New Functional Materials for Fluid Control and Sensing in Microfluidic Devices

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A little bit about myself:

National Centre for Sensor Research

- 26 PI, 80 SENIOR RESEARCHERS AND ALMOST 120 POST-GRADUATE STUDENTS, SUPPORTED BY AN ADMINISTRATIVE TEAM OF 16.
- INVESTMENTS AND INCOME SINCE 1999 NOW APPROACHING €100 MILLION.
- 3200 m^2 WELL-EQUIPPED SPECIALIST LAB SPACE AND OFFICE.
- MULTIDISCIPLINARY COMPOSITION OF THE RESEARCH TEAM: PHYSICISTS, CHEMISTS, BIOTECHNOLOGISTS AND ENGINEERS.

CLARITY – SFI CSET

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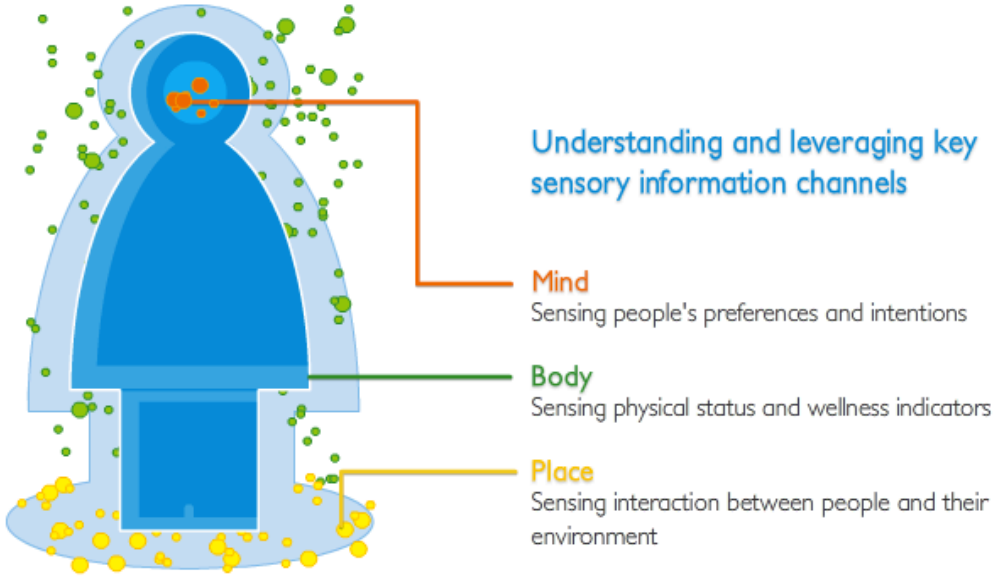
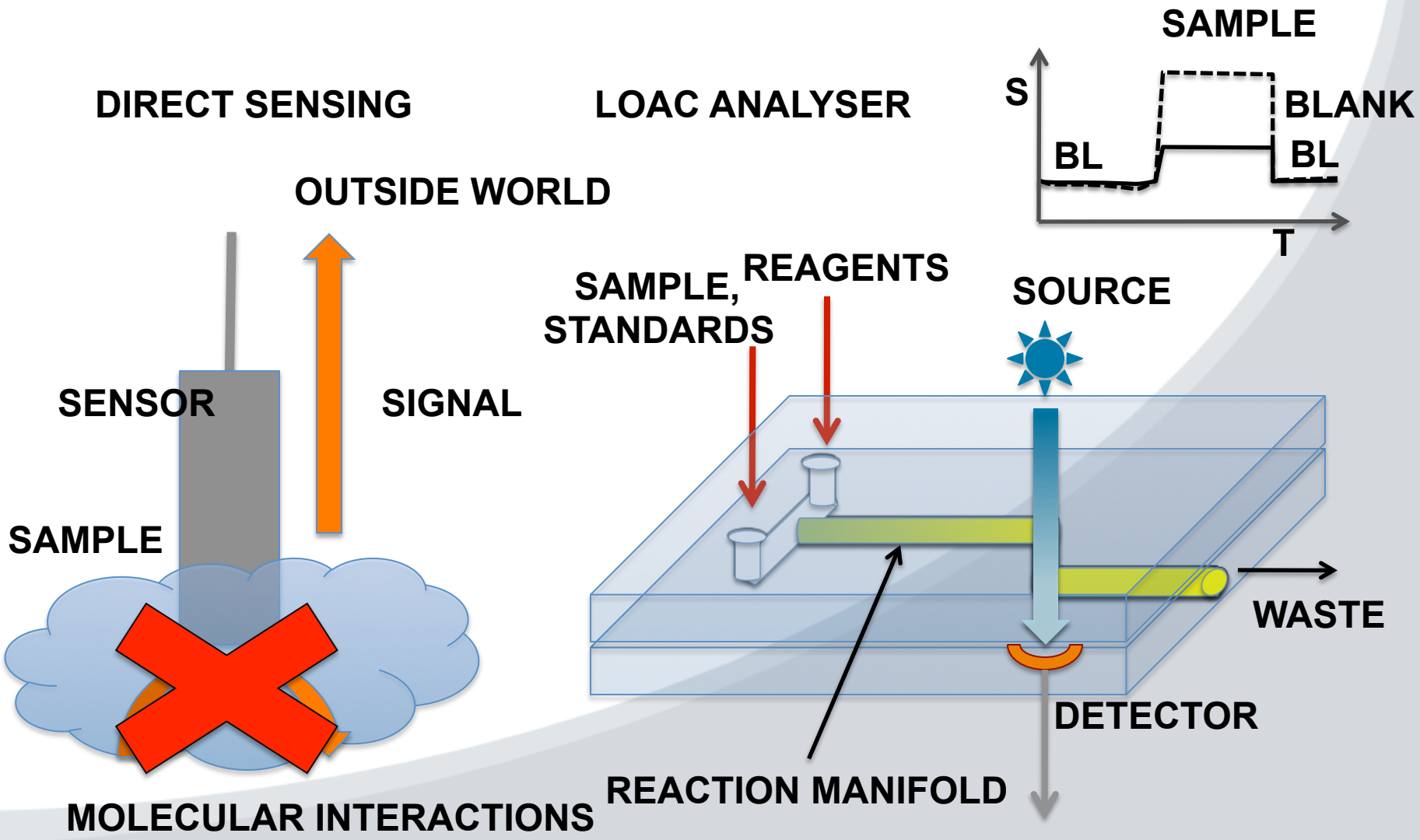
Vision: Sensing Mind, Body & Place



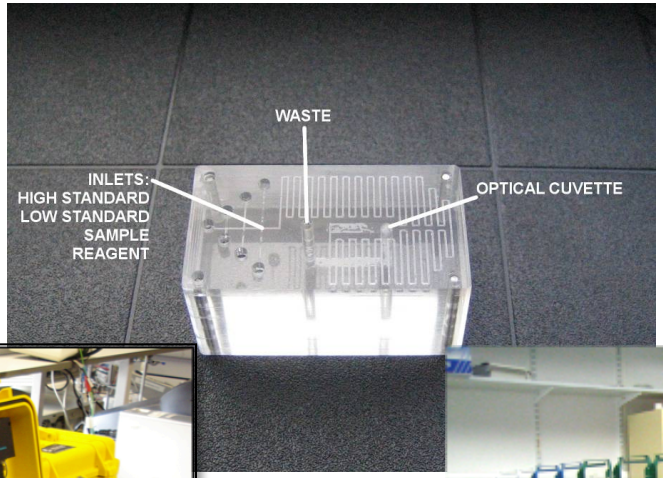
- **5-YEAR, €16.4 MILLION RESEARCH PROGRAM TO DEVELOP NEXT GENERATION SENSOR WEB TECHNOLOGIES WITH SIGNIFICANT ENVIRONMENTAL FOCUS**
- **BRINGS TOGETHER FUNDAMENTAL MATERIALS SCIENCE, FUNCTIONAL POLYMERS, DEVICE PROTOTYPING, ENERGY MANAGEMENT, ADAPTIVE MIDDLEWARE, WEARABLE SENSORS, DISTRIBUTED ENVIRONMENTAL MONITORING ….**

Direct Sensing *vs.* Reagent Based LOAC



Phosphate Analyser

- GEN1: component cost ca. €2,000 per unit
- GEN2 developed; component cost now < €200 per unit.



