‘Water, water, every where,
Nor any drop to drink’

(*The Rime of the Ancient Mariner,* Samuel Taylor Coleridge, 1798)

Dermot Diamond

INSIGHT Centre for Data Analytics

National Centre for Sensor Research

Dublin City University

Invited public lecture presented at

The Royal Society of Chemistry

Burlington House, Piccadilly, London

3rd April 2014

Water and the Romans…

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'The sewers, covered with a vault of tightly fitted stones, have room in some places for hay wagons to drive through them. And the quantity of water brought into the city by aqueducts is so great that rivers, as it were, flow through the city and the sewers; almost every house has water tanks, and service pipes, and plentiful streams of water...'

Strabo, (Greek author ca.60 BC to AD 24, writing about the Romans); see http://www.britannica.com/EBchecked/topic/567832/Strabo

Water supply & demand cycle

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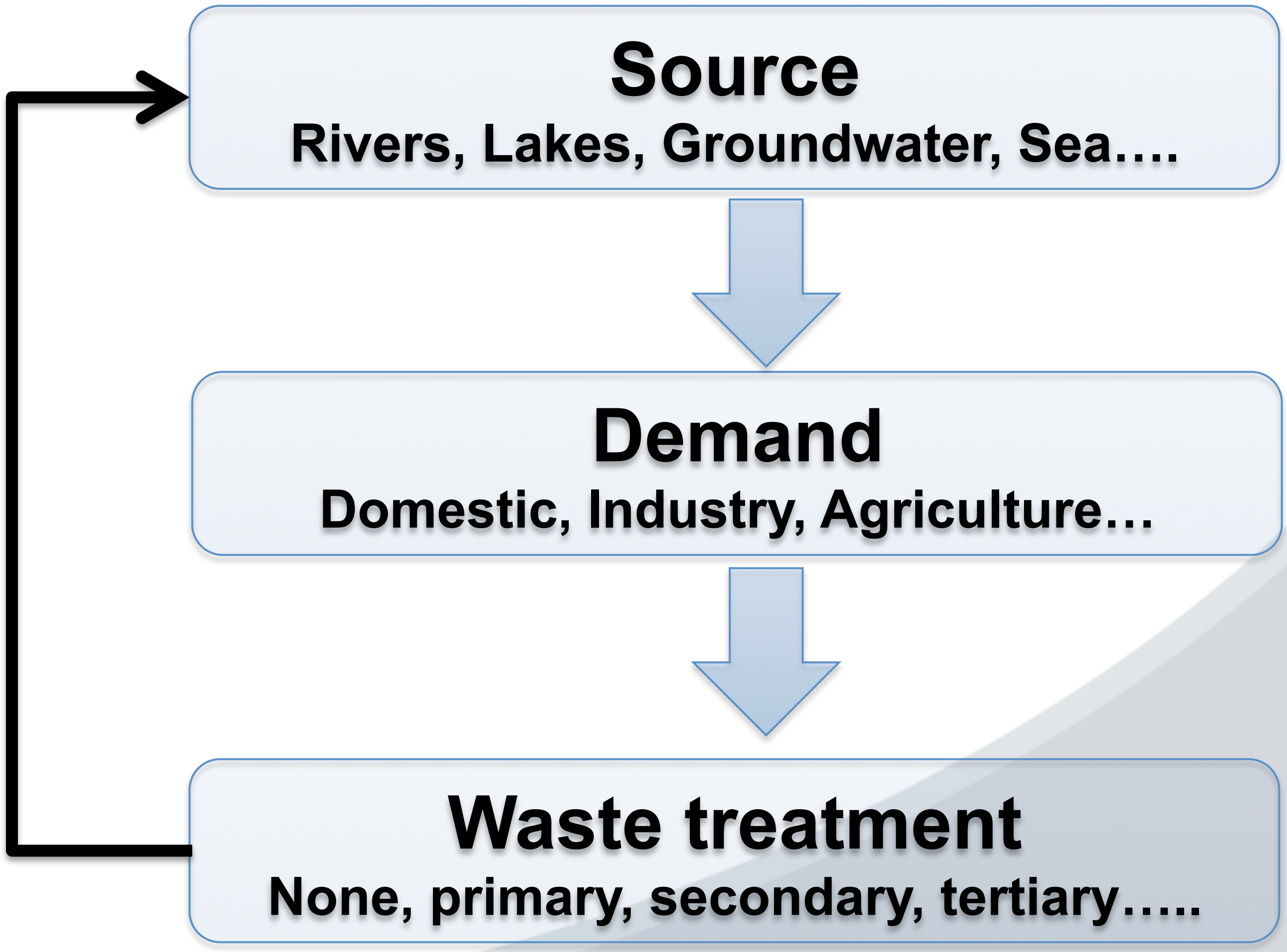

Importance of Water

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Drinking Water

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In the UK our drinking water is of the highest standard, at a record level of quality and among the best in the world. We can turn on our taps with the certainty of a safe, clean and refreshing supply.

- Quality standards
- UK drinking water quality reports
- How water quality is assured
- Technical briefings

Quality standards

UK water suppliers place the highest priority on assuring the quality of water provided to their customers. Strict standards for the quality of the public supply are laid down in national regulations derived from the EU Drinking Water Directive (98/83/EC). These standards are based on advice from the World Health Organization (WHO) and are regularly reviewed.

Latest figures for drinking water quality compliance with the strict UK and European standards are:
England and Wales 99.96%
Scotland 99.86%
Northern Ireland 99.78%

Water quality is closely checked and regulated by independent drinking water inspectorates in England and Wales, Scotland and Northern Ireland.

UK drinking water quality reports

Drinking water quality

Publications

Water supply hygiene; quality reporting

Technical briefings

How the quality of drinking water is assured
Access technical briefing papers here

Quality regulators

Drinking Water Inspectorate
England & Wales

Drinking Water Quality Regulator for Scotland

Drinking Water Inspectorate (within the Northern Ireland Environment Agency)
Northern Ireland

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News > Society > Health

Sanitation rated the greatest medical advance in 150 years

Sarah Boseley, health editor
The Guardian, Friday 19 January 2007

Sanitation is the greatest medical milestone of the last century and a half, acccording to a poll carried out by the British Medical Journal.

Sanitation was the clear winner among 15 milestones shortlisted by readers of the journal, including the development of vaccines, which has safeguarded many children's lives, and the invention of the contraceptive pill, which was a contributory factor to significant social change.

The winner was chosen by more than 11,000 members of the public around the world, who were invited to read articles championing each of the 15 contenders by prominent scientists, either in the journal or on the BMJ website. The competition was to mark the relaunch of the BMJ and all the innovations had to have taken place since it was first published in 1840.

Sanitation was the undisputed winner, with 1,795 votes, over antibiotics in second place with 1,642 votes, and anaesthesia which took third place with 1,574.

Examples of Legislation (water only)

- Bathing Water Directive,
- Drinking Water Directive
- Environmental Impact Assessment Directive
- Sewage Sludge Directive
- Urban Waste Water Treatment Directive
- Nitrate Directive
- Integrated Pollution Prevention Control Directive,
  - cost recovery for water use,
  - measures to promote efficient and sustainable use of water,
  - protection of drinking water sources,
  - authorisation of discharges to groundwater,
  - control of point source discharges and diffuse source pollution,
  - prevention or reduction of accidental pollution

WFD (1)

- **The Directive aims to achieve 'good water status' for all waters by 2015.**
  - including inland waters (surface and groundwater, drinking water) and transitional and coastal waters up to one sea mile (and for chemical status also territorial waters which may extend to 12 sea miles) from the territorial baseline of a Member State
- **According to Article 8, 'monitoring networks should be made operational by 2006'.**
  - These networks are part of the establishment of two primary monitoring programmes: the Surveillance Monitoring (SM) and the Operational Monitoring (OM) networks for surface waters and groundwater.

Key Analytical Targets under WFD

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Rivers

Chemical / Physico-chemical	Biological
Thermal conditions: Temperature	Benthic Invertebrates
Oxygenation conditions: DO	Macrophytes
Salinity: Conductivity	Benthic Algae
Acidification status: pH ANC Alkalinity	Fish
Nutrients: TP, TN, SRP,* NO3 + NO2 NH4	Phytoplankton

*SRP = soluble reactive phosphorus

Transitional Waters

Chemical / Physico-chemical	Biological
Thermal conditions: Thermal profiles	Benthic Invertebrate fauna
Oxygenation: DO profiles	Macroalgae
Salinity: ppt, psu*	Angiosperms
Transparency: light penetration	Fish fauna
Nutrients: Reactive species and total budgets (N,P,Si)	Phytoplankton

*PSU = practical salinity units; 1 PSU = ca. 1000 ppm NaCl
Sea water is ca. 35 PSU

Coastal Waters

Chemical / Physico-chemical	Biological
Thermal conditions: Thermal profiles	Benthic Invertebrate fauna
Oxygenation: DO profiles	Macroalgae / Angiosperms
Salinity: ppt, psu	Phytoplankton
Transparency: light penetration	
Nutrients: NO3, NO2, NH4, PO4, Si, TN, TP	

Examples of Priority Substances

Number	CAS numberi	EU numberii	Name of priority substanceiii	Identified as priority hazardous substance
(1)	15972-60-8	240-110-8	Alachlor	
(2)	120-12-7	204-371-1	Anthracene	X
(3)	1912-24-9	217-617-8	Atrazine	
(4)	71-43-2	200-753-7	Benzene	
(5)	not applicable	not applicable	Brominated diphenyletheriv	X
	32534-81-9	not applicable	Pentabromodiphenylether (congener numbers 28, 47, 99, 100, 153 and 154)	
(6)	7440-43-9	231-152-8	Cadmium and its compounds	X
(7)	85535-84-8	287-476-5	Chloroalkanes, C10-13 iv	X
(8)	470-90-6	207-432-0	Chlorfenvinphos	
(9)	2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)	
(10)	107-06-2	203-458-1	1,2-Dichloroethane	
(11)	75-09-2	200-838-9	Dichloromethane	
(12)	117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	
(13)	330-54-1	206-354-4	Diuron	
(14)	115-29-7	204-079-4	Endosulfan	X
(15)	206-44-0	205-912-4	Fluoranthenevi	
(16)	118-74-1	204-273-9	Hexachlorobenzene	X
(17)	87-68-3	201-765-5	Hexachlorobutadiene	X
(18)	608-73-1	210-158-9	Hexachlorocyclohexane	X

	CAS number	Name of other pollutant
(6a)	56-23-5	Carbon-tetrachloride(1)
(9b)	not applicable	DDT total (1)(2)
	50-29-3	para-para-DDT (1)
(9a)		Cyclodiene pesticides
	309-00-2	Aldrin (1)
	60-57-1	Dieldrin (1)
	72-20-8	Endrin (1)
	465-73-6	Isodrin (1)
(29a)	127-18-4	Tetrachloro-ethylene (1)
(29b)	79-01-6	Trichloro-ethylene (1)

(1) This substance is not a priority substance but one of the other pollutants for which the EQS are identical to those laid down in the legislation that applied prior to 13 January 2009

(2) DDT total comprises the sum of the isomers 1,1,1-trichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 50-29-3; EU number 200-024-3); 1,1,1-trichloro-2 (o-chlorophenyl)-2-(p-chlorophenyl) ethane (CAS number 789-02-6; EU Number 212-332-5); 1,1-dichloro-2,2 bis (p-chlorophenyl) ethylene (CAS number 72-55-9; EU Number 200-784-6); and 1,1-dichloro-2,2 bis (p-chlorophenyl) ethane (CAS number 72-54-8; EU Number 200-783-0).

