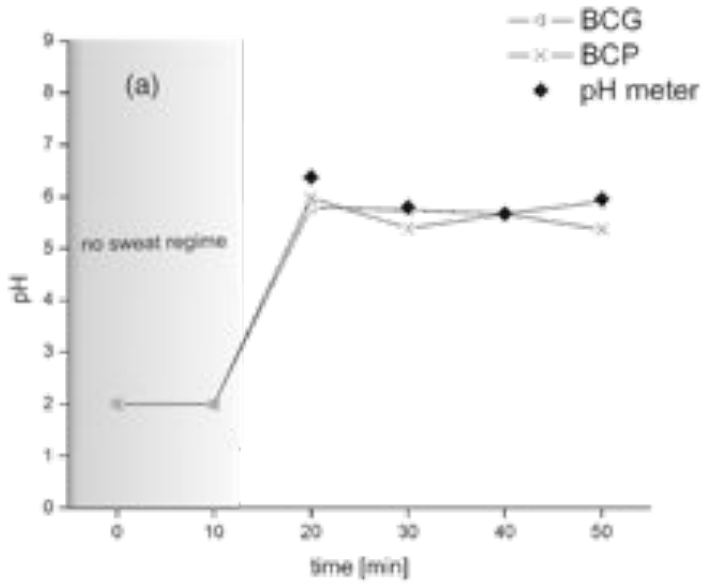
pK_a= 3.43 – lit. pK_a=4.6

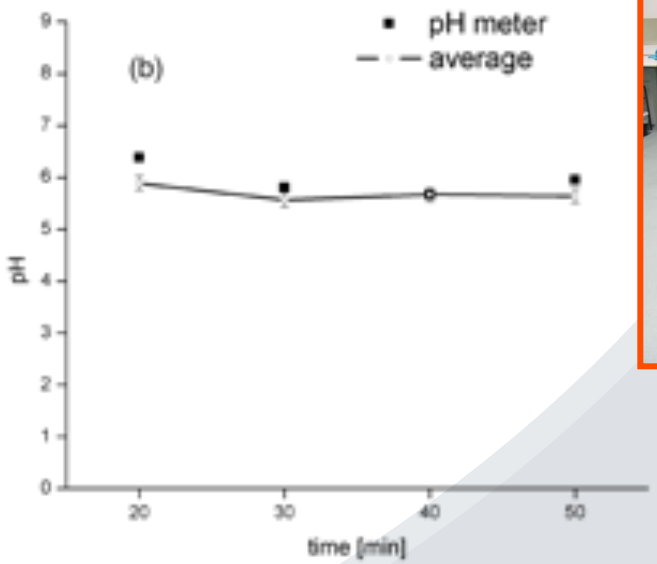


pK_a= 7.61 – lit. pK_a=6.2

Performance On-Body Trial

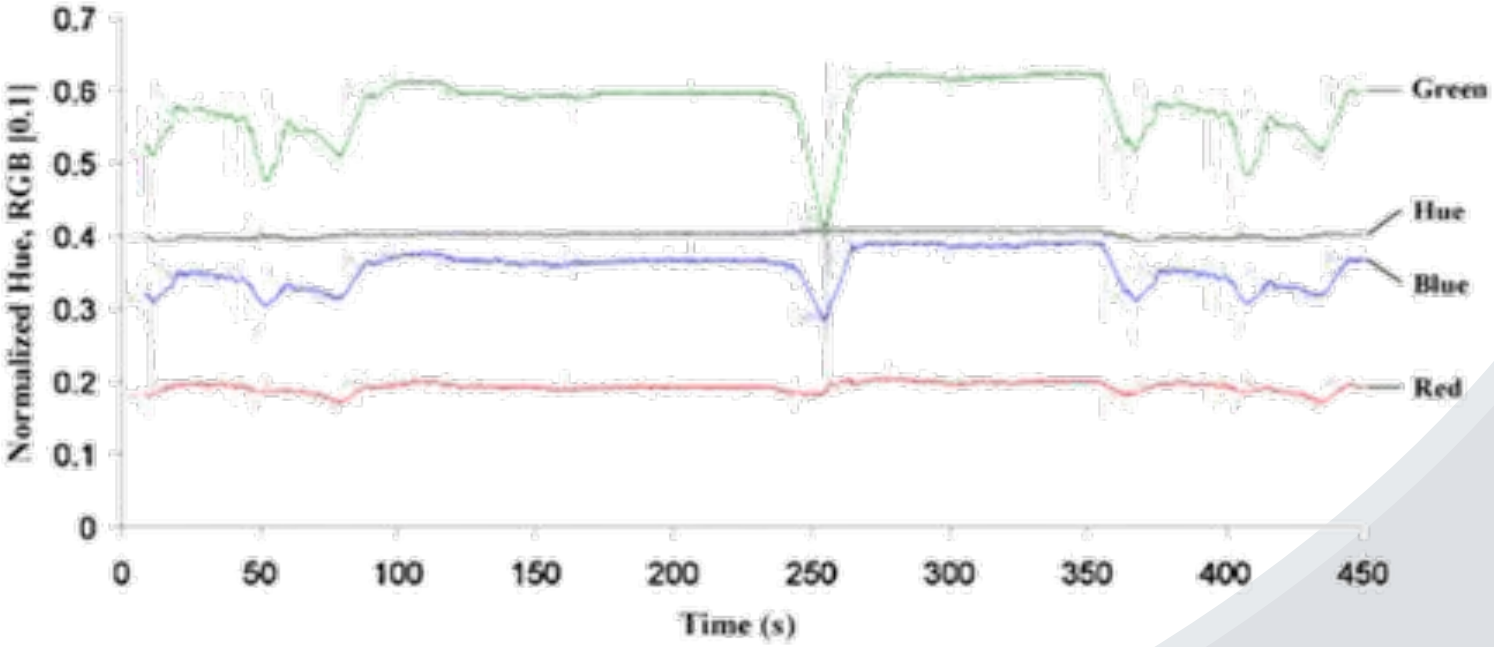
Sweat pH determination using the barcode in an athlete during a 50 min training period