Gen1

Gen2

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MANY PEOPLE, MYSELF INCLUDED, EXPECTED THAT THE ABILITY TO MANIPULATE FLUID STREAMS, IN MICROCHANNELS, EASILY, WOULD RESULT IN A PROLIFERATION OF COMMERCIAL LOAC SYSTEMS, AND THAT WE WOULD SEE APPLICATIONS OF THESE DEVICES PROLIFERATING THROUGHOUT SCIENCE. IN FACT, IT HAS NOT (YET) HAPPENED.

EDITORIAL 'SOLVING PROBLEMS', GEORGE WHITESIDES
LAB CHIP 10 (2010) 2317-2318

Achieving Scale-up

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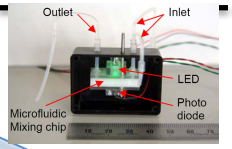
CURRENT PLATFORMS

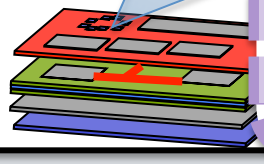
1

2. REVOLUTIONARY MATERIALS BREAKTHROUGHS; HIDDEN COMPLEXITY, BIOMIMETIC PLATFORMS, ALL FLUID HANDLING INTEGRATED ON CHIP, INDEFINITELY SELF-SUSTAINING



1. EVOLUTIONARY DEVELOPMENT, COST DRIVEN DOWN, RELIABLE, IMPROVED SCALABILITY

2



MASSIVELY SCALED DEPLOYMENTS OF THE FUTURE

COST/COMPLEXITY->

Scalability ->

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MICROFLUIDICS FOCUS:
SCIENCE & TECHNOLOGY
(scientific papers)

Use of microfluidics for the solution of problems??

PROBLEM ⇄ **MICROFLUIDIC TECHNOLOGY**

BETTER THAN EXSISTING TECHNOLOGY

MARKET

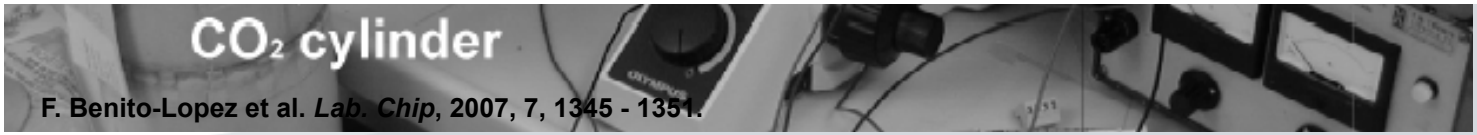
DEVELOPMENT!!!

Disadvantage of Microfluidics

NEW GENERATION OF MICROFLUIDIC DEVICES

↓

ADVANCES IN FUNDAMENTAL MATERIAL SCIENCE



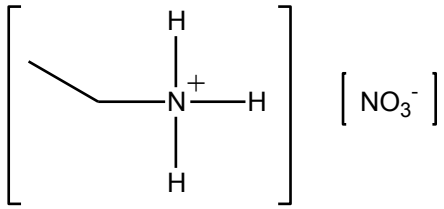
F. Benito-Lopez et al. *Lab. Chip*, 2007, 7, 1345 - 1351.

What is an Ionic Liquid (IL)?

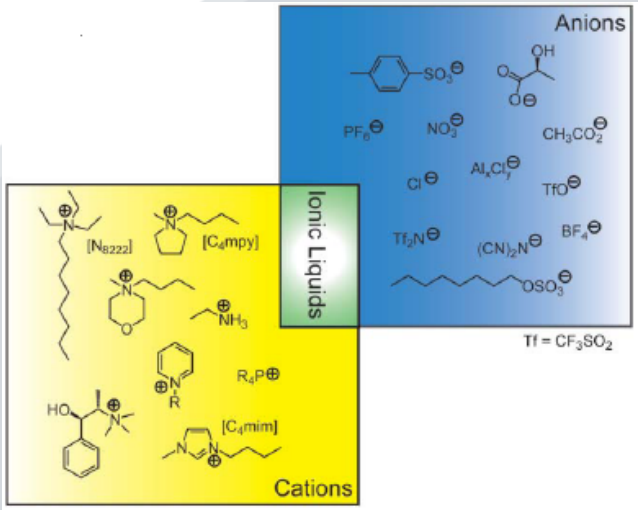
- According to current convention, a salt melting below the normal boiling point of water is known as an “ionic liquid”

- The first IL was reported almost a century ago by Walden[1], who protonated ethylamine with nitric acid to yield ethylammonium nitrate

- The number of potential anion-cation combinations available reputedly equate to one trillion (1012) different ILs[2]



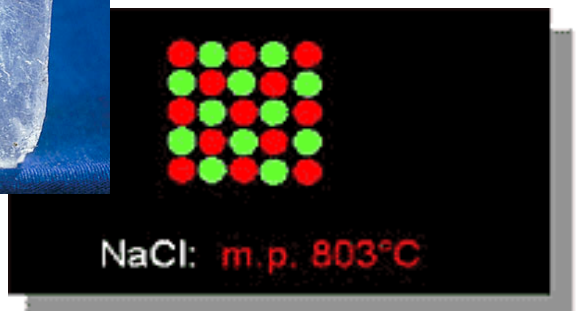
M.P. 12ºC

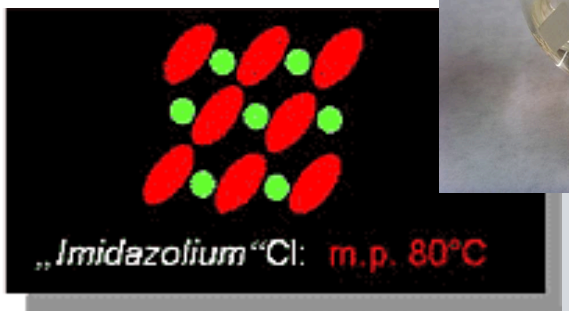


[1] P. Walden, Bull. Acad. Sci. St. Petersburg, 1914, 405.
[2] R. D. Rogers and K. R. Seddon, Ionic Liquids as Green Solvents: Progress and Prospects, American Chemical Soceity, 2003.

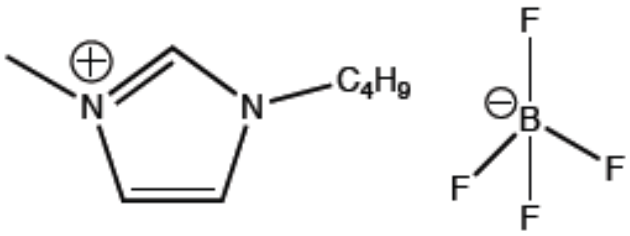
Ionic Liquids

Why are ionic liquids “liquids”?