Only the most powerful analytical techniques can detect these complex mixtures of target molecules at low concentrations; e.g., LC-MS; GC-MS

There is no alternative to grab sampling and subsequent analysis back in a certified laboratory

Cocaine in Dublin Waste Water

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PAPER www.rsc.org/jem | Journal of Environmental Monitoring

Using environmental analytical data to estimate levels of community consumption of illicit drugs and abused pharmaceuticals†

Jonathan Bones,[a] Kevin V. Thomas[b] and Brett Paull*[a]

Received 23rd February 2007, Accepted 1st May 2007
First published as an Advance Article on the web 17th May 2007
DOI: 10.1039/b702799k

A solid phase extraction (SPE) method has been developed and applied in conjunction with a previously reported liquid chromatography tandem mass spectrometry (LC–MS–MS) procedure for the determination of illicit drugs and abused pharmaceuticals in treated wastewater and surface water samples at the ng L^{-1} level. A full method validation was also performed and determined levels of analytical sensitivity were found to lie in the 1–10 ng L^{-1} range using river water as a test sample matrix and a sample size of 500 mL. The developed procedure was successfully applied for the determination of the chosen analytes in wastewater treatment plants in Dublin, Ireland and rapidly expanding commuter towns in the surrounding counties. Cocaine was detected in 70% of the collected samples in the range of 25–489 ng L^{-1}, its primary metabolite, benzoylecognine (BZE) was also detected in the range of 22–290 ng L^{-1}. Other substances detected included morphine, Tempazepam and the primary metabolite of methadone.

Highlights in Chemical Science
News from across RSC Publishing.

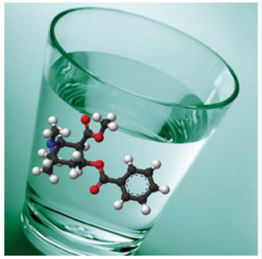
Something in the water

18 May 2007

How much cocaine is going up Dublin's nose? The answer lies in the output from the city's wastewater treatment plants - at least according to research done at Dublin City University by Brett Paull and colleagues. The researchers have estimated the levels of consumption of substances such as cocaine and morphine by measuring their concentrations, and the concentrations of their metabolites, in effluent and surface water.[1]

'There are currently very few ways to non-invasively assess community consumption of illicit drugs,' said Paull. 'Social survey data, although useful, is often subject to sampling bias, whereas environmental forensic approaches such as this, when subject to stringent quality assurance and controls, could provide a more accurate assessment.'

Previously, Paull's team surveyed drug contamination on euro banknotes in Dublin.[2] 'However, as an indicator of societal abuse, such samples provide only limited information,' said Paull. But water treatment plants accurately record the volume of water flow and serve a known number of people, allowing total consumption to be estimated.


Cocaine is just one of the illicit drugs flowing through Dublin's water treatment plants

Using samples taken from the water plant that serves 1.7 million people within the Dublin metropolitan area, the researchers calculated that more than 220 grams of cocaine flowed through the plant per day. Taking into account the way cocaine is metabolised in the body, this equates to the total consumption of more than 2200 grams of cocaine. The researchers estimate that this is equivalent to a consumption level of about 1.4 grams per 1000 people per day.

'The problem of cocaine consumption is not wholly confined to the capital city,' said Paull. Similar measurements on wastewater treatment plants that serve small towns just outside Dublin revealed consumption levels at about one fifth that of the metropolitan area.

The researchers believe that their method could be used for the routine monitoring of cocaine consumption within a community, revealing any usage trends, such as increases during weekends and public holidays.

Colin Batchelor

References

1. J Bones, K V Thomas and B Paull, *J. Environ. Monit.*, 2007, **DOI**: 10.1039/b702799k
2. J Bones, M Macka and B Paull, *Analyst*, 2007, **DOI**: 10.1039/b615669j

Link to journal article

Using environmental analytical data to estimate levels of community consumption of illicit drugs and abused pharmaceuticals
Jonathan Bones, Kevin V. Thomas and Brett Paull, *J. Environ. Monit.*, 2007, **9**, 701
DOI: 10.1039/b702799k

www.rsc.org/Publishing/ChemScience/Volume/2007/06/Dublin_cocaine.asp

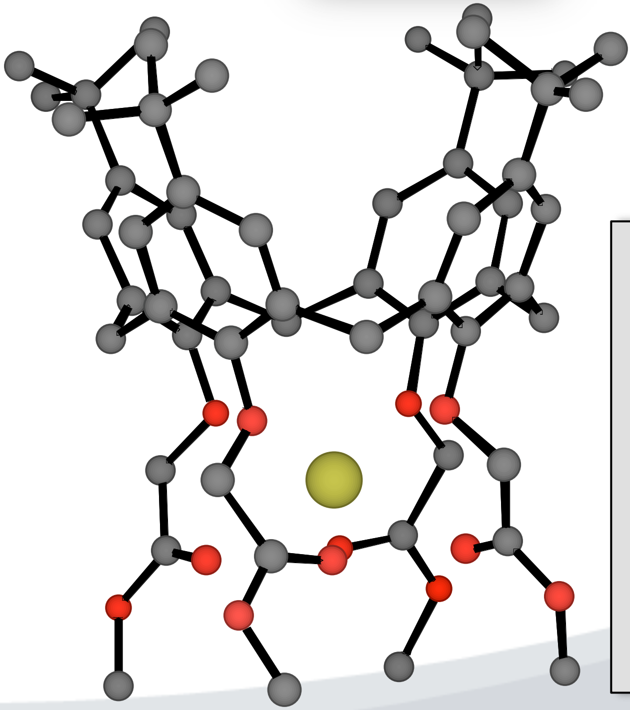
Environmental Regulation – What about Enforcement??

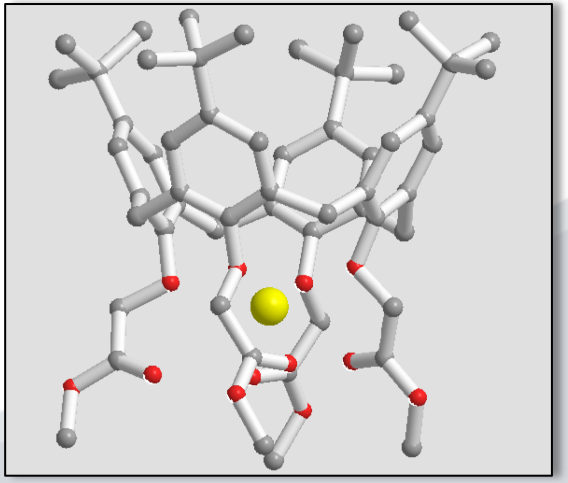
- **Challenges**
  - A detailed regulatory framework is in place
  - Regulations cannot be enforced without measurements
  - Current norm is manual grab sampling 3 or 4 times a year
  - We do not measure the status of our environment often enough in enough locations
- **Solution**
  - Simple: Measure **more often** in **more locations**
  - **Why is this not happening?**

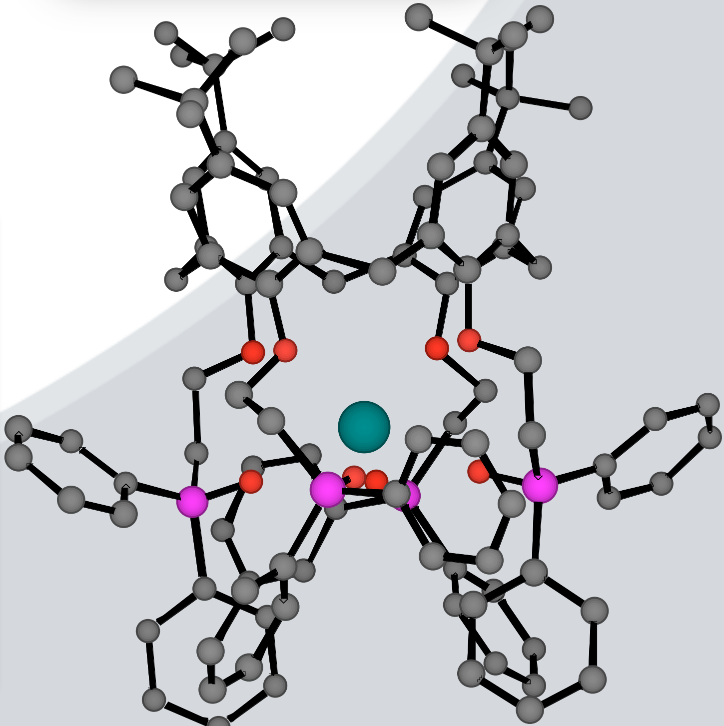
Conventional Analytical Equipment used for environmental monitoring is too expensive to buy and maintain:
Transporting samples to centralised laboratories is not a scalable model

