EuroNanoForum 2015

Revolutionising Environmental Monitoring Technologies: Key Barriers and Possible Solutions

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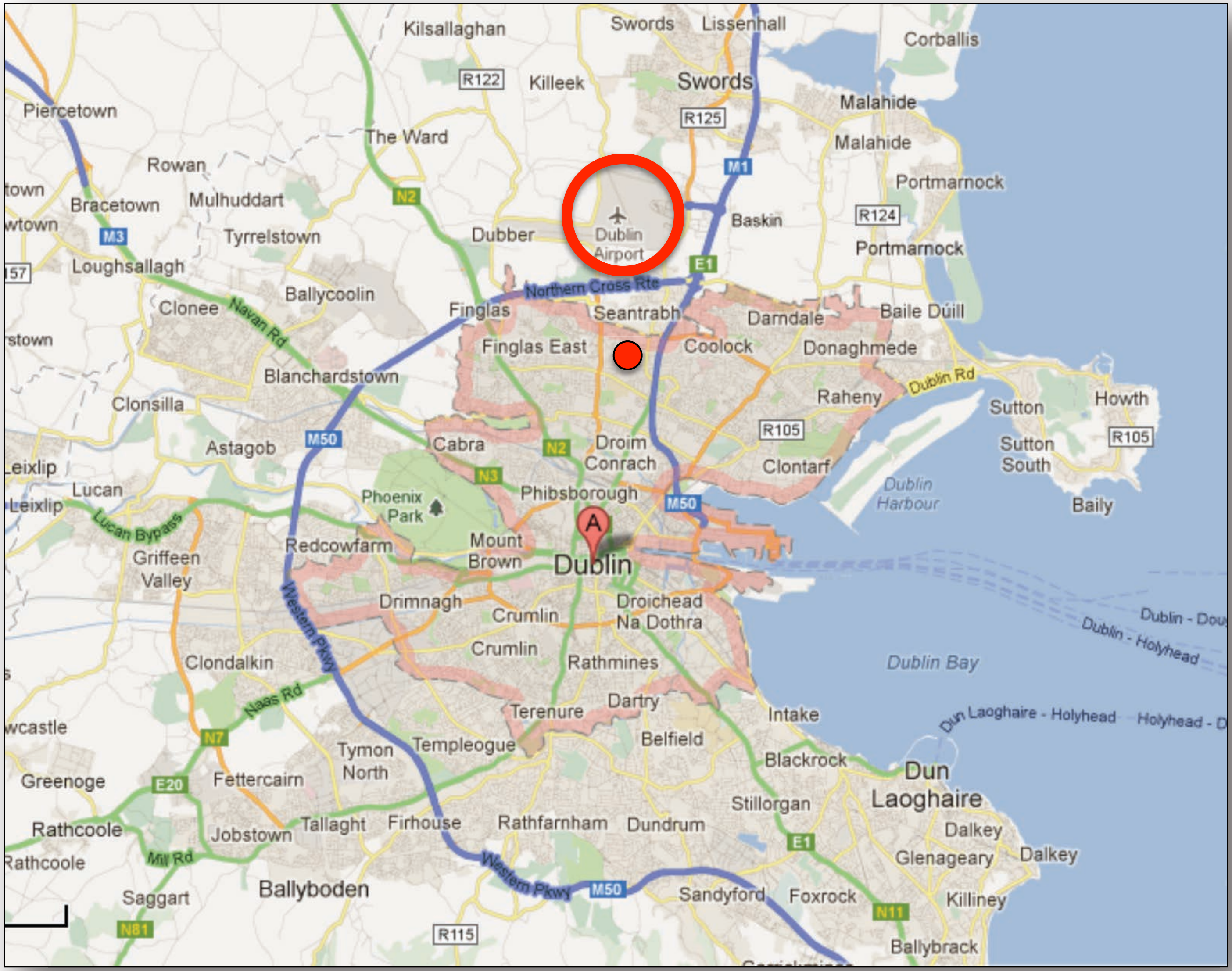
Dublin City University, Dublin 9, Ireland

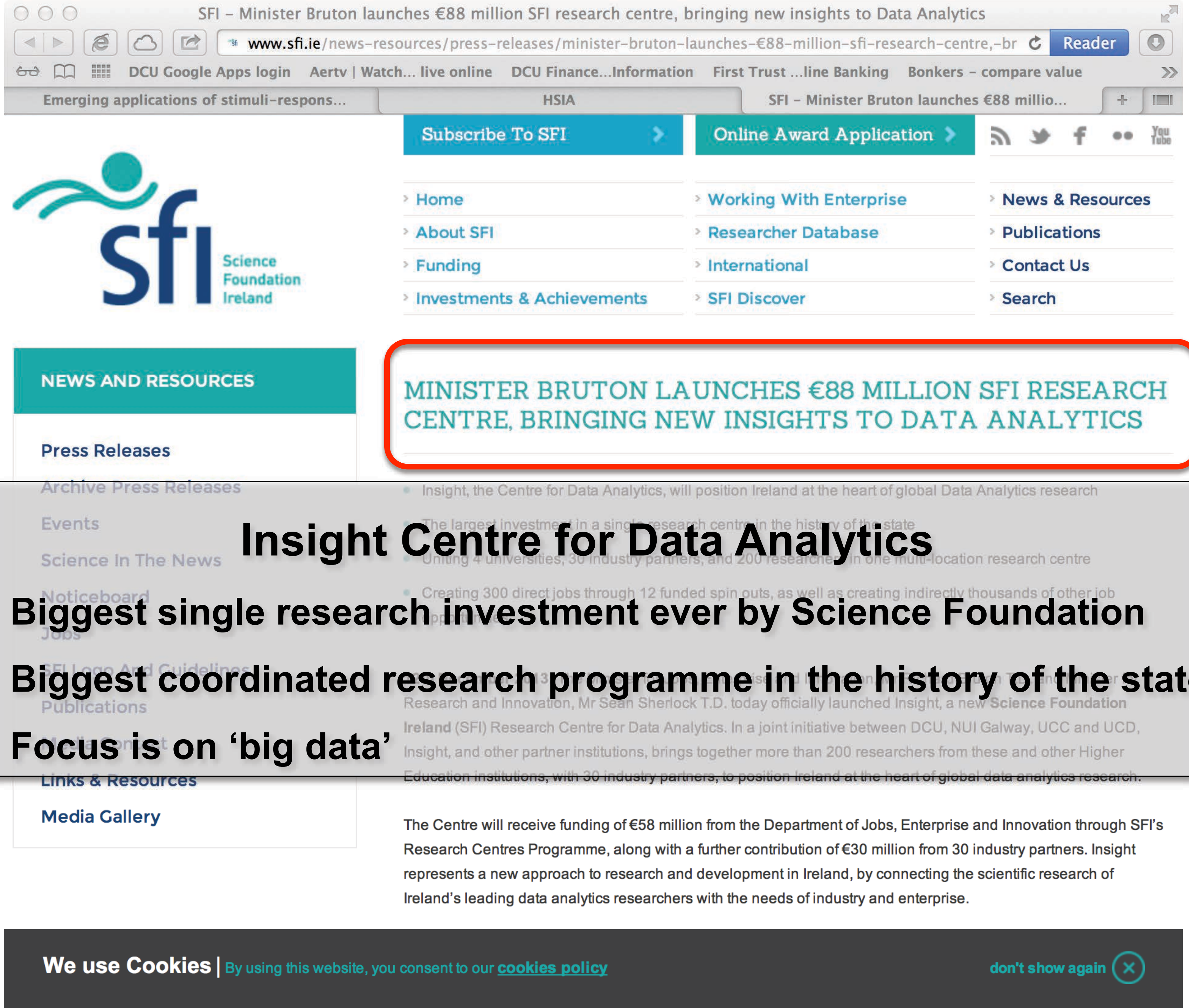
EuroNanoForum 2016, Riga, Latvia
S4: Nanotechnology's role for a sustainable environment (water, soil, air)
27th May 2015