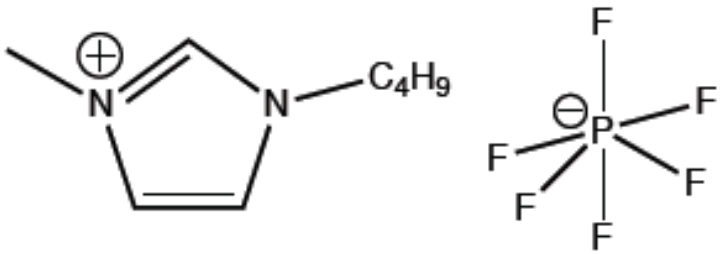




Typical ions to form ionic liquids



Hydrophilic
Tg -81ºC only



Hydrophobic
M.P. of 6.4ºC

Ionic Liquids features:

Very low vapor pressure

High thermal stability (~250-400ºC)

Variable viscosity

Hydrophobic or hydrophilic

Capable of undergoing multiple solvation* interactions

(excellent solvents for a wide range of inorganic, organic, and polymeric materials)

broad liquid range

renewable & reusable

may be air & water stable; otherwise inert

non-flammable

may be water immiscible

may exhibit BrÖnsted, Lewis, and super-acidity

*Solvation: attraction and association of solvent and solute hydrogen bonding, ion-dipole and dipole-dipole attractions or van der Waals forces

Ionic Liquids applications:

Analytical extractions and separations

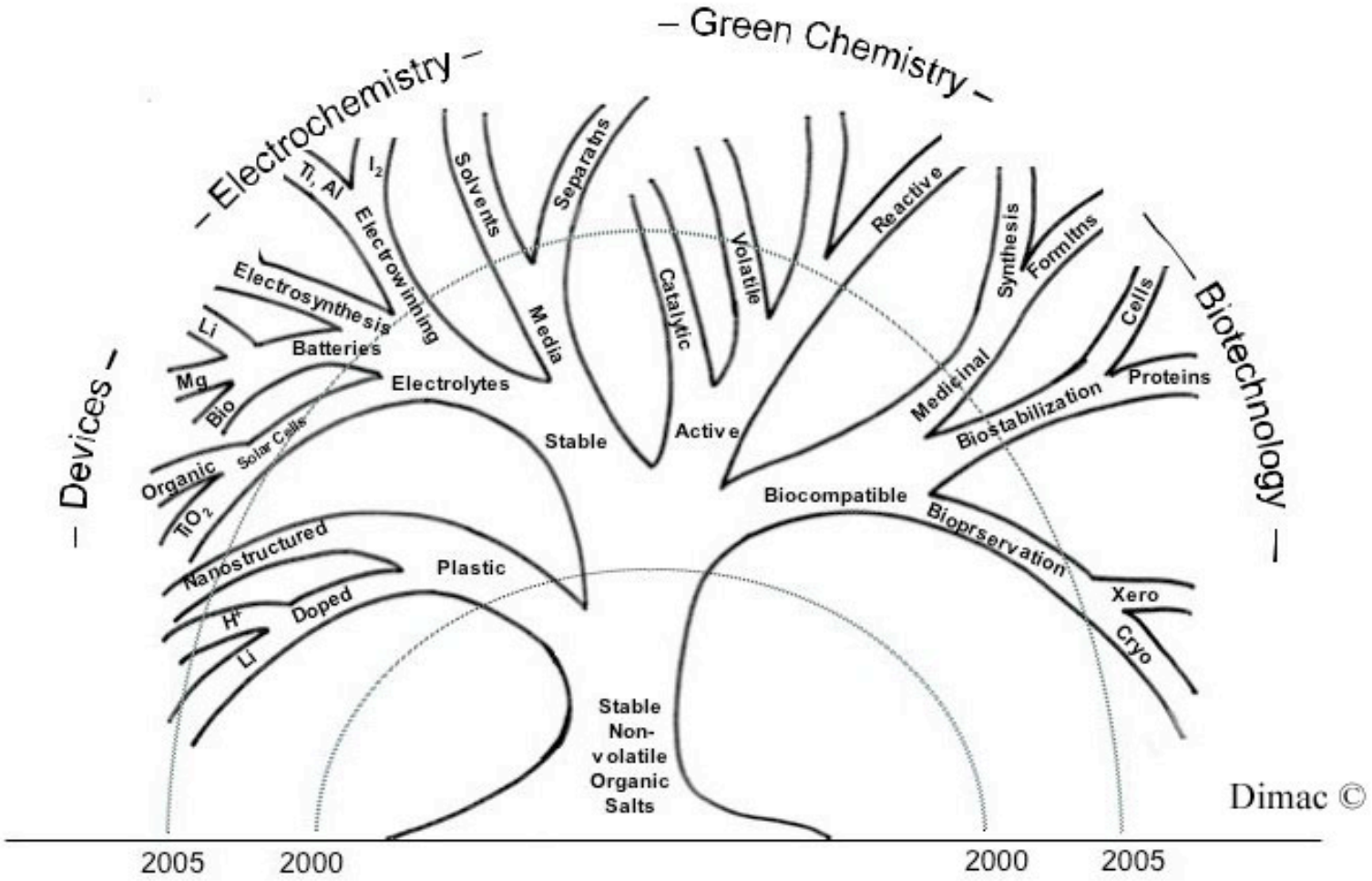
Liquid/liquid extraction and liquid phase microextraction