Budapest - 1956

History: Calixarenes, 1984/5





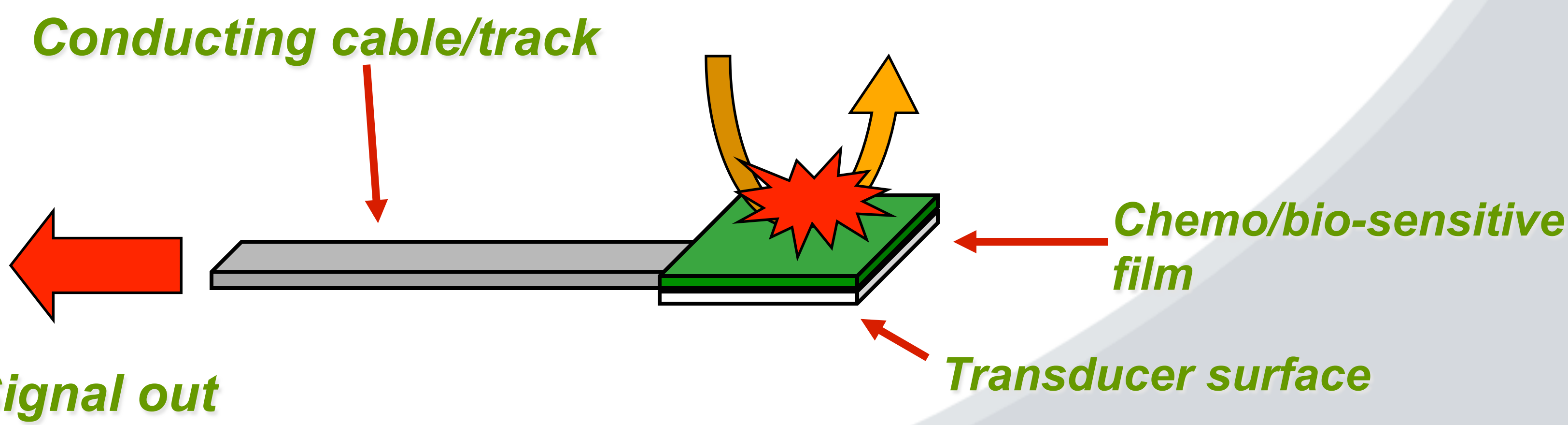


Tetraester - Na+ selective

Tetraphosphine oxide - Ca^{2}+ selective

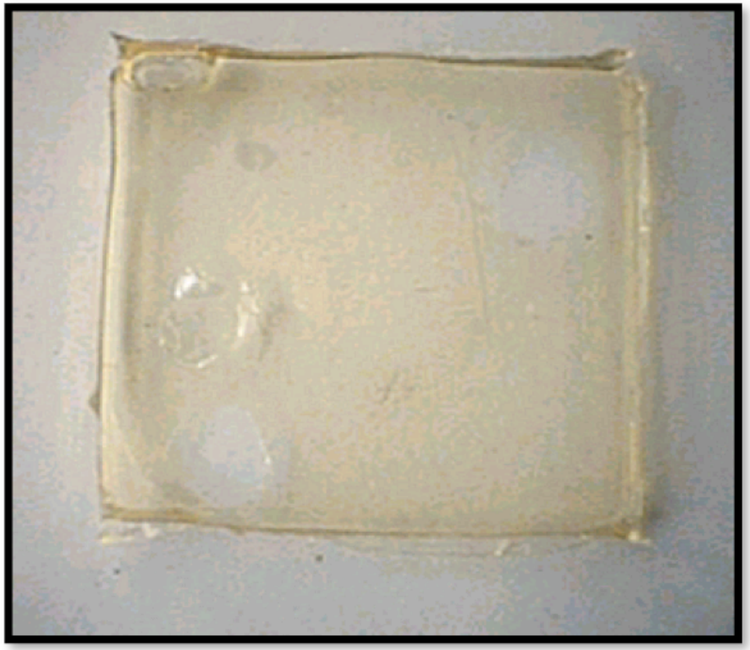
What is a Chemo/Bio-Sensor?

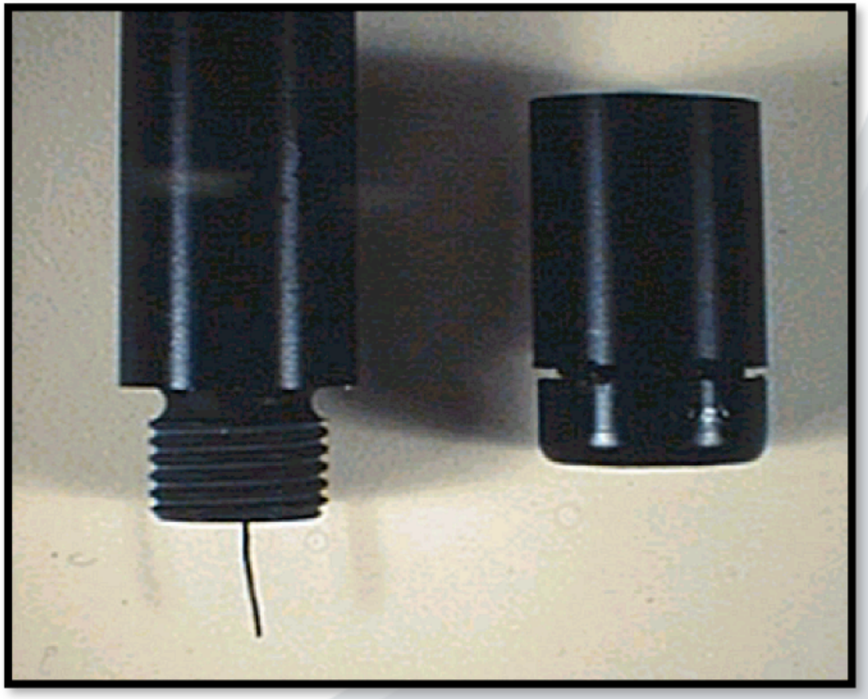
'a device, consisting of a transducer and a chemo/bio-sensitive film/membrane, that generates a signal related to the concentration of particular target analyte in a given sample'



Chemo/Bio-sensing involves selective **BINDING** & **TRANSDUCTION** on the device surface; this also implies the target analyte MUST meet the device surface (**LOCATION** & **MOVEMENT**). It provides a signal observable in the macroscopic world (**COMMUNICATION**)

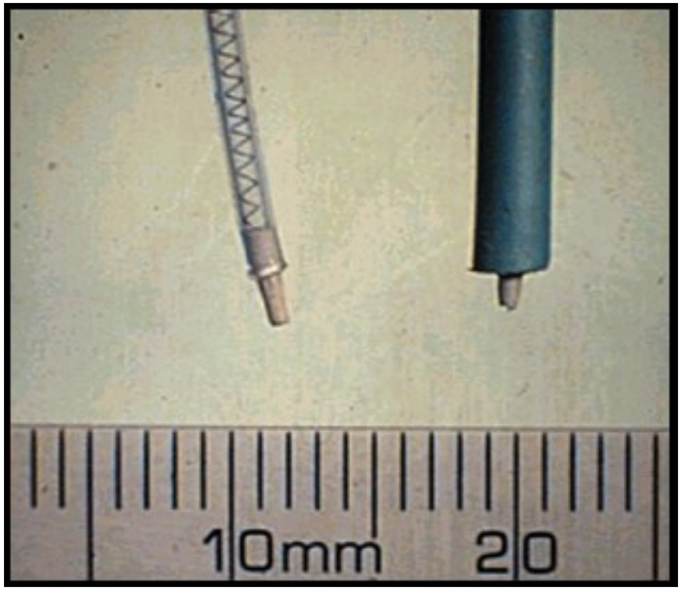
PVC - Membrane ISEs





Typical membrane cocktail (%w/w); PVC:33%, NPOE (plasticiser):66%; ionophore/exchanger: 1% (ratio at least 2:1 by mole); dissolve in a volatile solvent e.g. THF and cast membrane from this solution

Blood Analysis; Implantible Sensors



1985: Catheter Electrodes for intensive care – function for 24 hrs

Dr. David Band, St Thomas's Hospital London

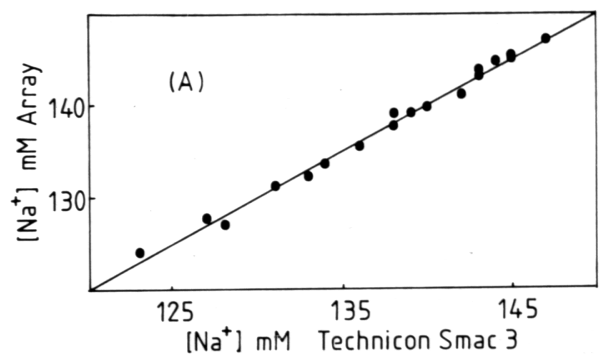
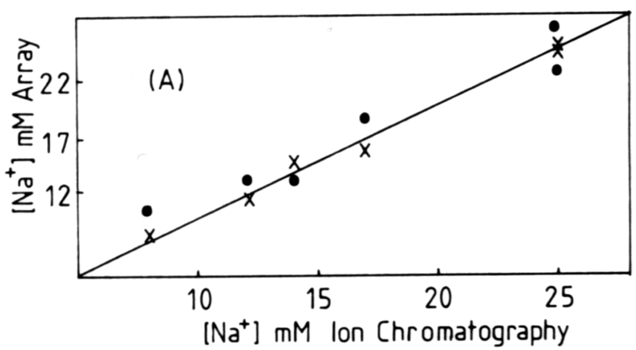


Fig. 3. Comparison of plasma sodium analysis using the array-FIA approach with a SMAC analyser. Good correlation without bias is obtained [5].