Latvian Presidency of the Council of the European Union
EU2015.LV

HORIZON 2020
EUROPEAN UNION FUNDING
FOR RESEARCH & INNOVATION

Dublin & DCU Location





SFI – Minister Bruton launches €88 million SFI research centre, bringing new insights to Data Analytics

www.sfi.ie/news-resources/press-releases/minister-bruton-launches-€88-million-sfi-research-centre,-br

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MINISTER BRUTON LAUNCHES €88 MILLION SFI RESEARCH CENTRE, BRINGING NEW INSIGHTS TO DATA ANALYTICS

- Insight, the Centre for Data Analytics, will position Ireland at the heart of global Data Analytics research
- The largest investment in a single research centre in the history of the state
- Uniting 4 universities, 30 industry partners, and 200 researchers in one multi-location research centre
- Creating 300 direct jobs through 12 funded spin outs, as well as creating indirectly thousands of other job opportunities

Research and Innovation, Mr Seán Sherlock T.D. today officially launched Insight, a new Science Foundation Ireland (SFI) Research Centre for Data Analytics. In a joint initiative between DCU, NUI Galway, UCC and UCD, Insight, and other partner institutions, brings together more than 200 researchers from these and other Higher Education institutions, with 30 industry partners, to position Ireland at the heart of global data analytics research.

The Centre will receive funding of €58 million from the Department of Jobs, Enterprise and Innovation through SFI's Research Centres Programme, along with a further contribution of €30 million from 30 industry partners. Insight represents a new approach to research and development in Ireland, by connecting the scientific research of Ireland's leading data analytics researchers with the needs of industry and enterprise.

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Insight Centre for Data Analytics

- **Biggest single research investment ever by Science Foundation**
- **Biggest coordinated research programme in the history of the state**
- **Focus is on 'big data'**

NAPES Consortium

NAPES
NEXT GENERATION ANALYTICAL PLATFORMS FOR ENVIRONMENTAL SENSING

DCU

institut Curie

TelLab

WIS
Williams Industrial Services

TU/e

CIC microGUNE
Microtechnologies Cooperative Research Center

UNIVERSITÀ DEGLI STUDI DI MILANO

Aquila Bioscience

Funded under grant agreement No. 604241 of the European Union's Seventh Framework Programme

SEVENTH FRAMEWORK PROGRAMME

‘Grand Challenge for Analytical Chemistry’

- “A **‘Grand Challenge’** posed for analytical chemistry is to develop a capability for sampling and **monitoring air, water and soil much more extensively and frequently than is now possible**”
- “Such goals will require **improvements in sampling methodology** and in **techniques for remote measurements**, as well as approaches that **greatly lower per-sample and per-measurement costs**”

Royce Murray, Editorial, Analytical Chemistry, February 2010

Remote (Continuous) Sensing Challenges: Platform and Deployment Hierarchies

Physical Transducers –low cost, reliable, low power demand, long life-time

Thermistors (temperature), movement, location, power,, light level, conductivity, flow, sound/audio, ……

Chemical Sensors – more complicated, need regular calibration, more costly to implement

Electrochemical, Optical, .. For metal ions, pH, organics…

Biosensors – the most challenging, very difficult to work with, die quickly, single shot (disposable) mode dominant use model

Due to the delicate nature of biomaterials enzymes, antibodies….

Increasing difficulty & cost

Increasing scalability

Gas/Air Sensing – easiest to realise

Reliable sensors available, relatively low cost

Integrate into platforms, develop IT infrastructure, GIS tools, Cloud Computing

On-land Water/ Monitoring

More accessible locations

Target concentrations tend to be higher

Infrastructure available

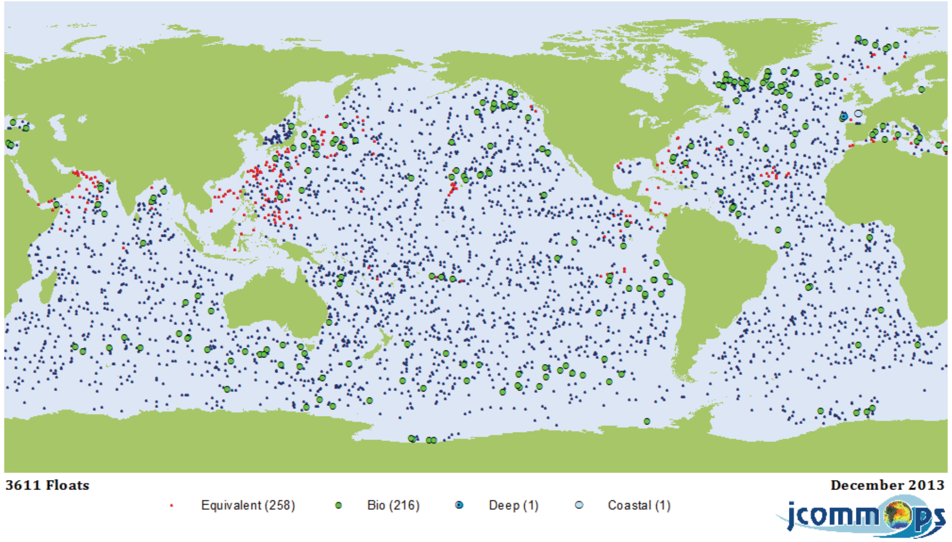
Marine Water

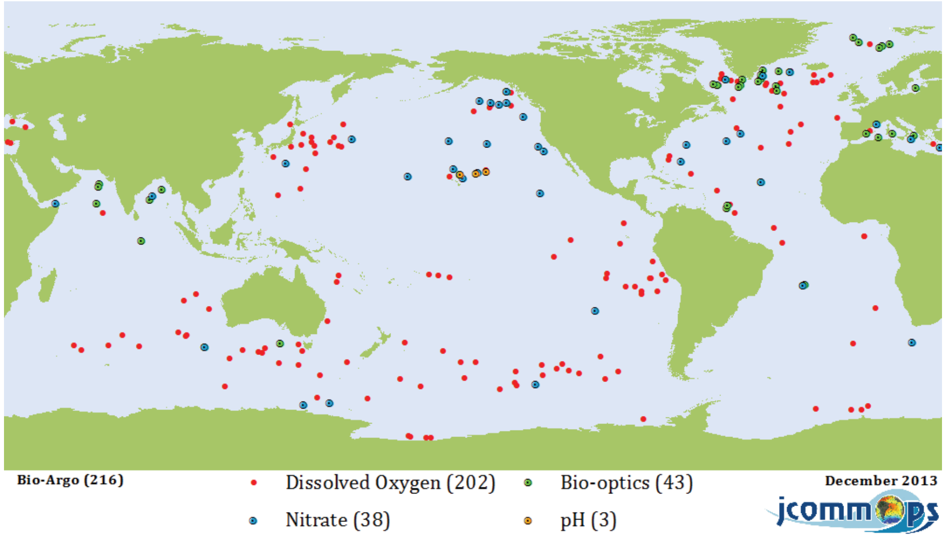
Challenging conditions

Remote locations & Limited infrastructure

Concentrations tend to be lower and tighter in range

Argo Project (accessed March 9 2014)





- **Ca. 3,600 floats: temperature and salinity**
- **Only 216 reporting chem/bio parameters (ca. 6%)**
- **Of these nitrate (38), DO (202), Bio-optics (43), pH (3)**

