



New Functional Materials for Fluid Control and Sensing in Microfluidic Devices

Fernando Benito Lopez

CLARITY Centre for Sensor Web Technologies

National Centre for Sensor Research

Dublin City University

9th June 2011, University of Granada

National Centre for Sensor Research

- OVER 260 RESEARCHERS AND SUPPORT STAFF
- 23 AFFILIATED FACULTY
- INVESTMENTS AND INCOME SINCE 1999 NOW APPROACHING €100 MILLION
- 1500 m² WELL-EQUIPPED SPECIALIST LAB SPACE AND OFFICE







CLARITY – SFI CSET



Vision: Sensing Mind, Body & Place



Understanding and leveraging key sensory information channels

Mind Sensing people's preferences and intentions

Body Sensing physical status and wellness indicators

Place Sensing interaction between people and their environment

- 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**

Sensor Hierarchy



- PHYSICAL TRANSDUCERS THE GOOD GUYS; LOW COST, RELIABLE, LOW POWER DEMAND, LONG LIFE-TIME
 - THERMISTORS (TEMPERATURE), MOVEMENT, LOCATION, POWER,, LIGHT LEVEL, CONDUCTIVITY, FLOW, SOUND/AUDIO,
- CHEMICAL SENSORS MORE COMPLICATED, MISBEHAVE, NEED REGULAR CALIBRATION, MUCH MORE COSTLY TO IMPLEMENT
 - ELECTROCHEMICAL, OPTICAL, ... FOR METAL IONS, PH, ORGANICS...
- BIOSENSORS THE WORST OF ALL, VERY DIFFICULT TO WORK WITH, DIE QUICKLY, SINGLE SHOT (DISPOSABLE) MODE
 - DUE TO THE DELICATE NATURE OF ENZYMES, ANTIBODIES....



BUT CAN WE USE THESE SENSORS IN CONTINUOUS DIRECT CONTACT WITH REAL SAMPLES TO PROVIDE LOW COST, AUTONOMOUS SENSING PLATFORMS...

Fundamental Problem: Sensor surface will CLARITY change with time!



SURFACES SUSCEPTIBLE TO BIOFOULING: THE SENSOR SAMPLES THE BIOFILM LAYER, NOT THE BULK SOLUTION!

=> DRIFT, LOSS OF SENSITIVITY/LOD/SELECTIVITY => REGULAR CALIBRATION (LIQUID HANDLING) => HIGH COST OF OWNERSHIP

Direct Sensing vs. Reagent Based LOAC CLA





8

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 A P P L I C A T I O N S O F T H E S E D E V I C E S PROLIFERATING THROUGHOUT SCIENCE. IN FACT, IT HAS NOT (YET) HAPPENED.

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

UNIVERSITY COLLEGE DUBLIN . DUBLIN CITY UNIVERSITY . TYNDALL NATIONAL INSTITUTE

Achieving Scale-up





Scalability ->



Use of microfluidics for the solution of problems??



MARKET

MICROFLUIDIC TECHNOLOGY



BETTER THAN EXSISTING TECHNOLOGY

DEVELOPMENT!!!



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



Photoswitchable Materials



TYNSALIDE ON ALENSTITUTE UNIVERSITY COLLEGE DUBLIN

DUBLIN CITY UNIVERSITY

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



- CONSIST SOLELY OF IONS AND LIQUIDUS AT RT
- NEGLIGIBLE VAPOUR PRESSURE, NON-FLAMMABLE, THERMALLY STABLE AT HIGH TEMPERATURES
- DESIGNER SOLVENTS (VISCOSITY, POLARITY, ACIDIC-BASIC, ELECTROCHEMICAL, ...)
- **ABILITY TO TUNE ION COMPOSITION**
- APPLICATIONS IN CATALYSIS, SEPARATIONS, POLYMERIZATIONS (IONIC LIQUIDS IN GELS, SOLID STATE ELECTROLYTES)
- THE NUMBER OF PAPERS PUBLISHED IN 1995 WAS APPROXIMATELY 20 AND ROSE TO 2,500 IN 2006.



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





Preparation of photo-responsive ionogel



Byrne et al., Biosens & Bioelectron, 26, 2010, 1392-1398

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[®]

P.



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.

UNIVERSITY COLLEGE DUBLIN . DUBLIN CITY UNIVERSITY . TYNDALL NATIONAL INSTITUTE

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

(a)

(b)



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.



UNIVERSITY COLLEGE DUBLIN • DUBLIN CITY UNIVERSITY • TYNDALL NATIONAL INSTITUTE

Calibration of 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.....



Dr. SHIRLEY COYLE & Dr. ROBERT BYRNE





LARISA FLOREA

CAROLINE BARRY



VINCENZO F. CURTO

MONIKA CZUGALA



Prof. DERMOT DIAMOND



07/CE/I1147





UNIVERSITY COLLEGE DUBLIN • DUBLIN CITY UNIVERSITY • TYNDALL NATIONAL INSTITUTE