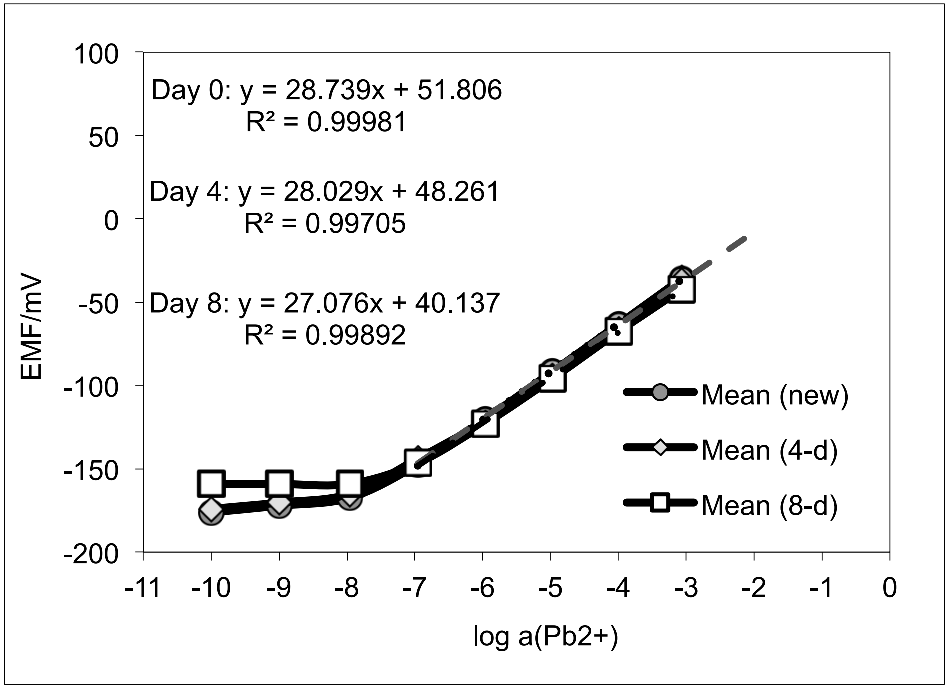


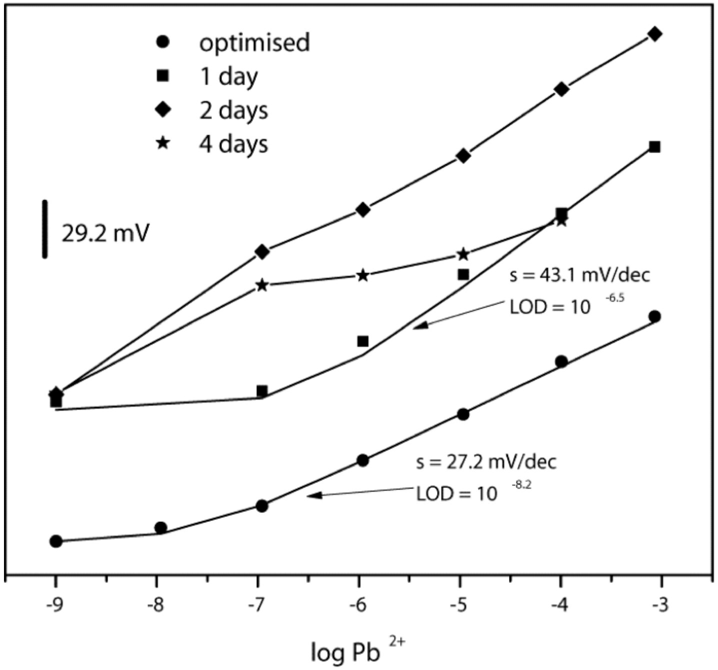
Anal. Chem., *64 (1992) 1721-1728.*

Ligand (and variations of) used in many clinical analysers for blood Na^+ profiling

Change in Electrode Function over Time

See Electrochimica Acta 73 (2012) 93–97





stored in 10^{-9}M Pb^{2+}, pH=4

Continuous contact with river water

Conventional PVC-membrane based ISEs

Biofilm Formation on Sensors

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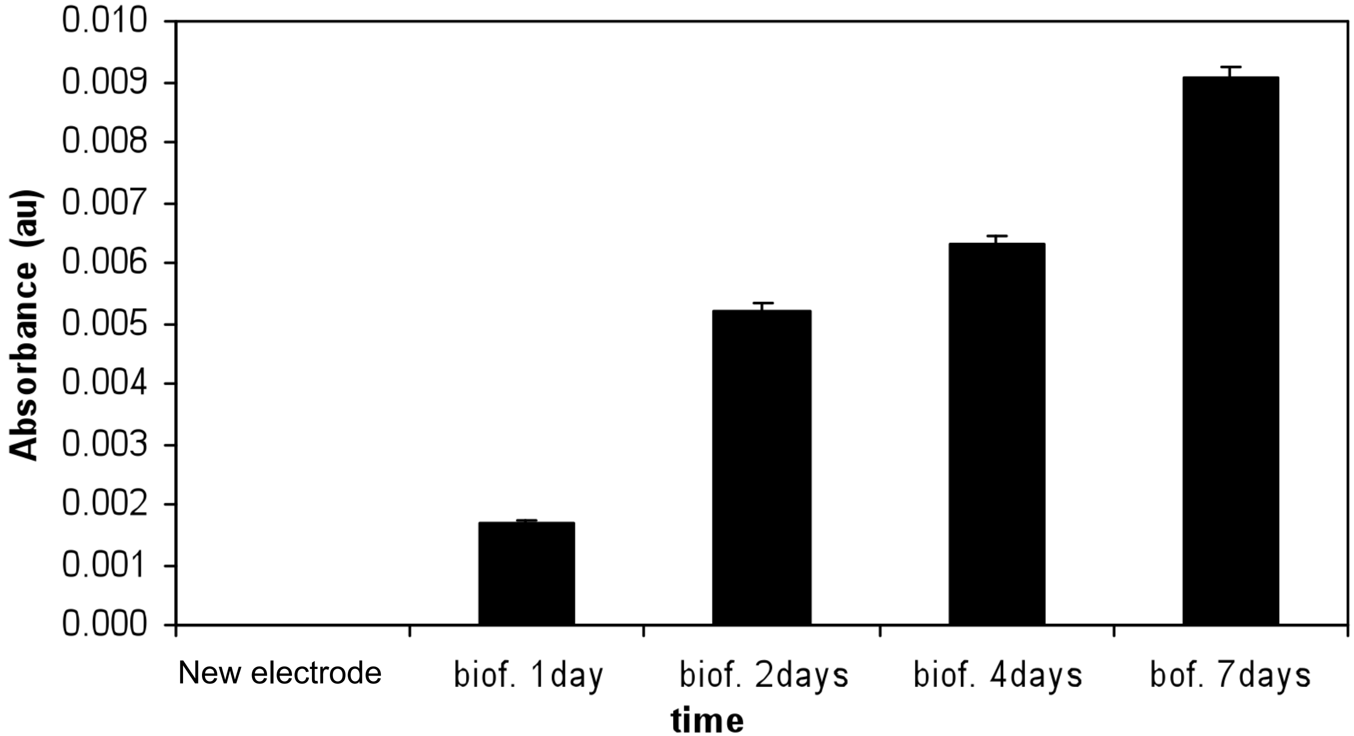

- **Electrodes exposed to local river water (Tolka)**
- **'Slime test' shows biofilm formation happens almost immediately and grows rapidly**

Control of membrane interfacial exchange & binding processes

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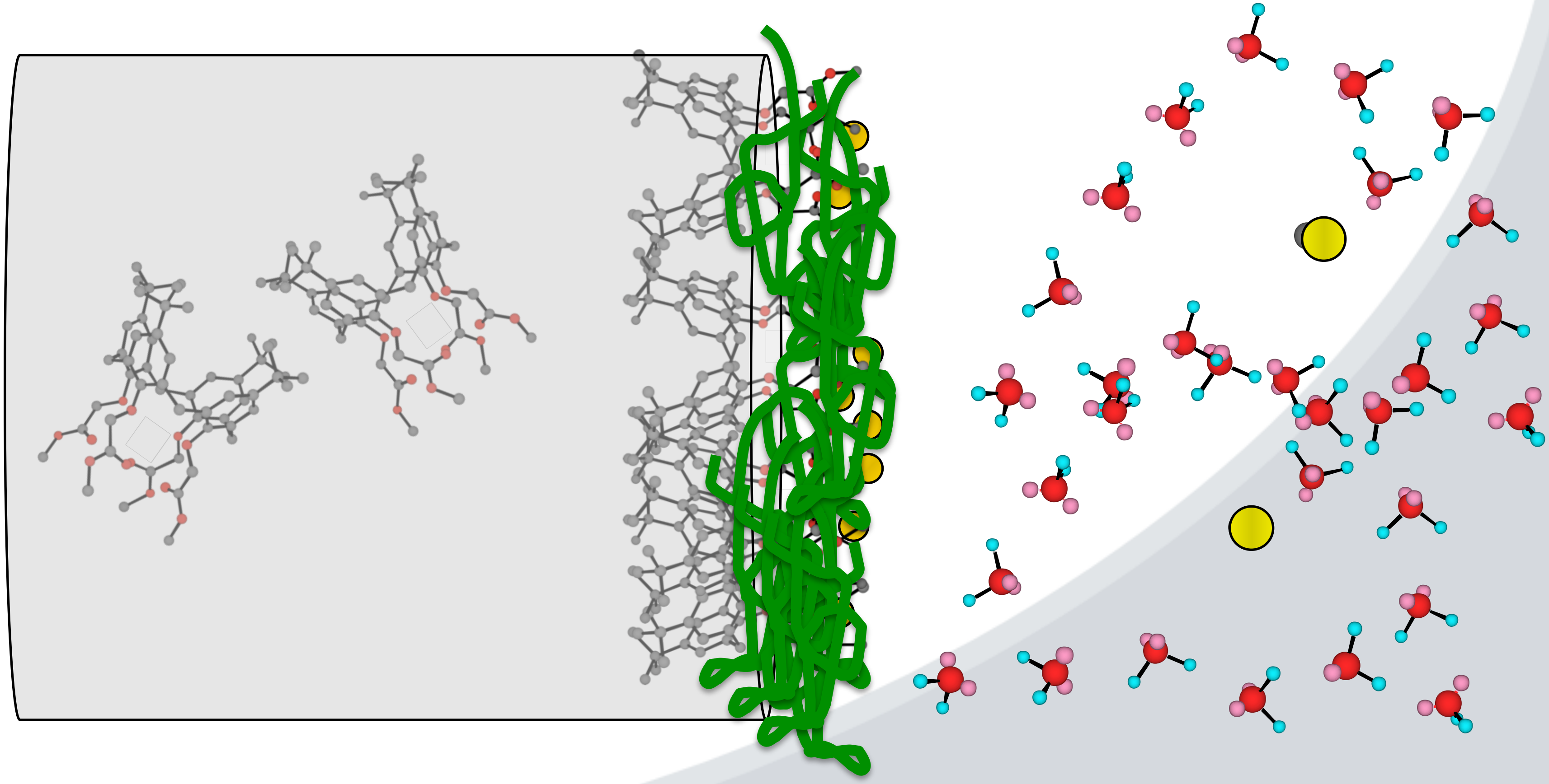

Remote, autonomous chemical sensing is a tricky business!