Time [min]	pH Meter	Dyes Prediction (pH)	% RE
20	6.38	5.89	7.68
30	5.8	5.56	4.14
40	5.67	5.67	0.00
50	5.95	5.63	5.38

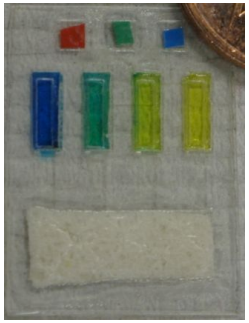
RGB *vs* HSV



- H value is stable, simple to calculate
- superior precision with variations in indicator concentration and illumination

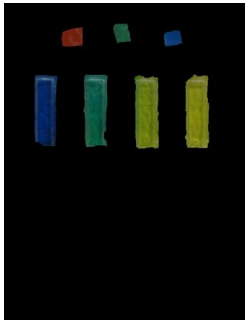
C. Fay *et al.*, Sensors and Actuators B 150 (2010) 425–435

HSV Detection

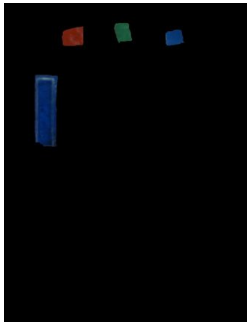


Original Image

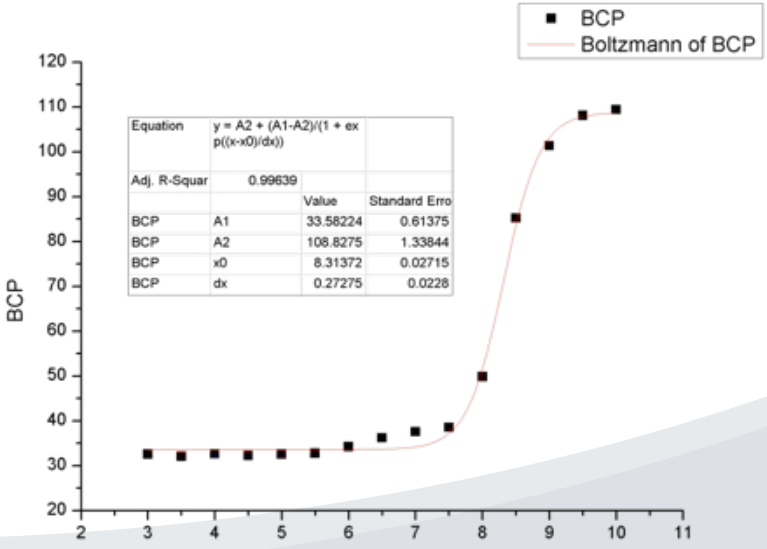
Mask Image



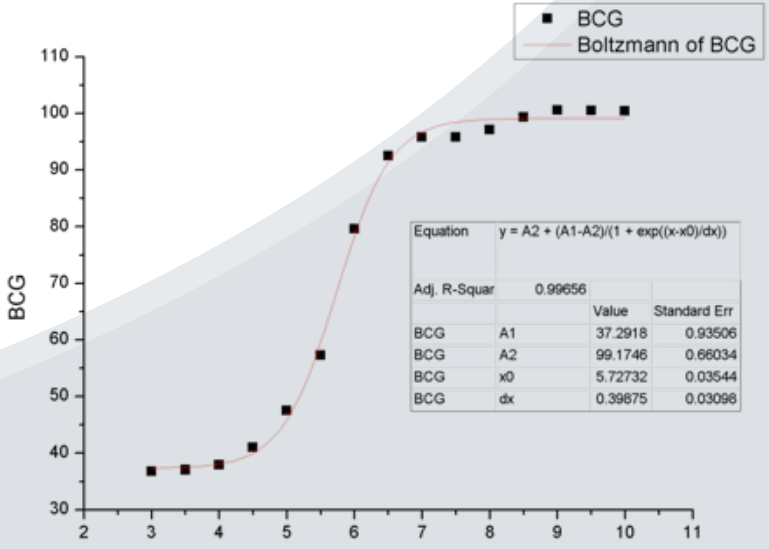
Mask Applied to Original Image



Analyse Each Region in Turns with Reference Patches



pK_a= 5.73 – lit. pK_a=4.6



pK_a= 8.31 – lit. pK_a=6.2

Conclusions

- The fabrication, characterisation and performance of a wearable micro-fluidic system based on ionogels for monitoring, in real-time mode, the pH of sweat generated during exercise has been presented.

- The ionogel/dye interactions ensure no leaching of the dyes.

- Accuracy on the pH of sweat measurements over time.

- The redesign of the barcode improves its wearability and makes it reusable.

- Image analysis through Hue value gives better performance at different light ambient conditions.

Acknowledgements

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Thank you for your attention