Mobile phase additives in HPLC

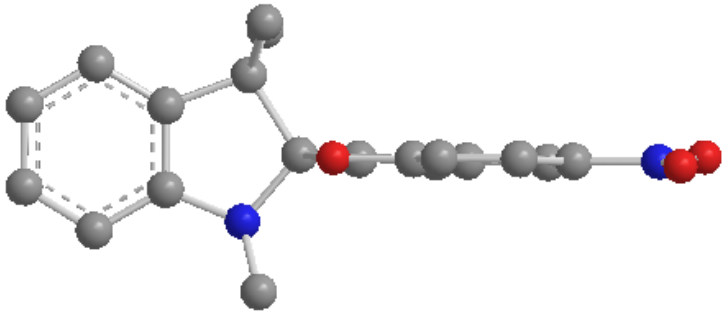
Stationary phases in GC

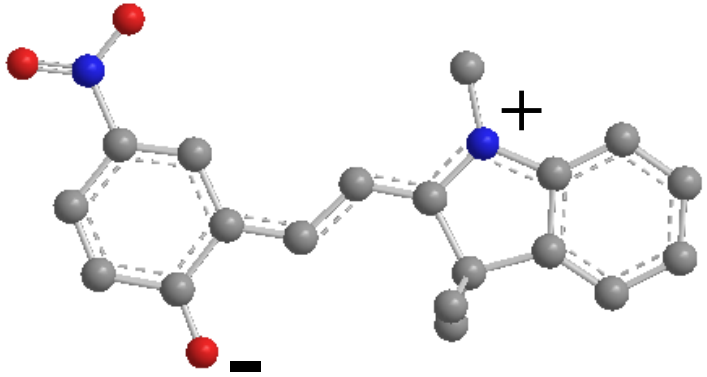
Run buffer additives in CE

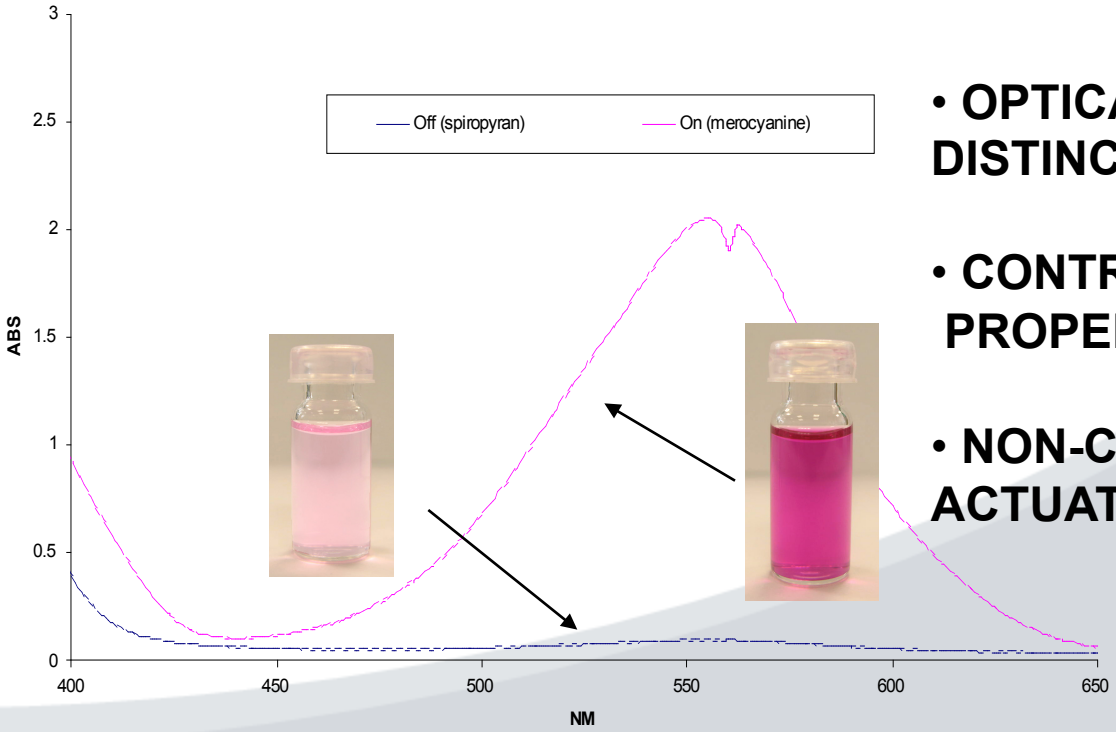
Ionic Liquids



Photoswitchable Materials

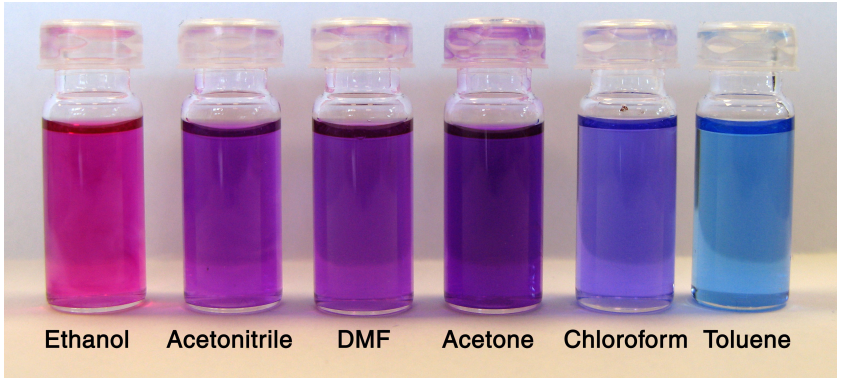


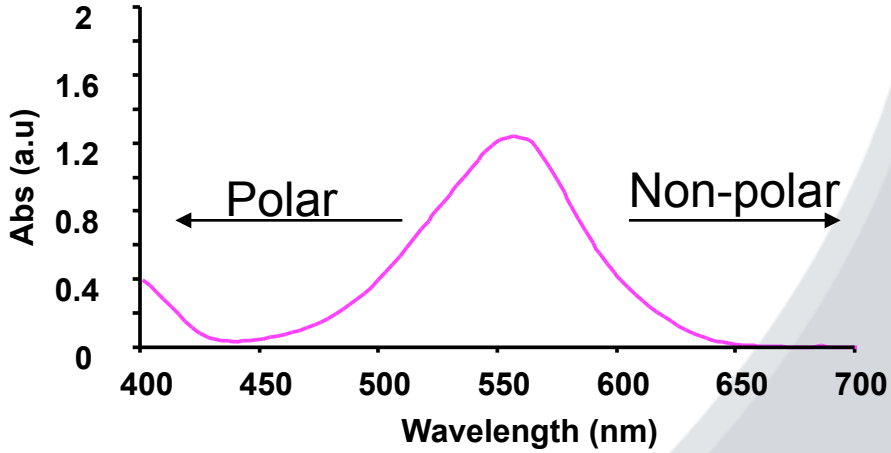




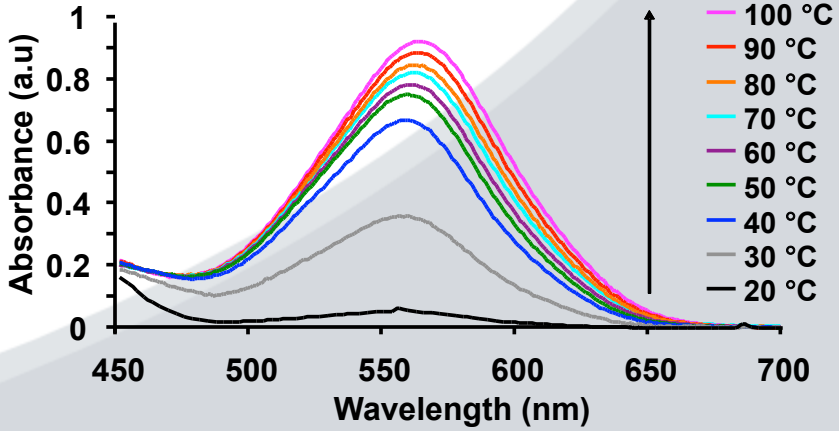
- **OPTICALLY ACTUATE BETWEEN TWO DISTINCT ISOMERS**
- **CONTROL PHYSICO-CHEMICAL PROPERTIES OF SYSTEM**
- **NON-CONTACT SPATIAL CONTROL OF ACTUATION**

Solvatochromic effect of spiropyran





Thermochromic effect of spiropyran



Multiple Personalities!