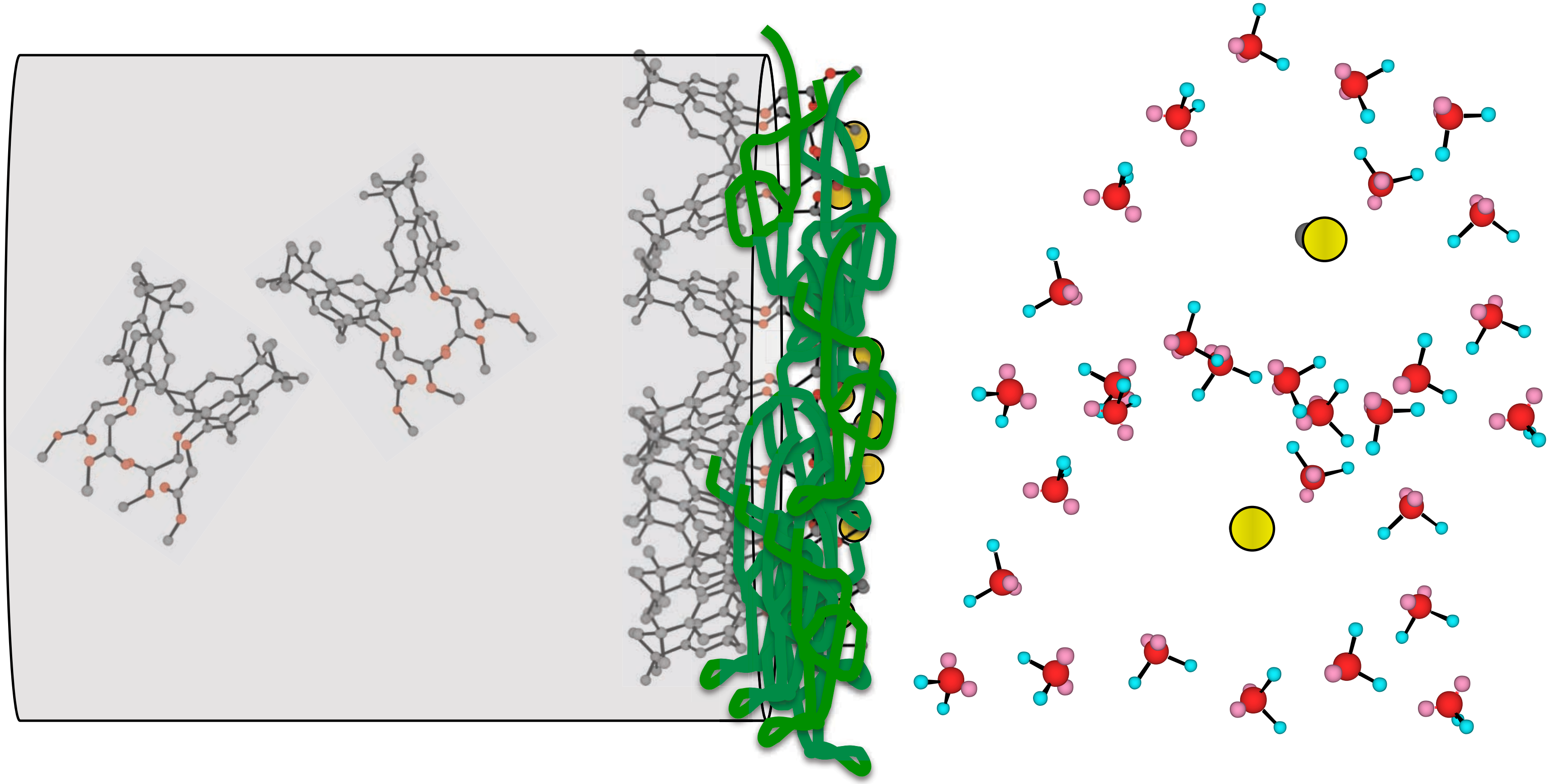
@€60K ea!

DO is by Clark Cell (Sea Bird Electronics) or Dynamic fluorescence quenching (Aanderaa)

See https://picasaweb.google.com/JCOMMOPS/ArgoMaps?authuser=0&feat=embedwebsite

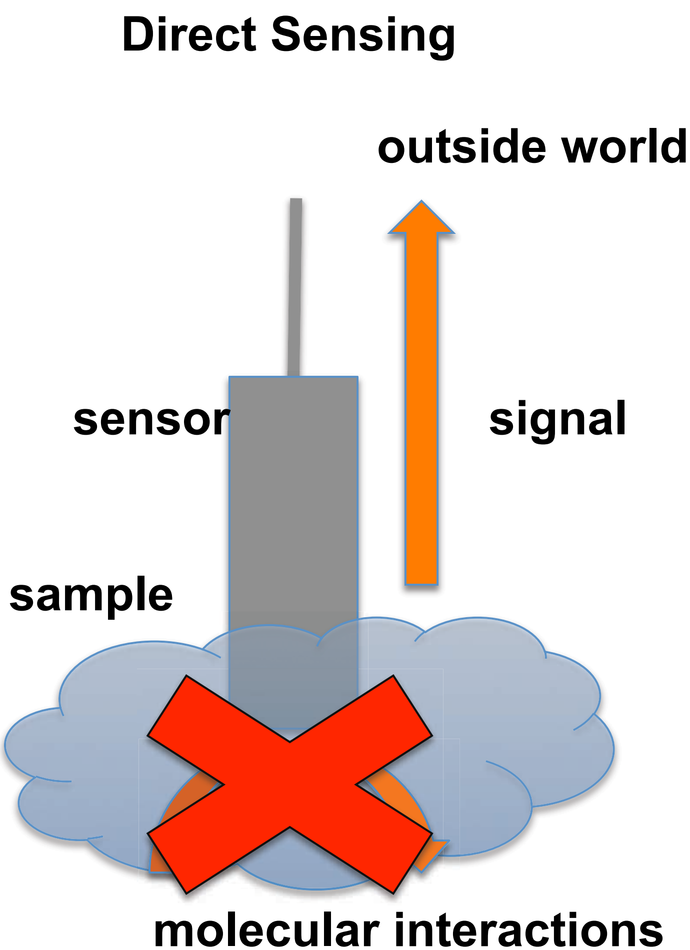
‘calibration of the DO measurements by the SBE sensor remains an important issue for the future’, Argo report ‘Processing Argo OXYGEN data at the DAC level’, September 6, 2009, V. Thierry, D. Gilbert, T. Kobayashi