Nokia 'Morph' Concept

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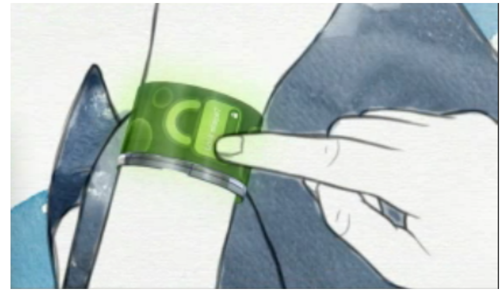
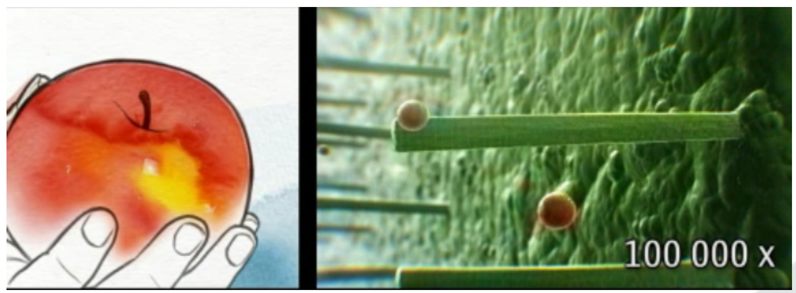
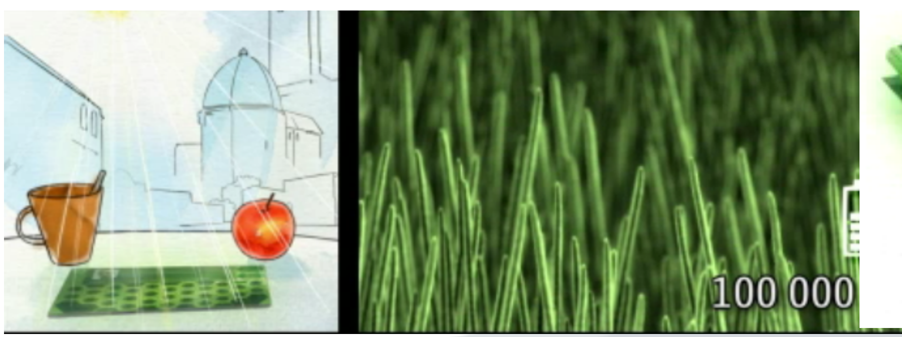
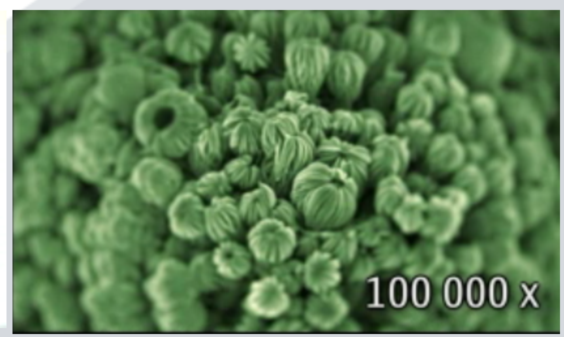




http://research.nokia.com/morph

INTEL….

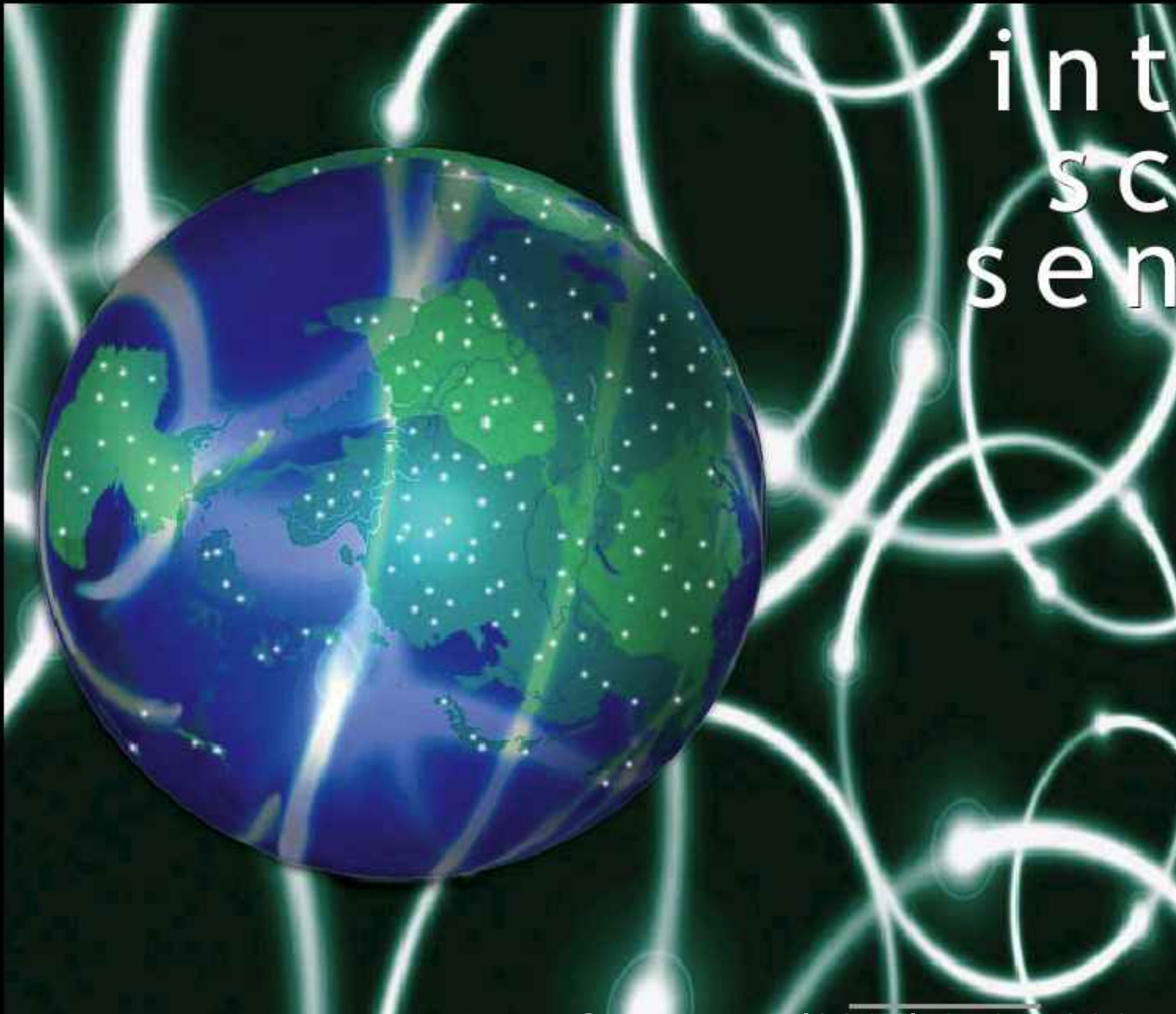
Up to 1,200 hi-tech sensors from Intel are being placed on lamp-posts, drains, public buildings and other facilities to start zeroing in on "quality of life" issues for Dubliners…..

The sensors will host new technology in the form of Intel 'Quark' chips, which will record sensitive environmental information and feed it back to computers, tablets and smartphones operated by Dublin City Council.

Network of hi-tech sensors to monitor capital's 'quality of life'

0 Comments Recommend 9 Tweet 80 +1 1 Share

Keynote Article: August 2004, Analytical Chemistry (A



internet scale sensing

Dermot Diamond
Dublin City University
(Ireland)

Incredible advances in digital communications and computer power have profoundly changed our lives. One chemist shares his vision of the role of analytical science in the next communications revolution.

Digital communications networks are at the heart of modern society. The digitization of communications, the development of the Internet, and the availability of relatively inexpensive but powerful mobile computing technologies have established a global communications network capable of linking billions of people, places, and objects. Email can instantly transmit complex documents to multiple remote locations, and websites provide a platform for instantaneous notification, dissemination, and exchange of information globally. This technology is now pervasive, and those in research and business have multiple interactions with this digital world every day. However, this technology might simply be the foundation for the next wave of development that will provide a seamless interface between the real and digital worlds.

The crucial missing part in this scenario is the gateway through which these worlds will communicate: How can the digital world sense and respond to changes in the real world? Analytical scientists—particularly those working on chemical sensors, biosensors, and compact, autonomous instruments—are

Dermot Diamond, Anal. Chem., 76 (2004) 278A-286A
(Ron Ambrosio & Alex Morrow, IBM TJ Watson)

Sensor Hierarchy and Deployment Scenarios

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- **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**
  - Due to the delicate nature of enzymes, antibodies….

Increasing difficulty

- **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)

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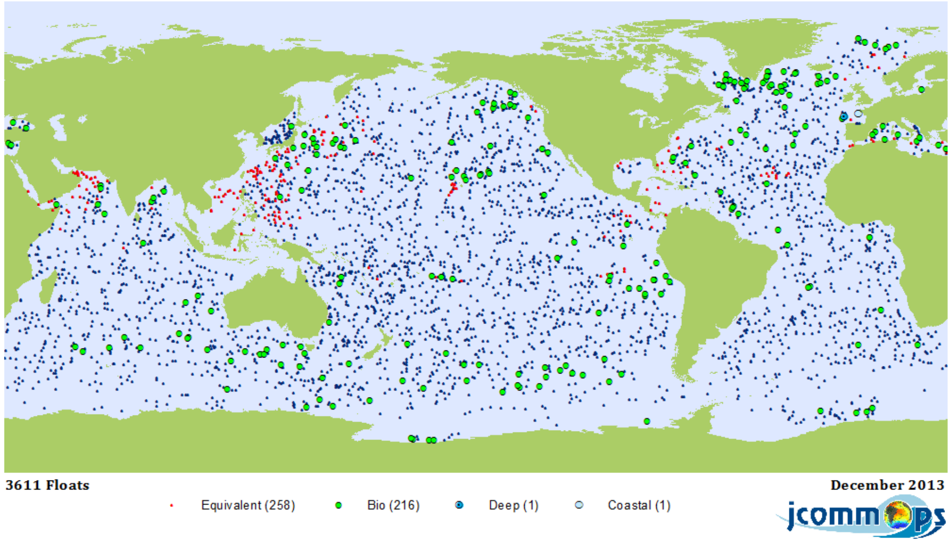

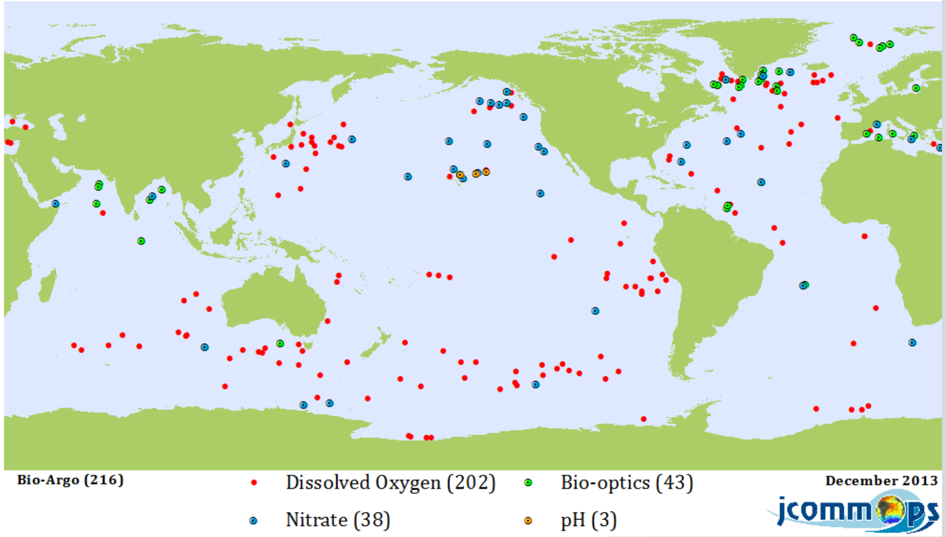

- **Ca. 3,600 floats: temperature and salinity**
- **Only 216 reporting chem/bio parameters (ca. 6%)**
- **Of these nitrate (38), DO (202), Bio-optics (43), pH (3)** **@€60K ea!**