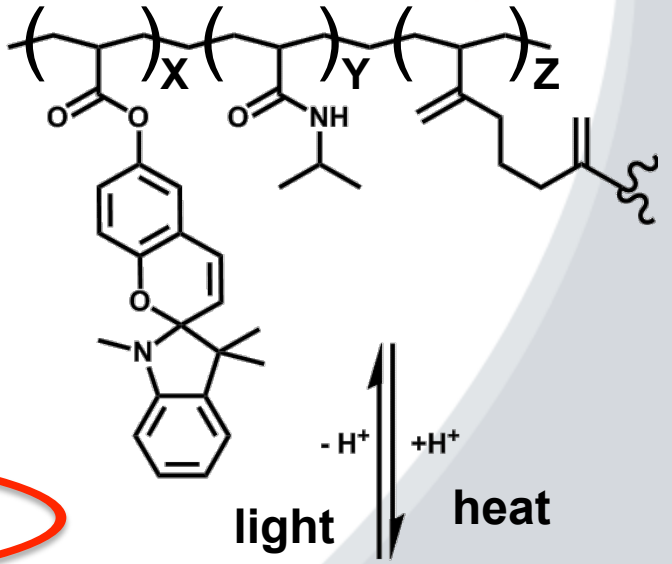
Photo-responsive polymer

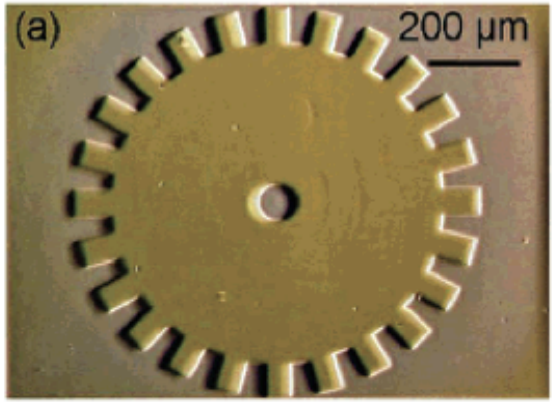
PROTONATED ISOMER INCORPORATED INTO CROSS LINKED THERMORESPONSIVE HYDROGEL

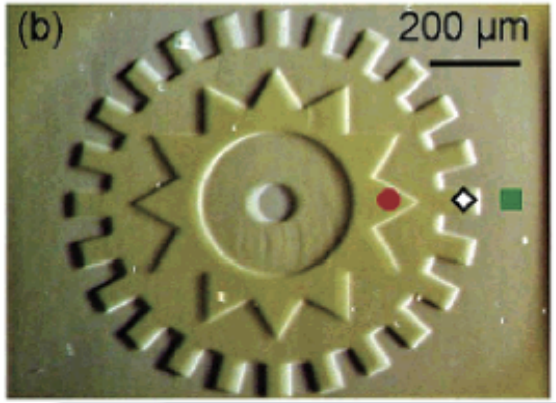
IRRADIATION OF BLUE LIGHT RESULTS IN CONTRACTION OF HYDROGEL

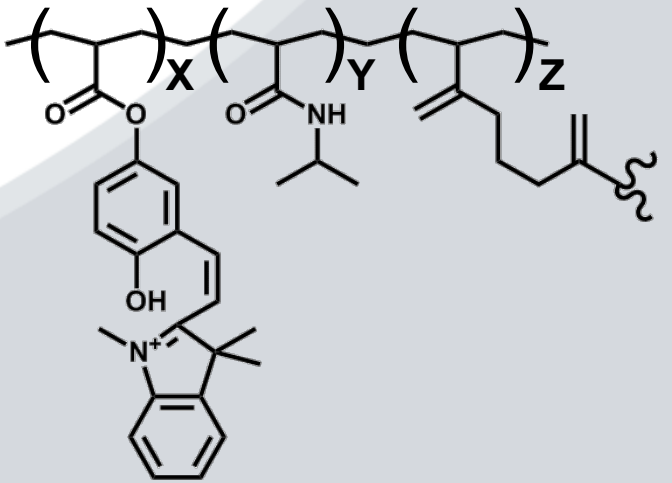
EXCELLENT SPATIAL RESOLUTION

TECHNICAL ISSUES INCLUDE EVAPORATION OF WATER FROM HYDROGEL









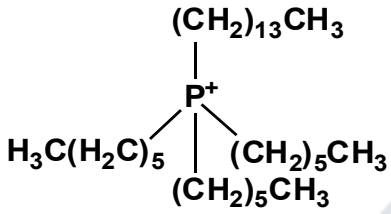
Sumaru *et al. Chem. Mater.*, 19 (11), 2730 -2732, 2007

Ionic Liquids- photoresponsive liquids

NEGLIGIBLE VAPOUR PRESSURE, NON-FLAMMABLE, THERMALLY STABLE AT HIGH TEMPERATURES

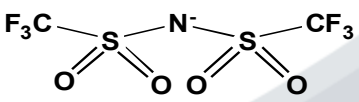
DESIGNER SOLVENTS (VISCOSITY, POLARITY, ACIDIC-BASIC, ELECTROCHEMICAL, ...)

ABILITY TO TUNE ION COMPOSITION

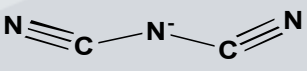


$[P_{6,6,6,14}]^+$

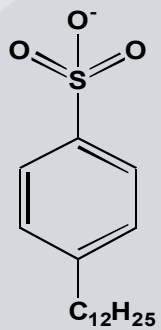
COMBINATION OF IONIC LIQUIDS AND PHOTO-RESPONSIVE MATERIALS OFFERS MANY ADVANTAGES!!!!



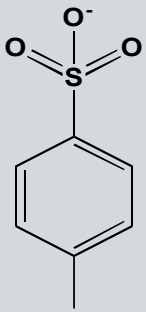
$[NTf_2]^-$



$[DCA]^-$



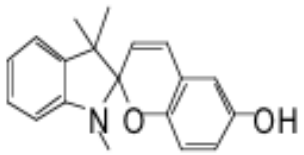
$[DBSA]^-$



$[Tos]^-$

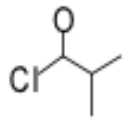
F. Benito-Lopez, et al., Mater. Today, 2010, 13, (7-8), July-August, 16-23.

Preparation of photo-responsive ionogel

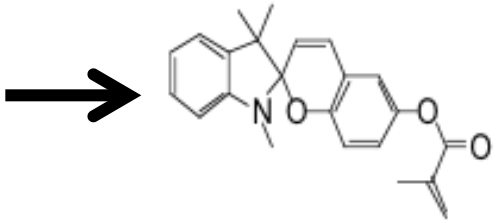


HYDROXYL-BENZOSPIROPYRAN

+

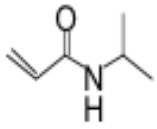


ACRYLOL CHLORIDE



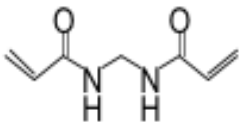
ACRYL ESTER BENZOSPIROPYRAN

+



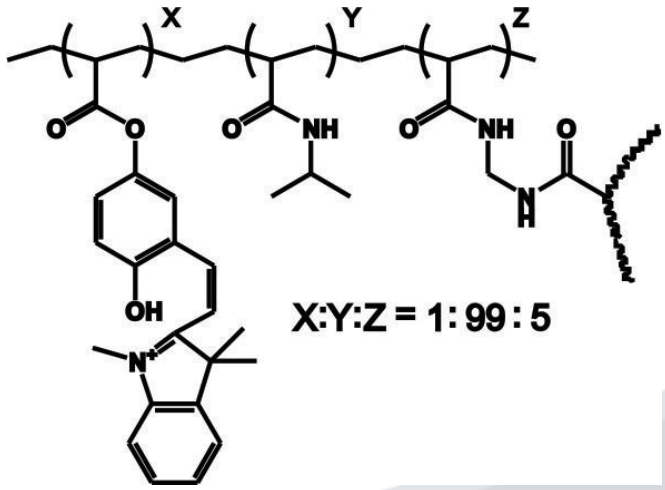
N-ISOPROPYLACRYLAMIDE

+

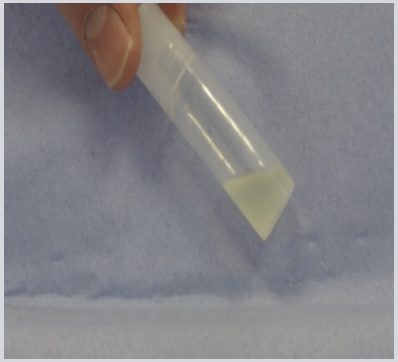


N,N-METHYLENE-BIS(ACRYLAMIDE)