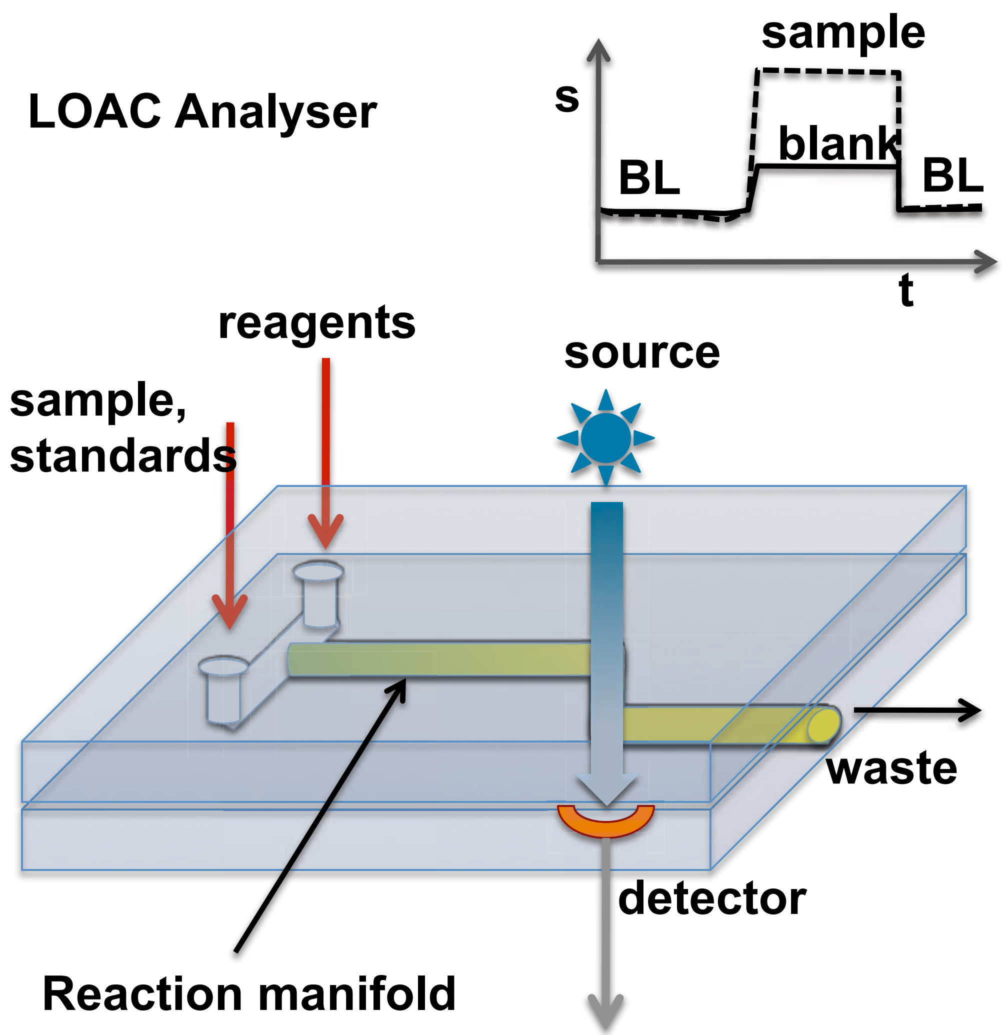
Control of membrane interfacial exchange & binding processes



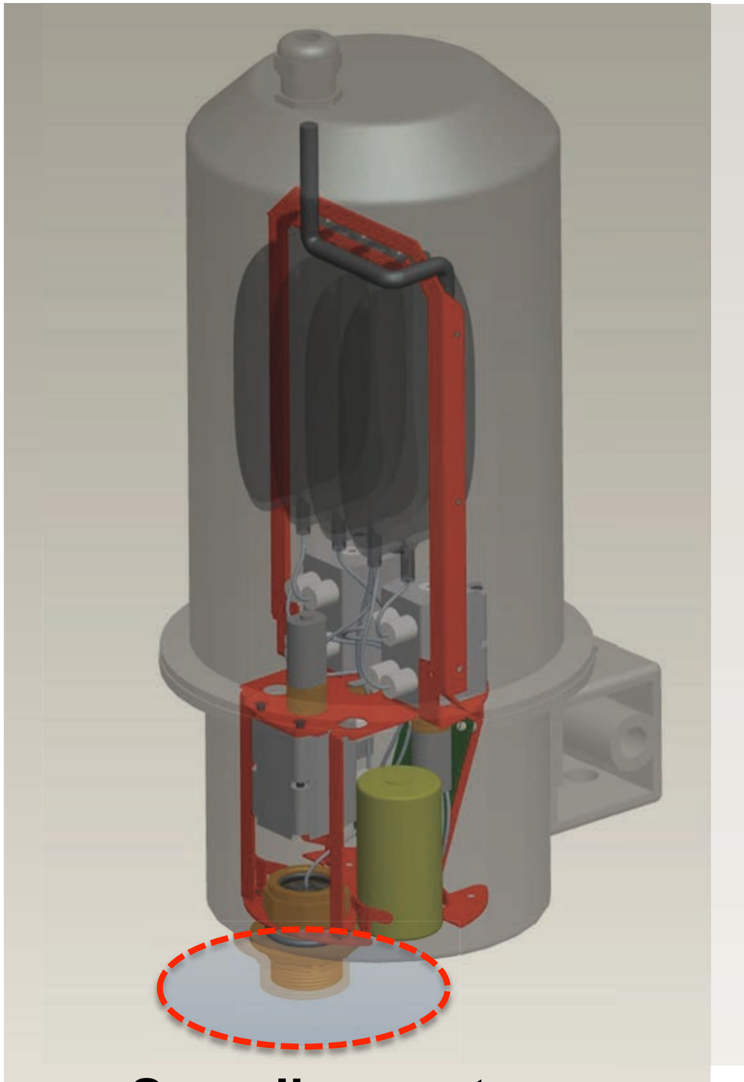
Remote, autonomous chemical sensing is a tricky business!