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

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After decades of intensive research, our capacity to deliver successful long-term deployments of chemo/bio-sensors in remote locations is still very limited

Direct Sensing vs. Reagent Based LOAC/ufluidics

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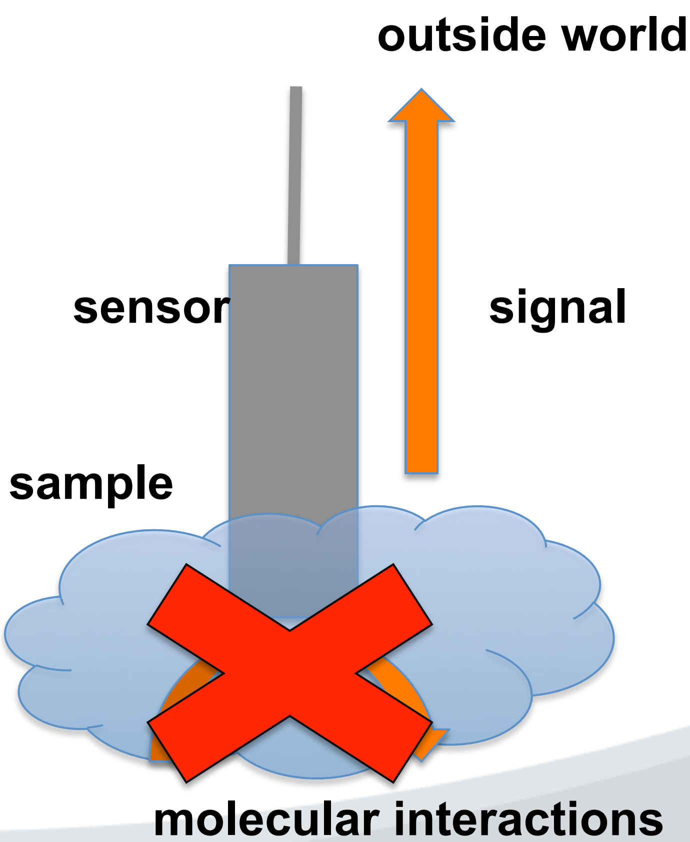
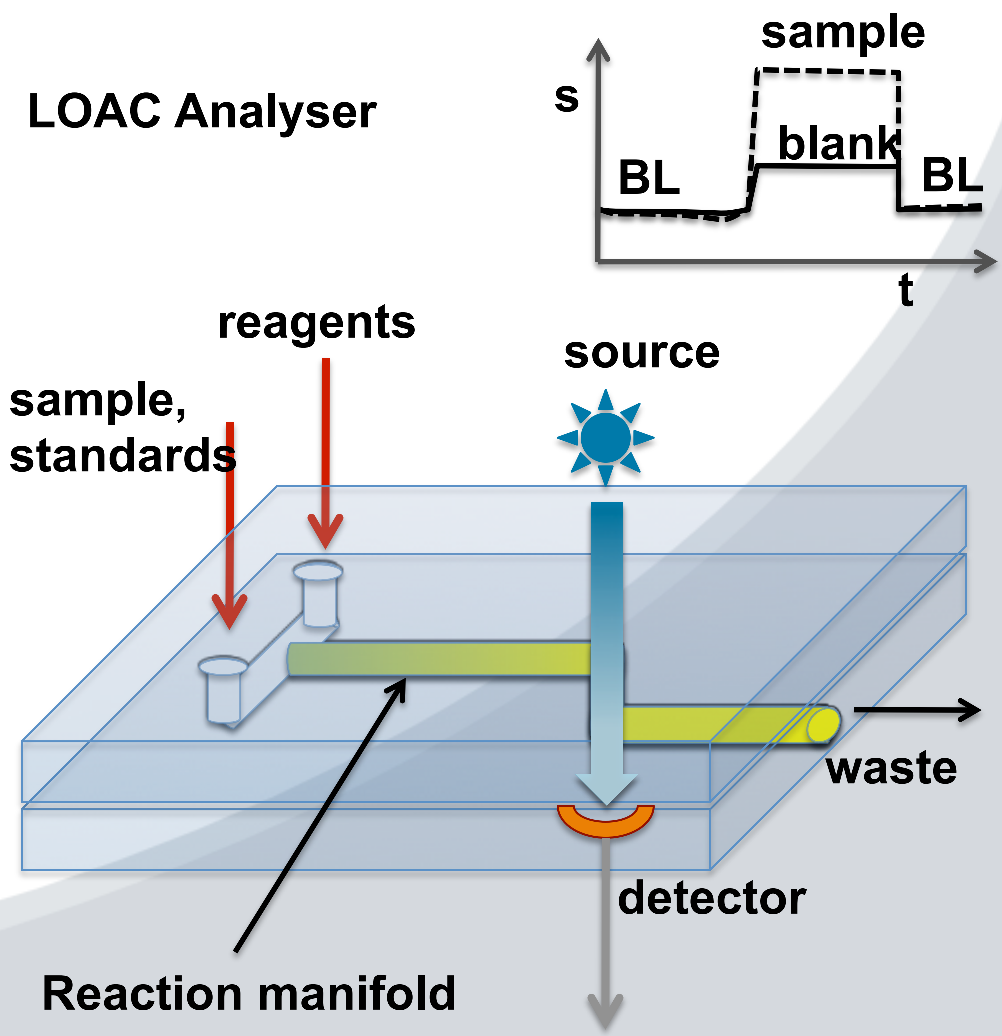
Direct Sensing



LOAC Analyser



MicroTAS/Lab on a Chip/Microfluidics

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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 LoC systems, and that we would see applications of these devices proliferating throughout science. In fact, it has not (yet) happened.

Microfluidics, to date, has been largely focused on the development of science and technology, and on scientific papers, rather than on the solution of problems

Editorial ‘Solving Problems’, George Whitesides, Lab Chip 10 (2010) 2317-2318

2nd Generation Analyser: Design

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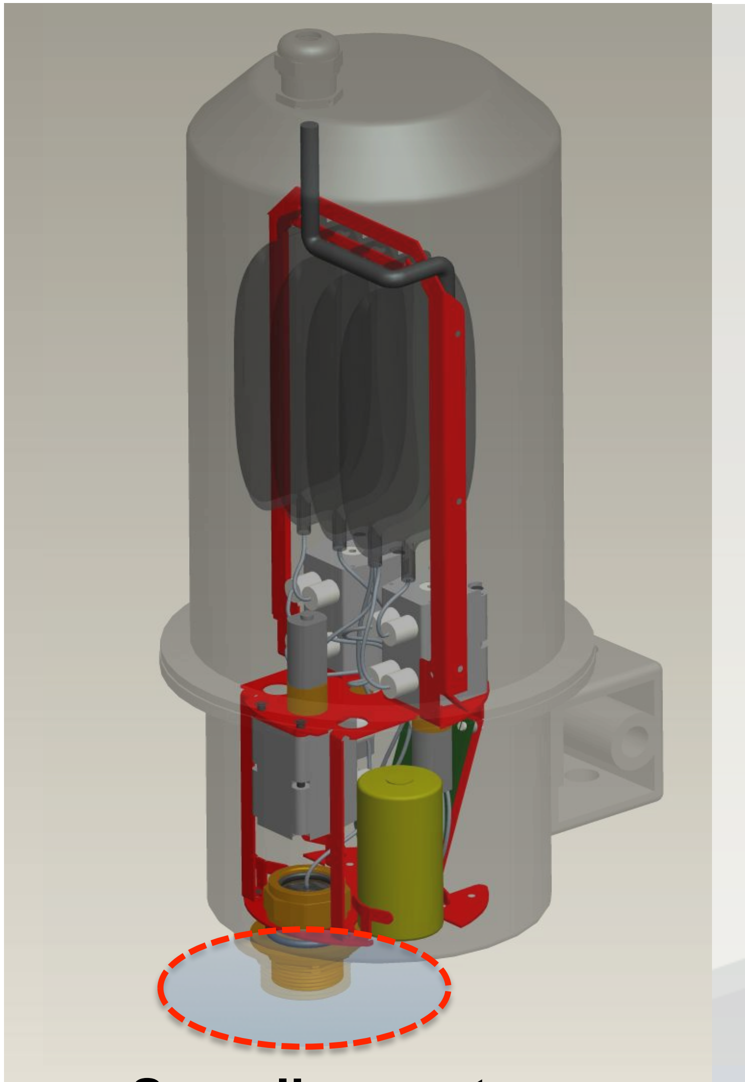
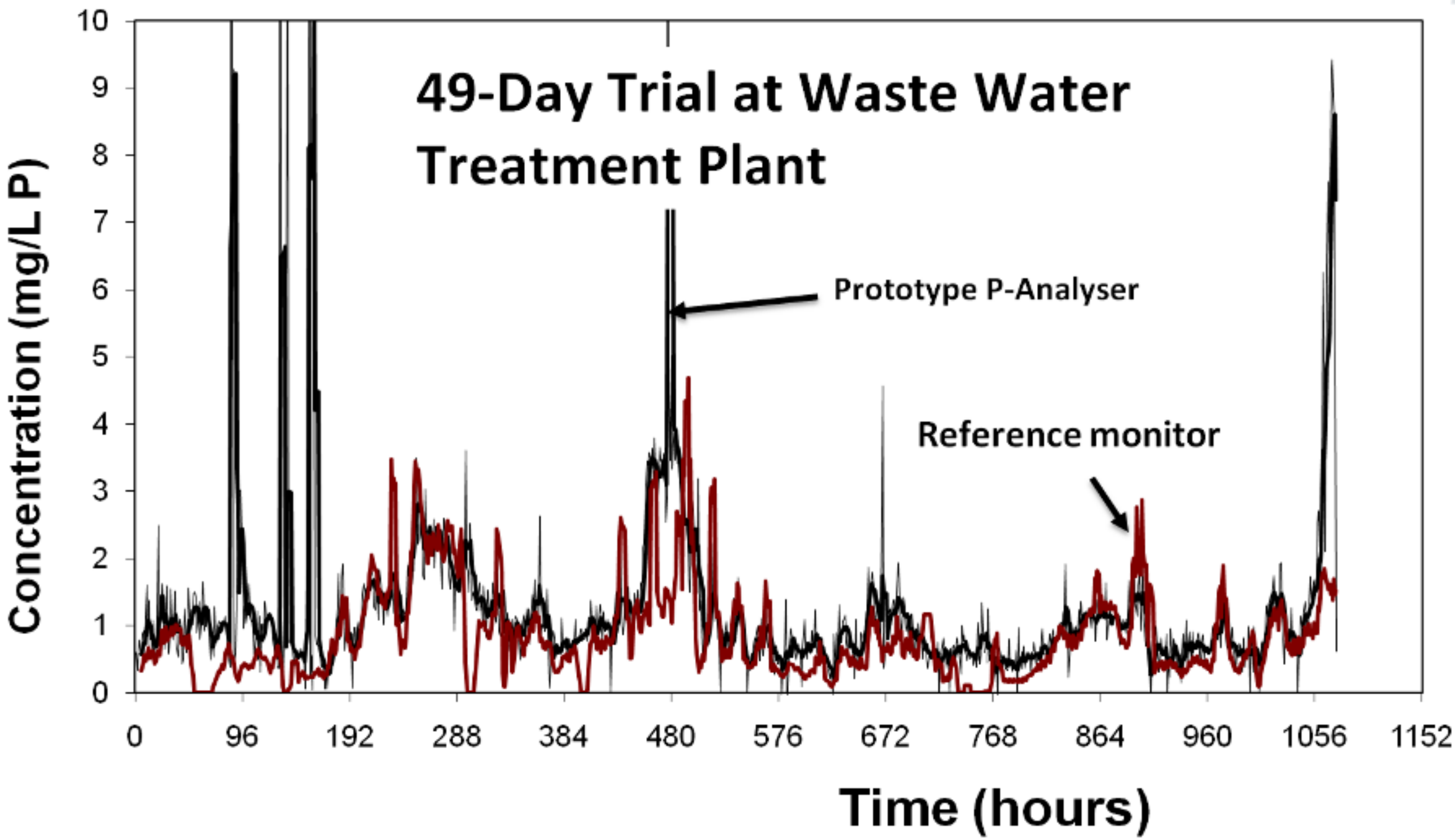