1- IL + PHOTO-INITIATOR
2- 365 nm IRRADIATION
3- 1mM HCl

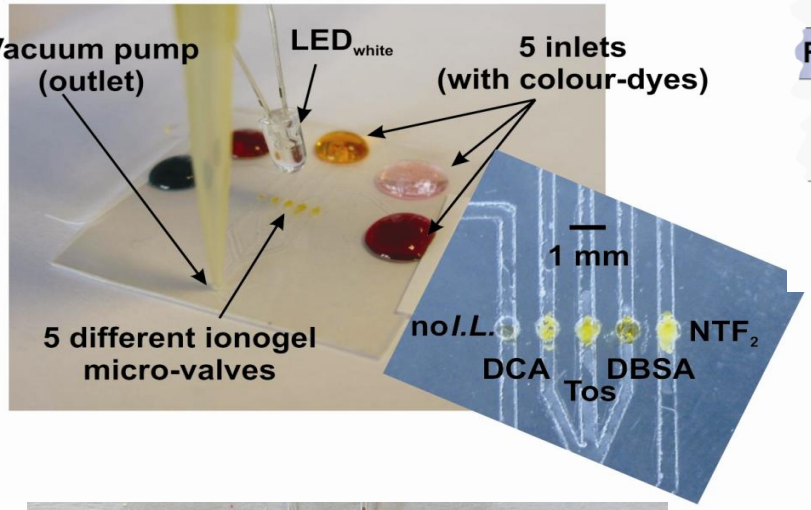


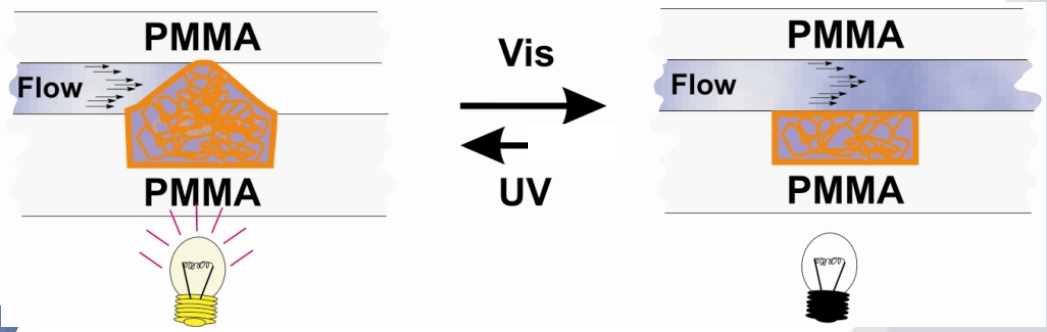
IONOGEL

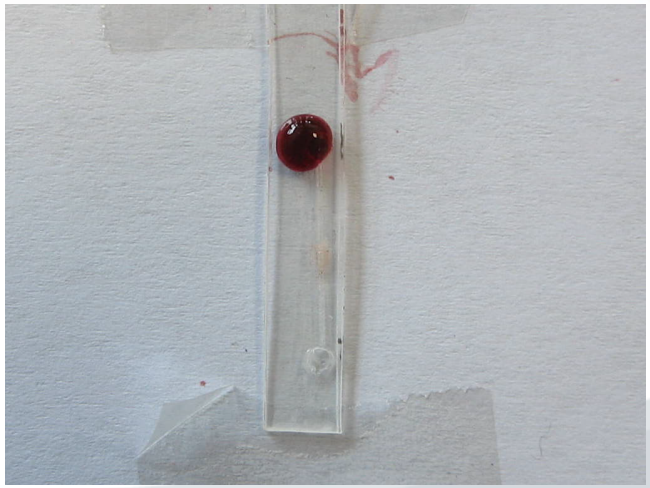


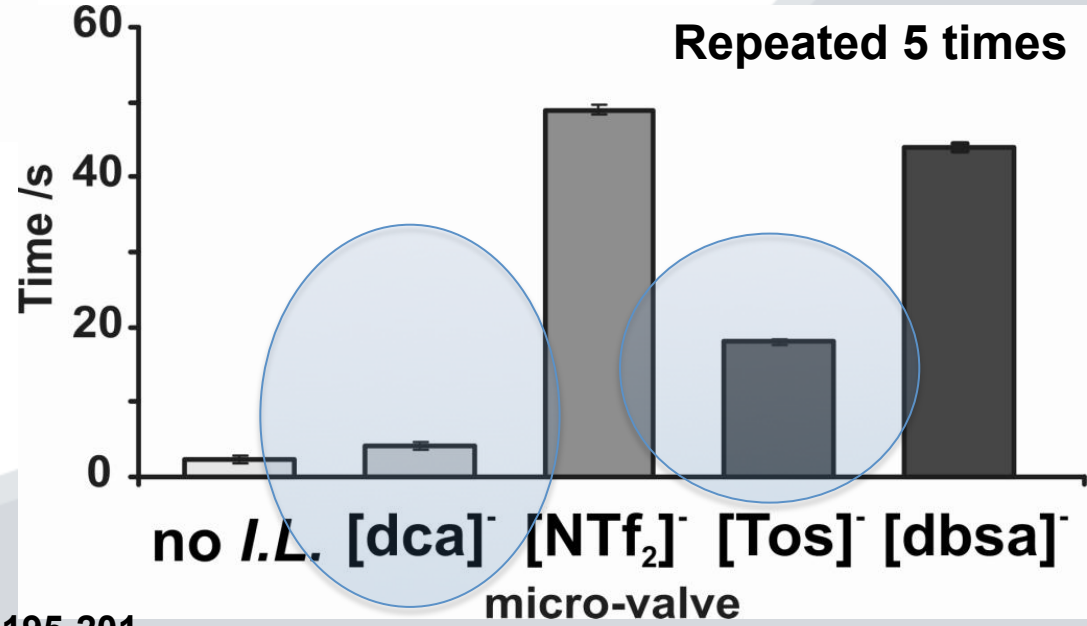
R. Byrne, C. Ventura, F. Benito-Lopez *et al.*, *Biosens & Bioelectron,* 26, 2010, 1392-1398

Multiple valves on one chip, using one actuation source!