Direct Sensing vs. Reagent Based LOAC/ufluidics



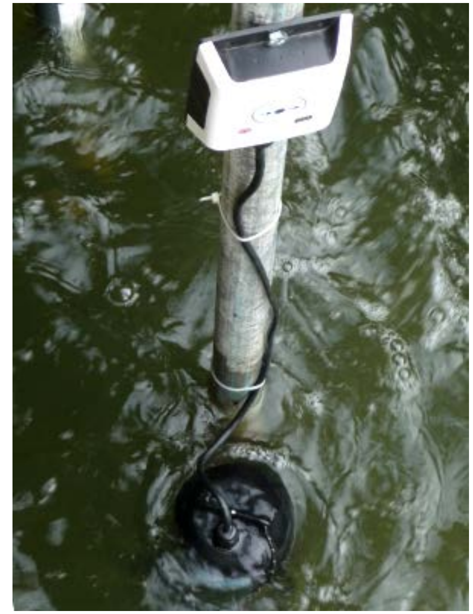


2nd Generation Analyser: Design



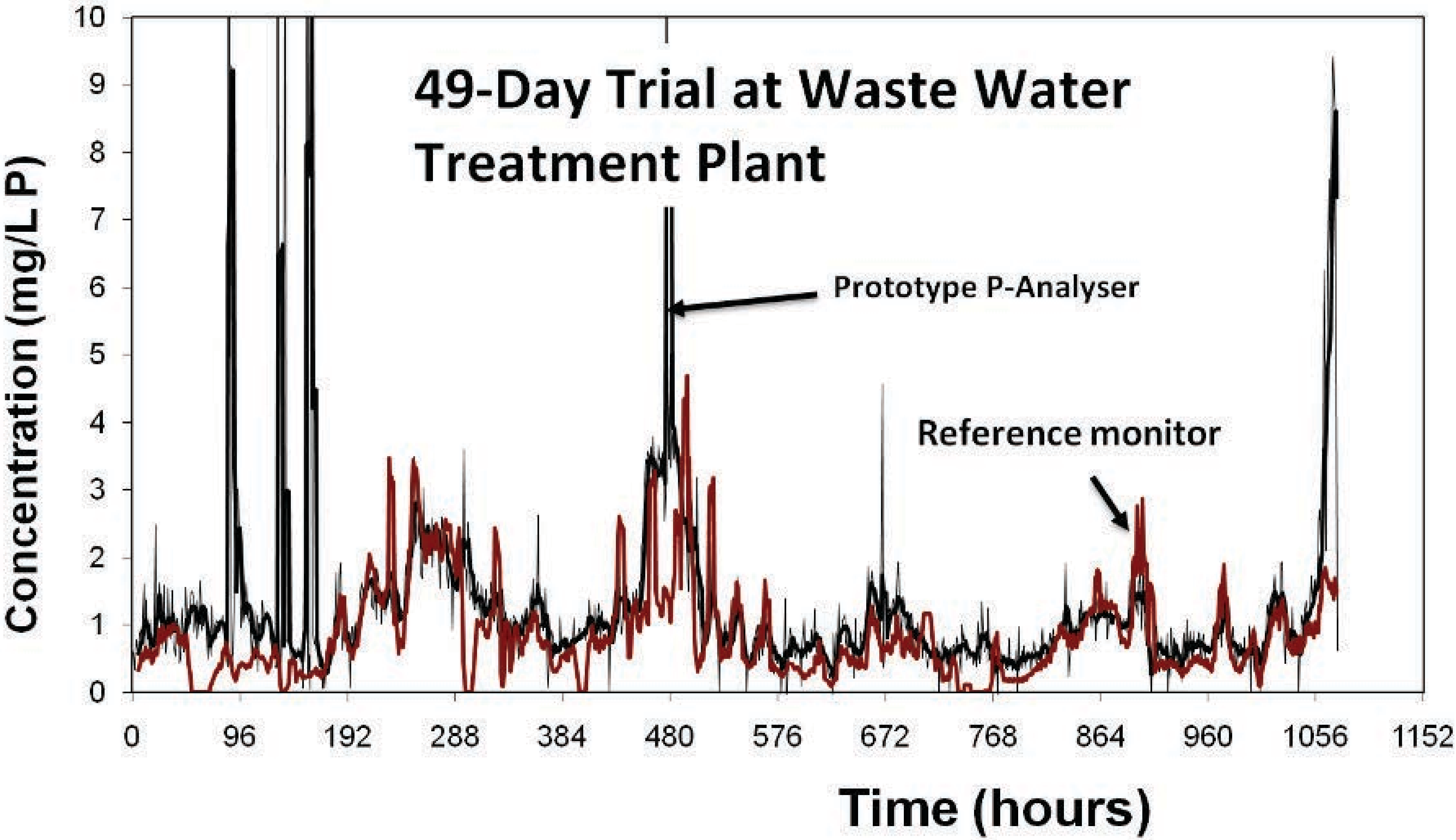
Sampling port

Deployment at Osberstown WWTP



- Phosphate monitoring unit deployed
- System is fully immersed in the treatment tank
- Wireless communications unit linked by cable
- Data transmitted to web

Autonomous Chemical Analyser

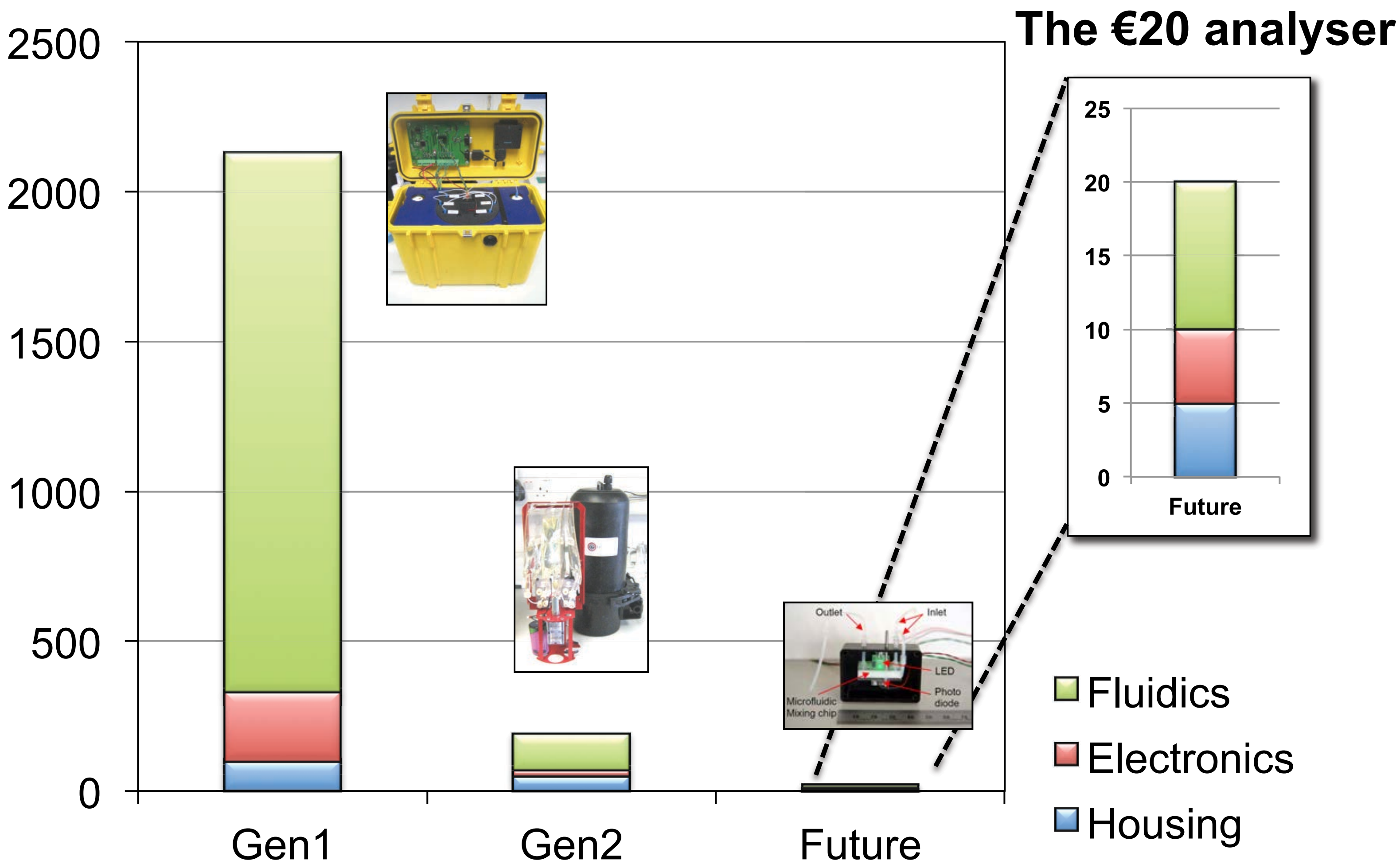


Phosphate monitoring using the Yellow Method

Osberstown – 3 week deployment

Biofouling of sensor surfaces is a major challenge for remote chemical sensing – both for the environment and for implantable sensors

Cost Comparison Analyser (€)

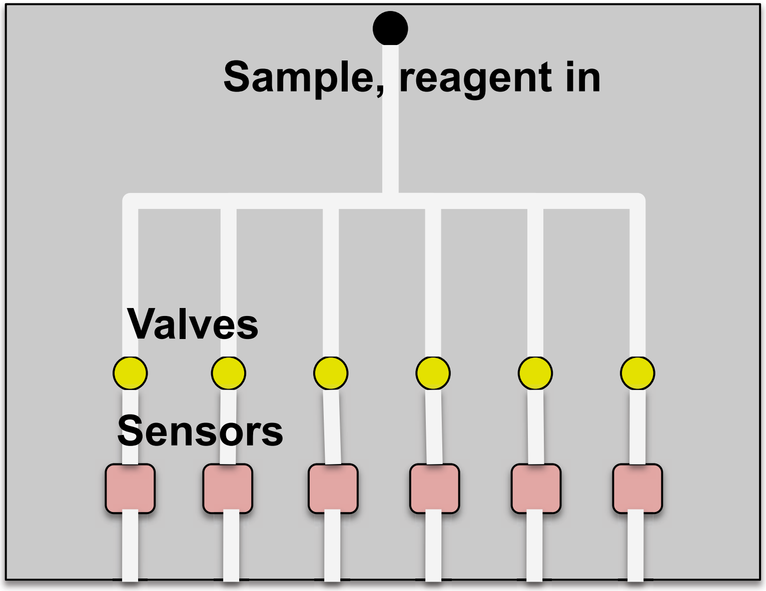


Multi-Functional Fluidics

- **At present, the fluidic system's function is to;**
  - Transport reagents, samples, standards to the detector
  - Perform relatively simple (but important) tasks like cleaning, mixing
  - Switching between samples, standards, cleaning solutions
- **In the future, the fluidic system will perform much more sophisticated 'bio-inspired' functions**
  - System diagnostics, leak/damage detection
  - Self-repair capability
  - Switchable behaviour (e.g. surface roughness, binding/release),
- **These functions will be inherent to the channels and integrated with circulating smart micro/nano-vehicles**
  - Spontaneously move under an external stimulus (e.g. chemical, thermal gradient) to preferred locations
  - Perform complex tasks on arrival

Extend Period of Use via Arrays of Sensors….?