Sampling port

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



Osberstown – 3 week deployment

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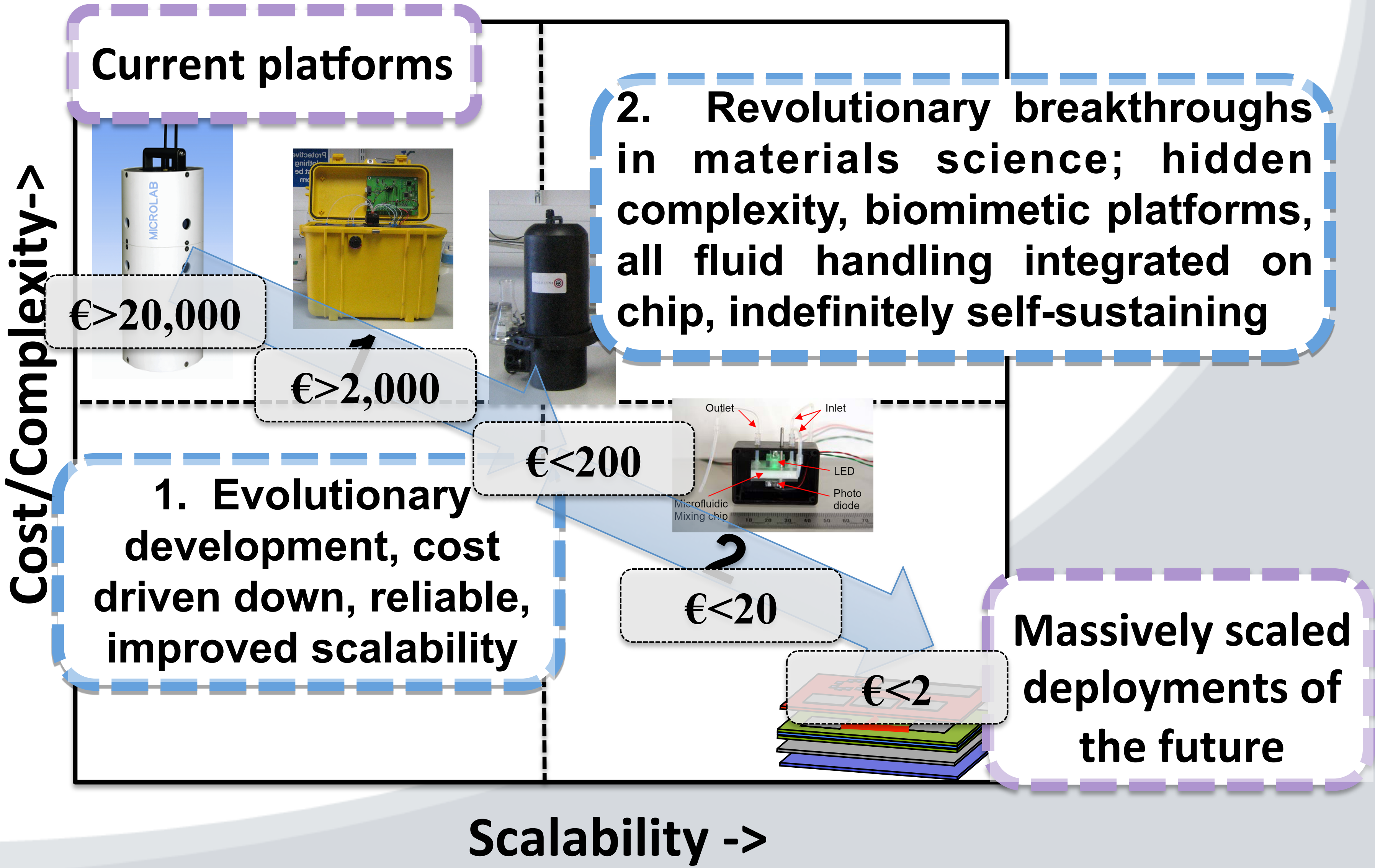
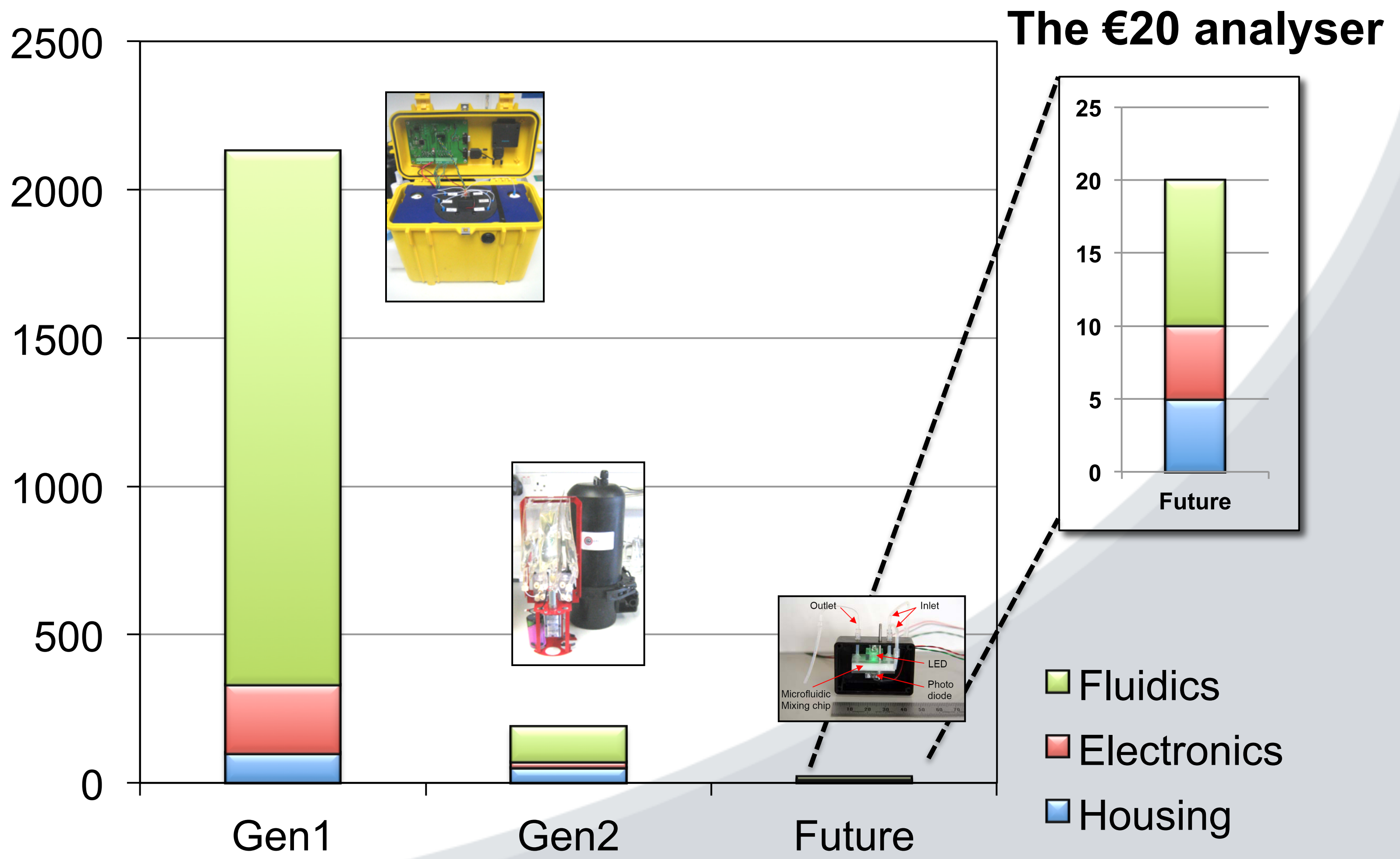
Biofouling of sensor surfaces is a major challenge for remote chemical sensing – both for the environment and for implantable sensors