F. Benito-Lopez *et al.*, *Lab on a Chip* 2010, *10*, 195-201.

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.**

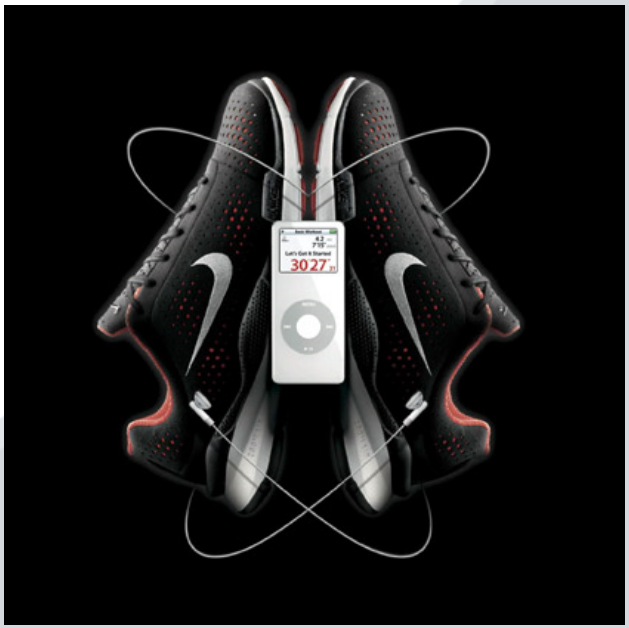
Introduction

LIFESHIRT®

PHYSIOLOGICAL SENSORS

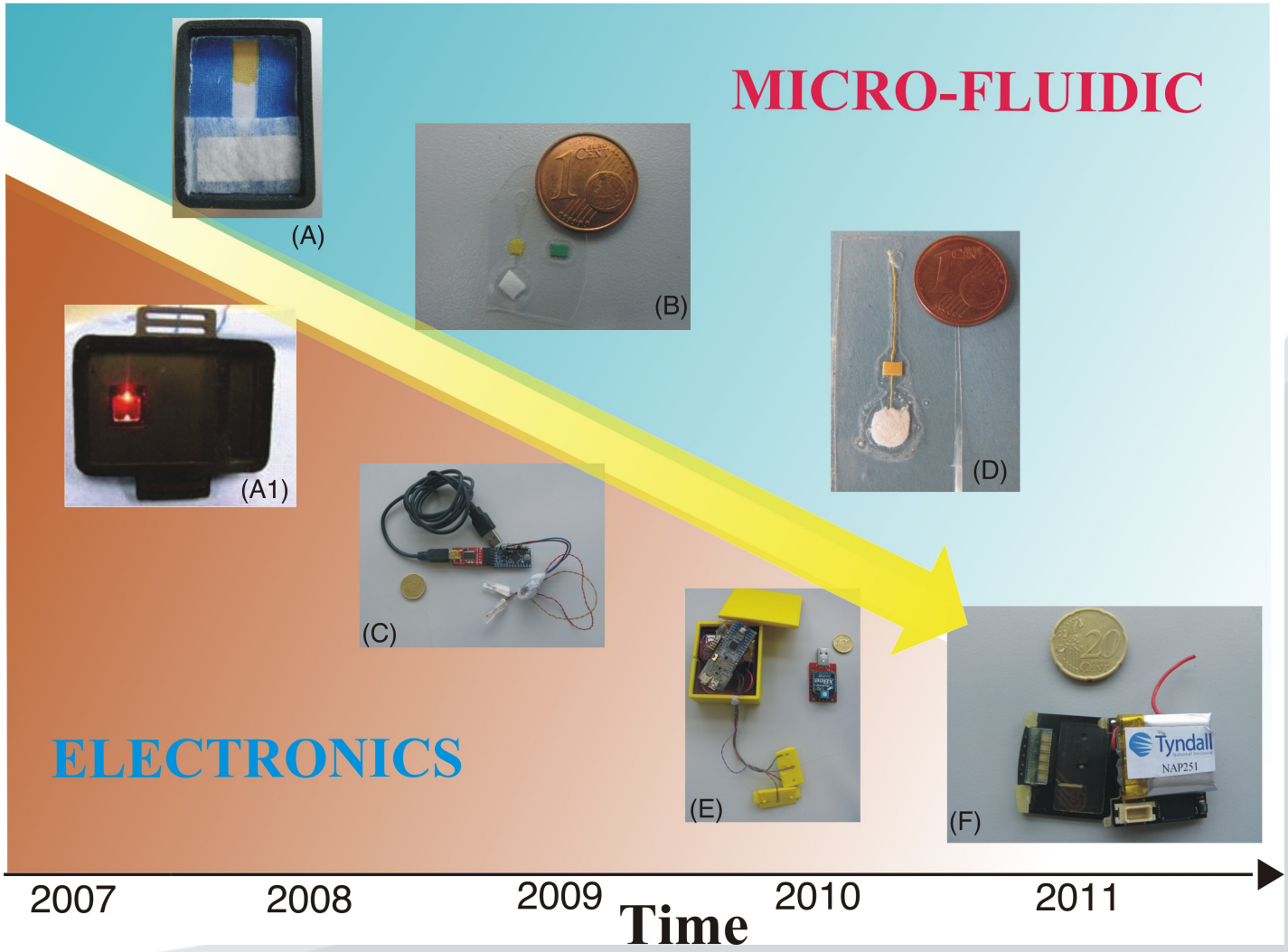
Breath rate, heart rate, activity, posture, skin temperature…