- If each sensor has an in-use lifetime of 1 week….
- And these sensors are very reproducible….
- And they are very stable in storage (up to several years)….

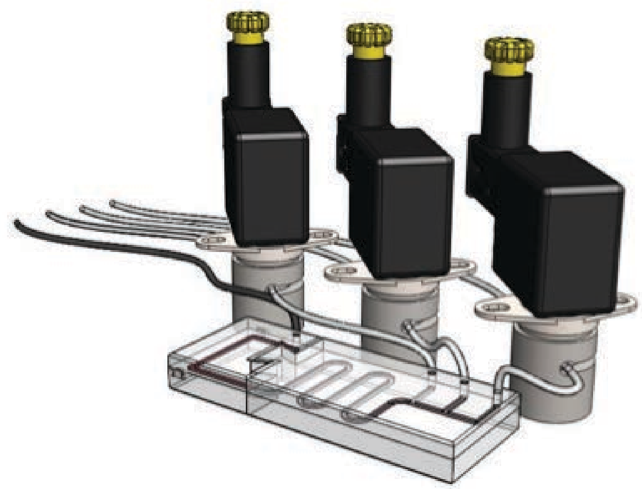


Then 50 sensors when used sequentially could provide an aggregated in-use lifetime of around 1 year

But now we need multiple valves integrated into a fluidic platform to select each sensor in turn

How to advance fluid handling in LOC platforms: re-invent valves (and pumps)!

- **Conventional valves cannot be easily scaled down - Located off chip: fluidic interconnects required**
  - Complex fabrication
  - Increased dead volume
  - Mixing effects
- **Based on solenoid action**
  - Large power demand
  - Expensive



Solution: soft-polymer (biomimetic) valves fully integrated into the fluidic system

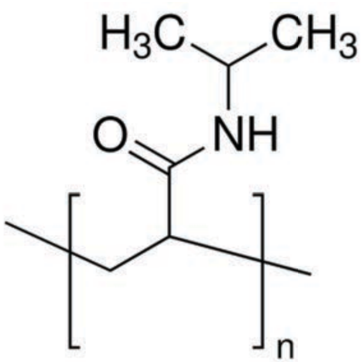
Famous Molecule….

From Prof. Thorfinnur Gunnlaugsson, TCD School of Chemistry
Spotted on Nickelodeon Cartoons February 2015

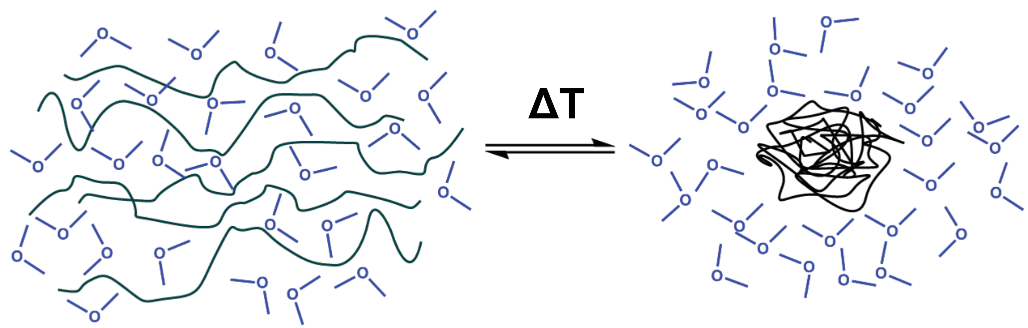
Poly(*N*-isopropylacrylamide)

- **pNIPAAM exhibits inverse solubility upon heating**
- **This is referred to as the LCST (Lower Critical Solution Temperature)**
- **Typically this temperature lies between 30-35^{o}C, but the exact temperature is a function of the (macro)molecular microstructure**
- **Upon reaching the LCST the polymer undergoes a dramatic volume change, as the hydrated polymer chains collapse to a globular structure, expelling the bound water in the process**

pNIPAAM



Hydrophilic **Hydrophobic**



Hydrated Polymer Chains

Loss of bound water -> polymer collapse

Polymer based photoactuators based on pNIPAAm

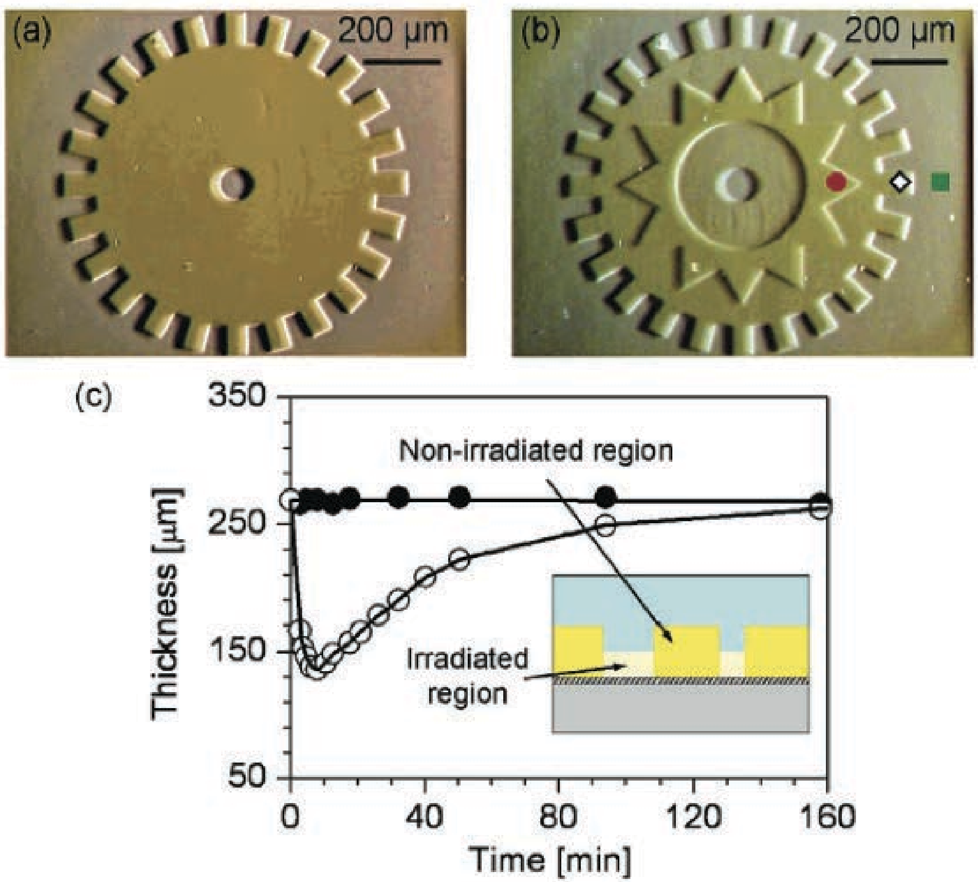
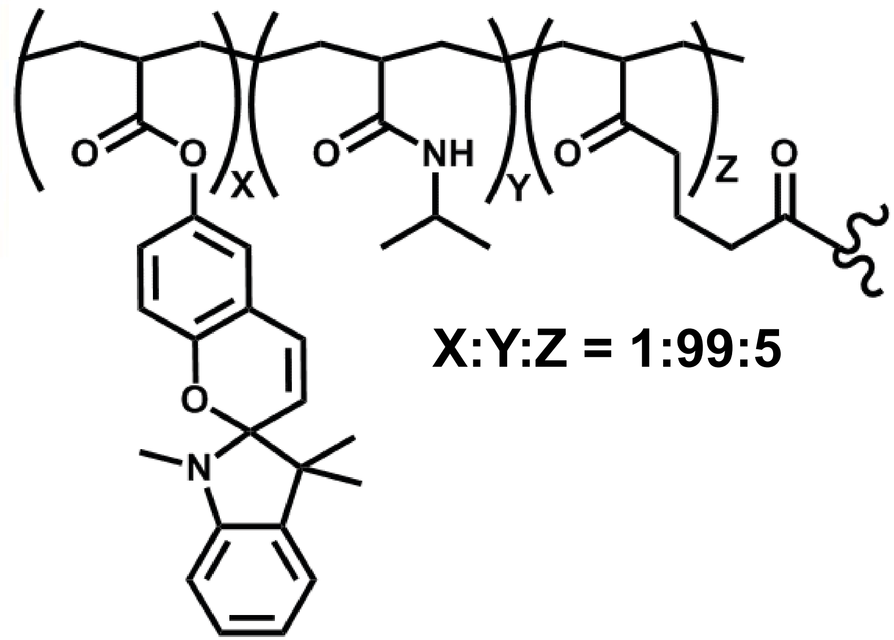