TRAINTRAK™



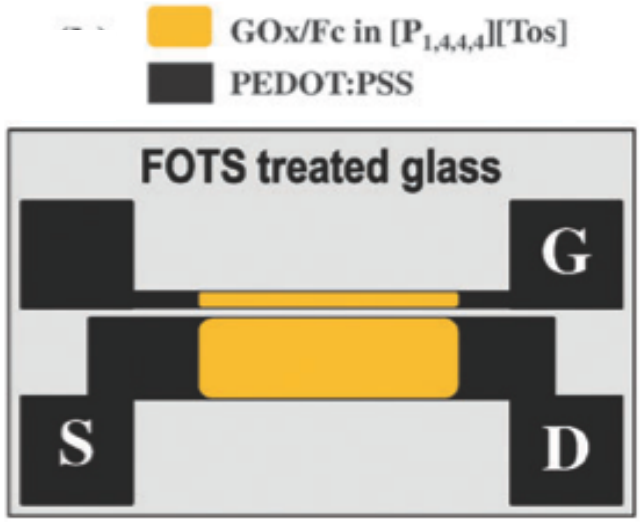
NIKE-APPLE IPOD SPORTS KIT

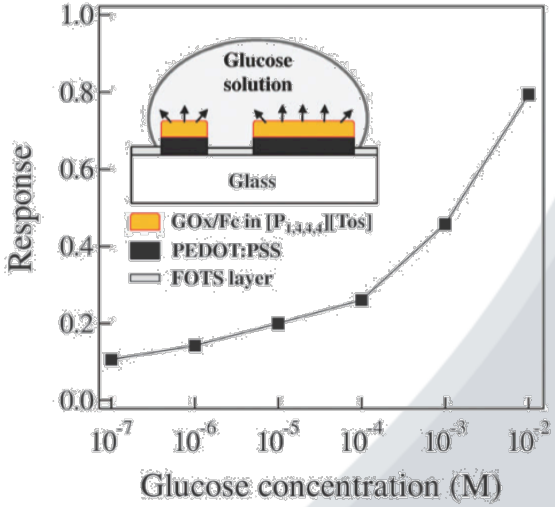
Device Evolution

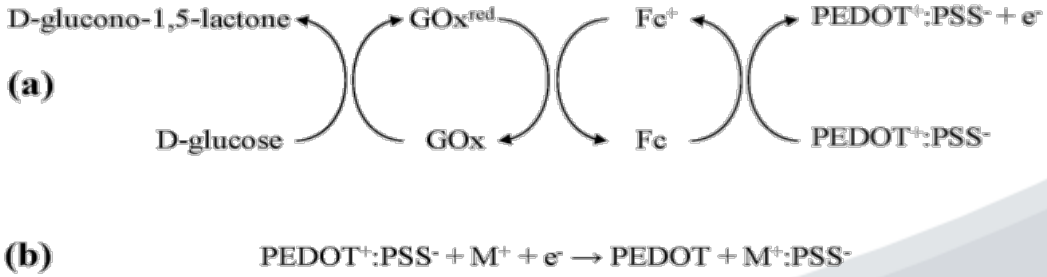


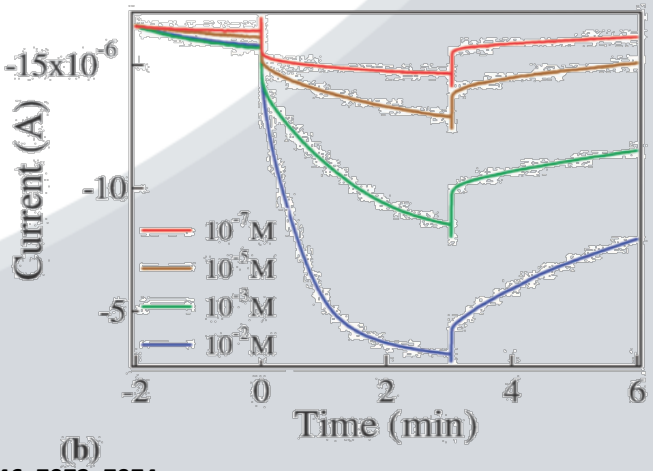
F. Benito-Lopez, S. Coyle, R. Byrne, A. Smeaton, N. E. O'Connor, D. Diamond, Procedia Chemistry, *1, 2009. 1103-1106.*

Glucose Detection by Organic Electrochemical Transistor (OECT)



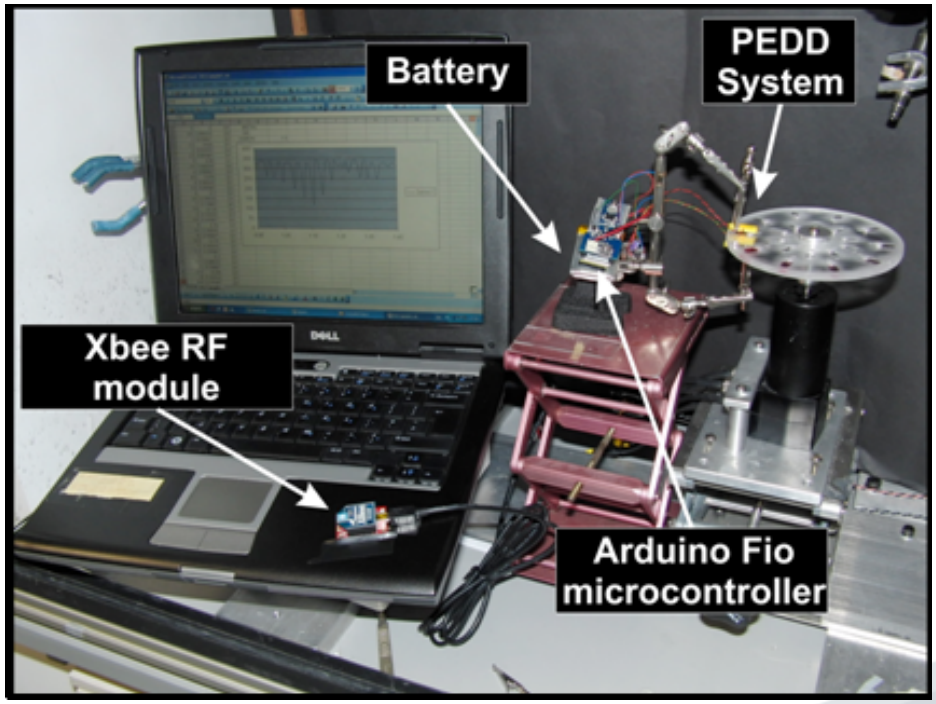


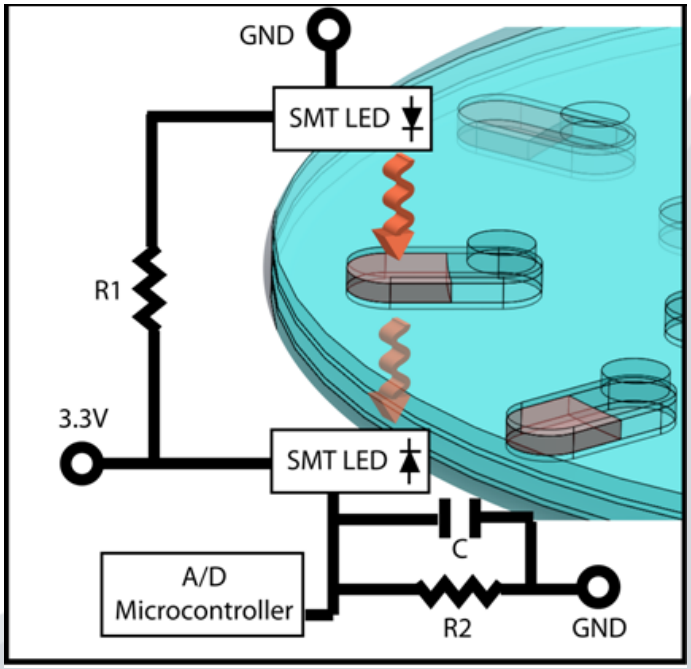




S. Yang, F. Cicoira, R. Byrne, F. Benito-Lopez, D. Diamond, G. Malliaras (2010) Chem. Commun., 46, 7972–7974

Wireless Paired Emitter Detector Diode Device as Optical Sensor for Lab-on-a-disc Applications





Prototype configuration of the PEDD system with schematic of circuit used in the system.

Conclusions

- MICROFLUIDICS HAS ACHIEVED MUCH IN TERMS OF DELIVERING A BASIC UNDERSTANDING OF FLUID HANDLING AND ANALYTICAL MEASUREMENTS IN MICRO/NANO-CHANNELS.

- THE NEXT PHASE HAS TO DELIVER FULLY INTEGRATED AND FUNCTIONING 'MICRO-TOTAL ANALYSIS SYSTEMS' THAT CAN PROVIDE SOLUTIONS WITH REAL SOCIO-ECONOMIC IMPACT.

- VITAL TO COMBINE STRONG APPLIED EFFORT TO PRODUCE NEXT GENERATION PLATFORMS & PROTOTYPES (EVOLUTIONARY ADVANCES) WITH FUNDAMENTAL BREAKTHROUGHS IN MATERIALS SCIENCE (REVOLUTIONARY ADVANCES).

Thanks to…..

CLARITY
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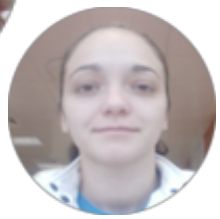
Dr. SHIRLEY COYLE, Dr. ROBERT BYRNE

KEVIN FRASER



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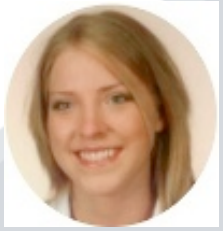

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QUESTIONS?