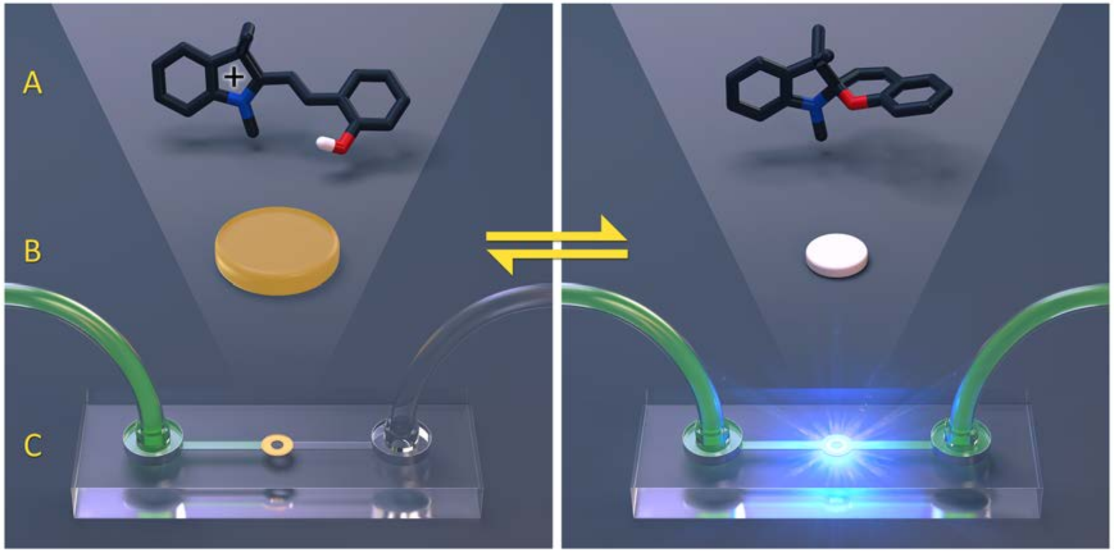
Figure 3. (a, b) Images of the pSPNIPAAm hydrogel layer just after the micropatterned light irradiation. Duration of irradiation was (●, red) 0, (◇) 1, and (■, green) 3 s. (c) Height change of the hydrogel layer in (●) non-irradiated and (○) irradiated region as a function of time after 3 s blue light irradiation.

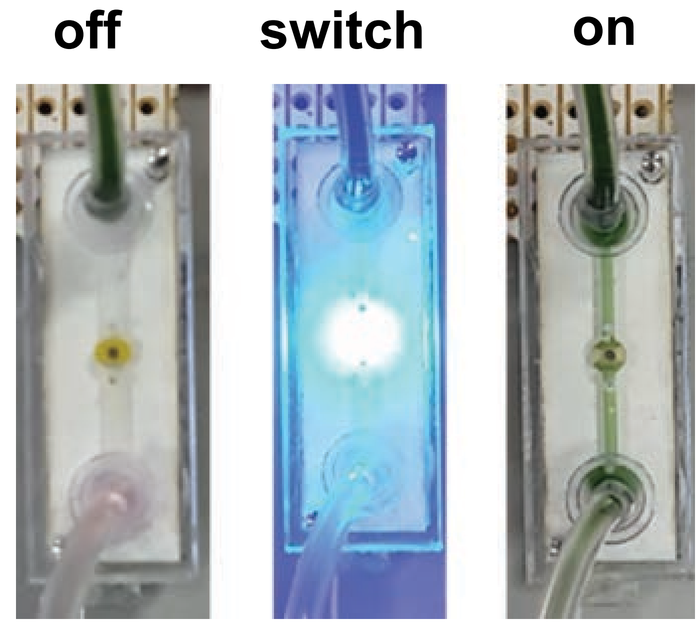


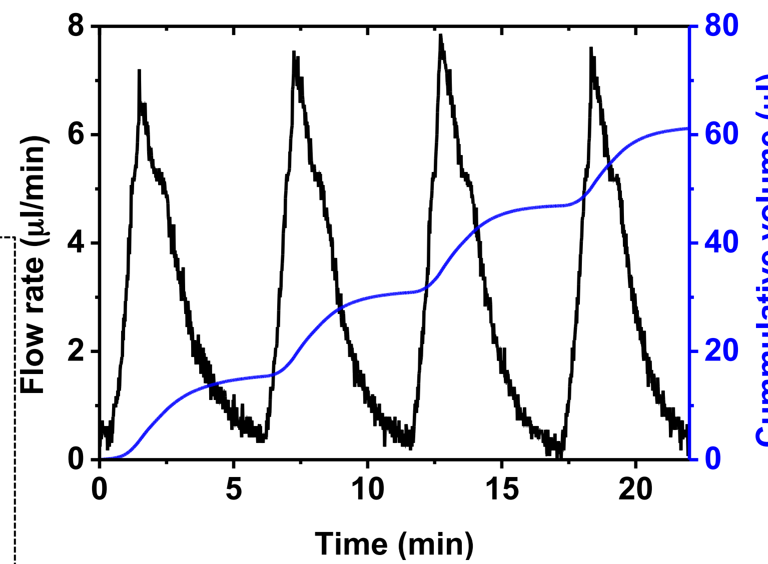
X:Y:Z = 1:99:5

poly(N-isopropylacrylamide) (PNIPAAm)
Formulation as by Sumaru et al[1]
***1) Chem. Mater.*, 19 (11), 2730 -2732, 2007.**

Reversible Photo-Switching of Flow







Above: scheme showing switching process protonated MC-H⁺ photoswitched to SP triggering p(NIPAAM-*co*-AA-*co*-SP) gel contraction and opening of the channel.

Right, Top: Photos of the valve in operation before (flow OFF) and after (flow ON) one minute of blue light irradiation.

Right, Bottom: Flowrate and cumulative volume measurements showing repeated opening and closing of microvalve: 1 min blue light irradiation opens valve followed by ~5.5 min thermal relaxation to close.

From: 'Molecular design of light-responsive hydrogels, for in-situ generation of fast and reversible valves for microfluidic applications ' (submitted for publication)

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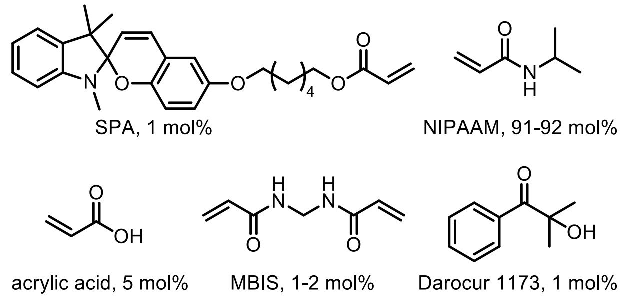
Photocontrol of Assembly and Subsequent Switching of Surface Features

ACS APPLIED MATERIALS & INTERFACES — Research Article — www.acsami.org

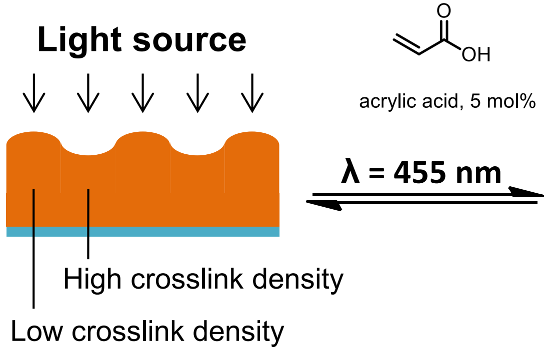
ACS applied materials & interfaces, 6 (2014) 7268-7274

Photoswitchable Ratchet Surface Topographies Based on Self-Protonating Spiropyran–NIPAAM Hydrogels

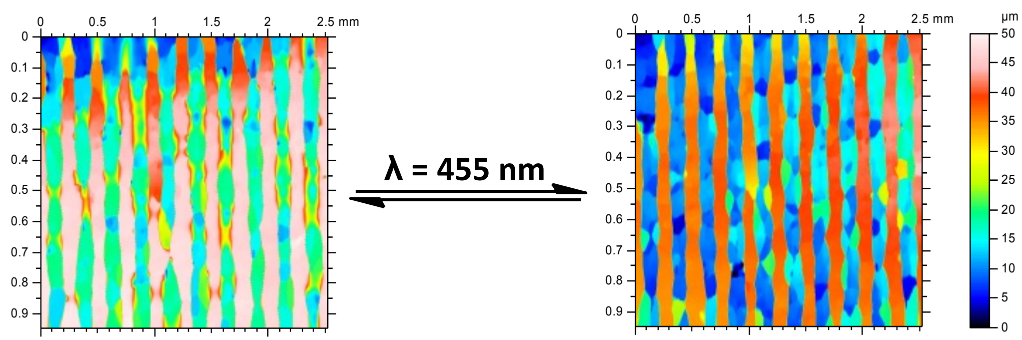
Jelle E. Stumpel,† Bartosz Ziółkowski,‡ Larisa Florea,‡ Dermot Diamond,‡ Dirk J. Broer,*,†,§ and Albertus P. H. J. Schenning*,†,§

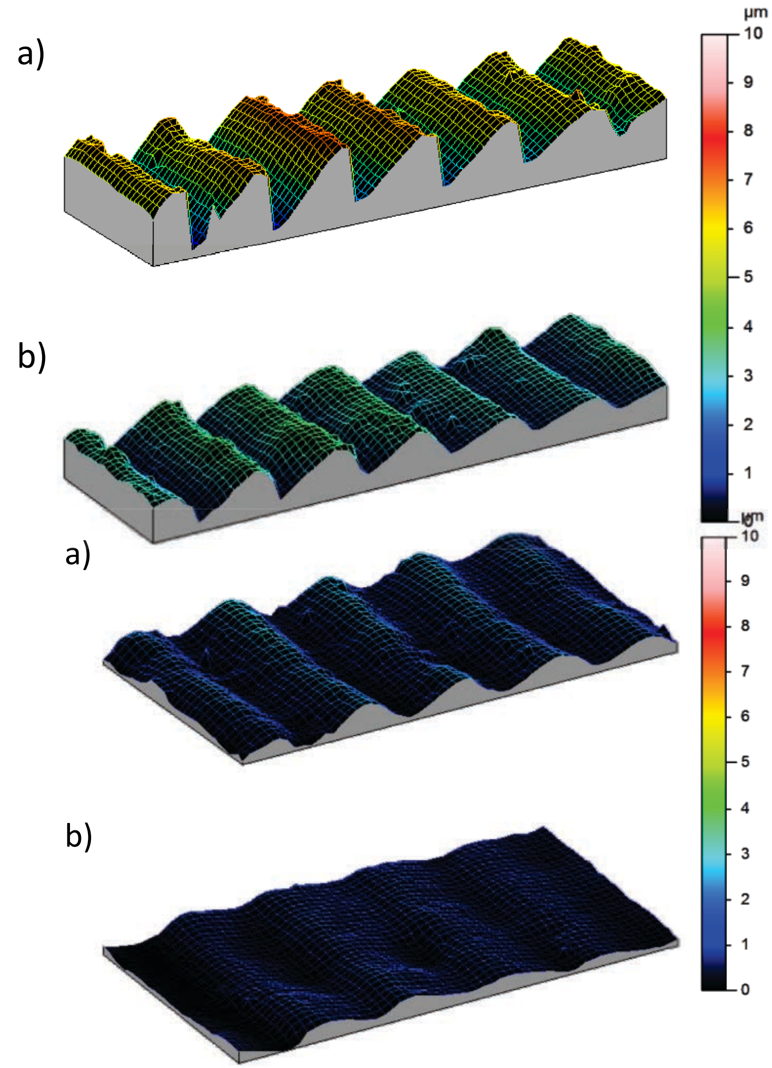


a)



b)

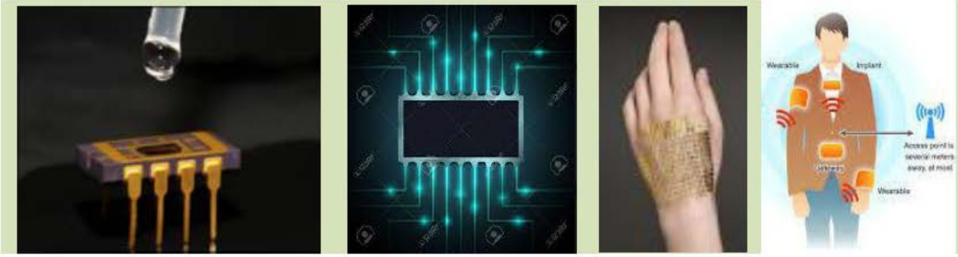




Time to re-think the game!!!

- New materials with exciting characteristics and unsurpassed potential…
- Combine with emerging technologies and techniques for exquisite control of 3D morphology
- And greatly improved methods for characterisation of structure and activity

We have the tools – now we need creativity!



The European Sensor Systems Cluster (ESSC)

European Sensor Systems Cluster - *ESSC*

Vision, Objectives, Strategies, Priorities and Challenges of EU Cluster

Cluster launched at Preparatory Workshop on 27 November 2014 in Brussels

sponsored and observed by EC DG Research and Innovation

www.cluster-essc.eu

Room Tunis, Session Time: 12:00 - 13:30

Nuremberg/Germany, 19 May 2015

Vision, Objectives and Position Paper

Michele Penza - Chairman of the ESSC

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ENEA, Materials Technologies, Brindisi - Italy