Achieving Scale-up

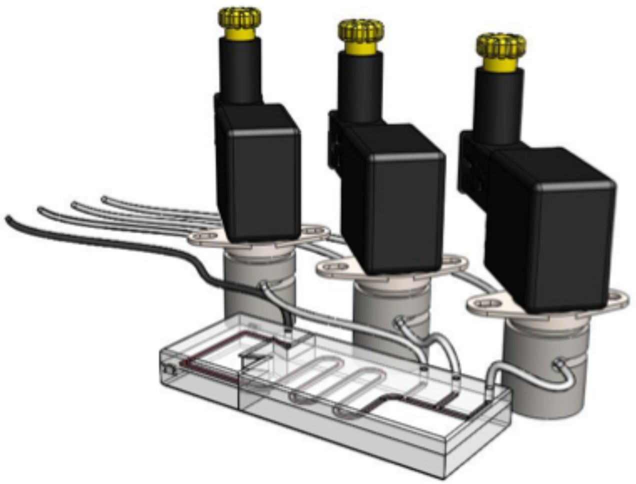


Cost Comparison Analyser (€)



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

Photoswitchable Materials

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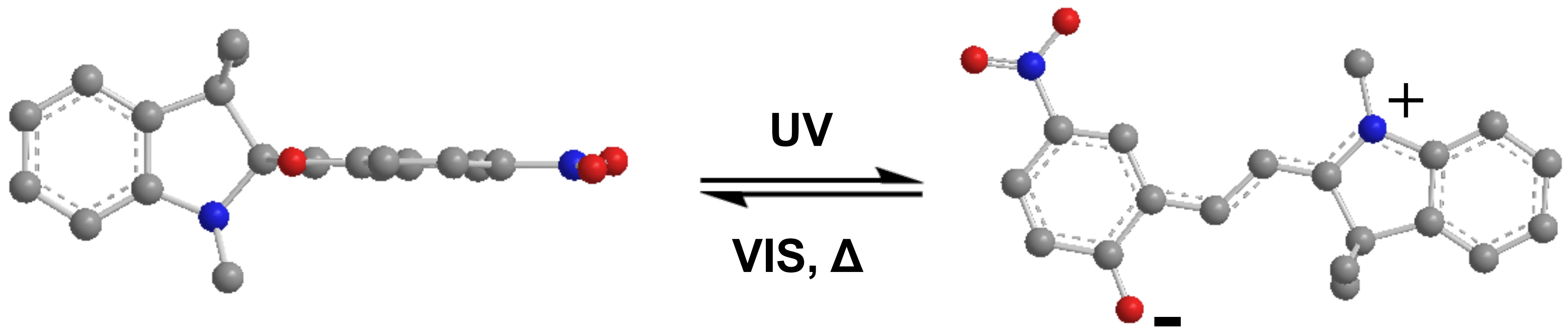
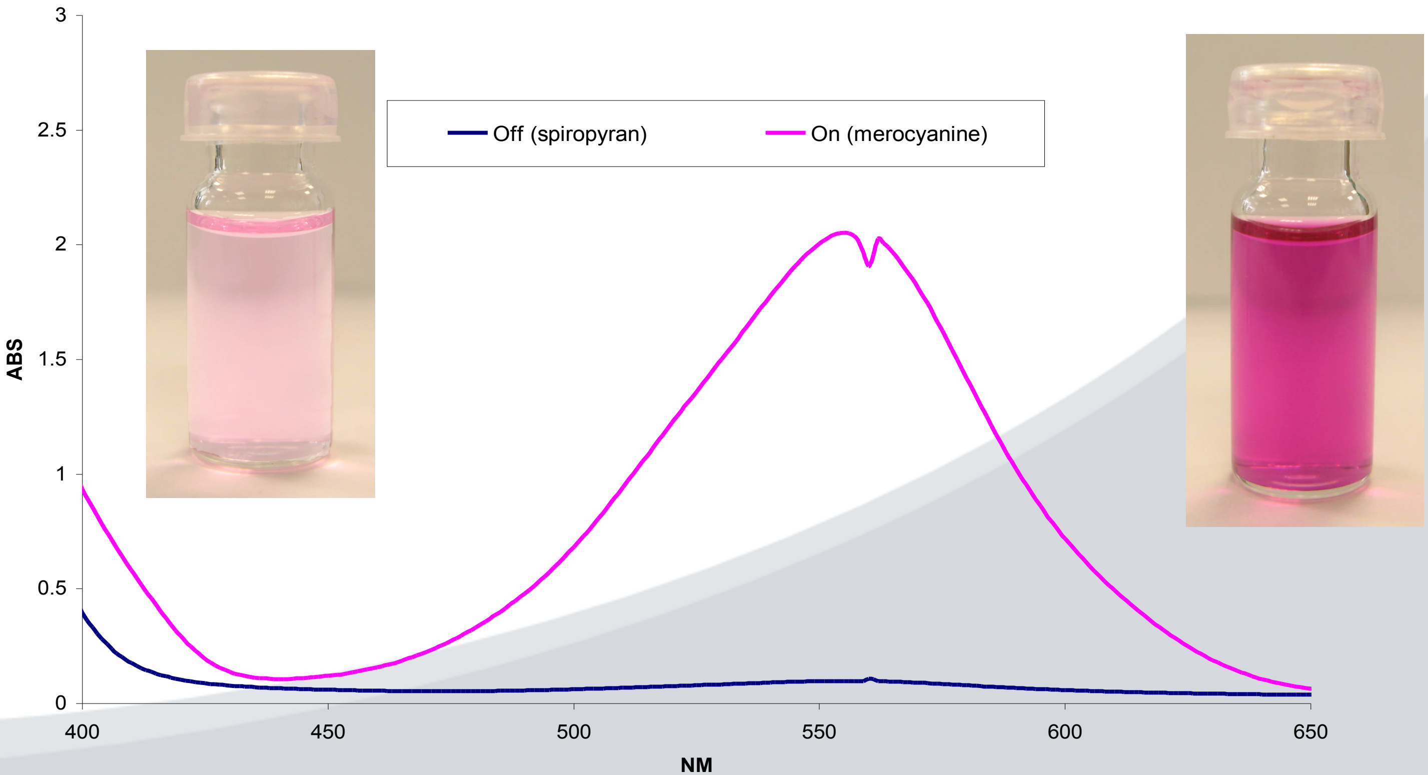
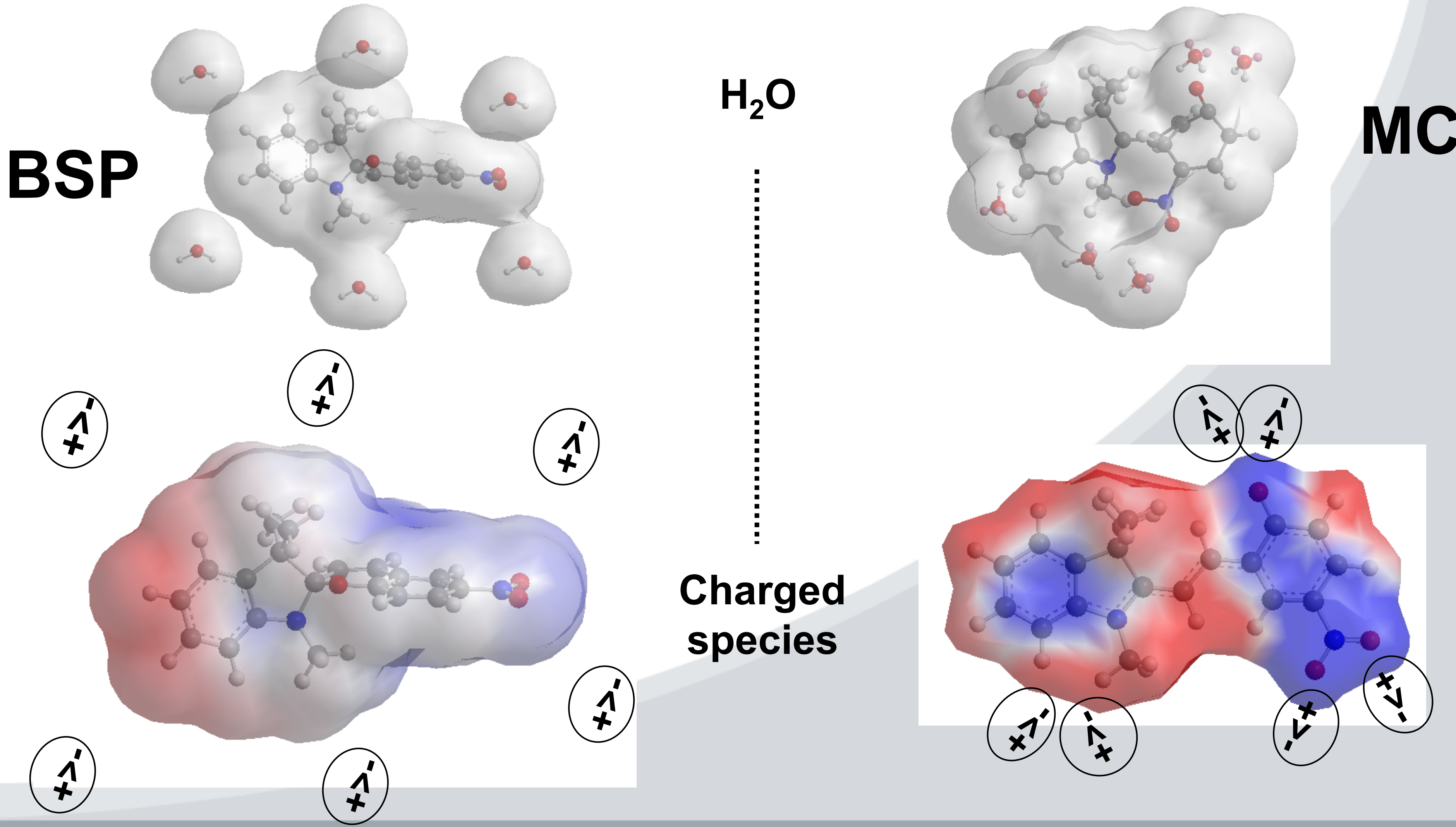




Non-specific (BSP) and specific (MC) Interactions



Poly(*N*-isopropylacrylamide)

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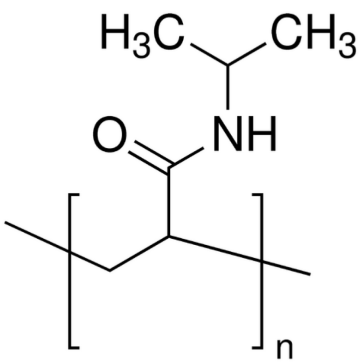
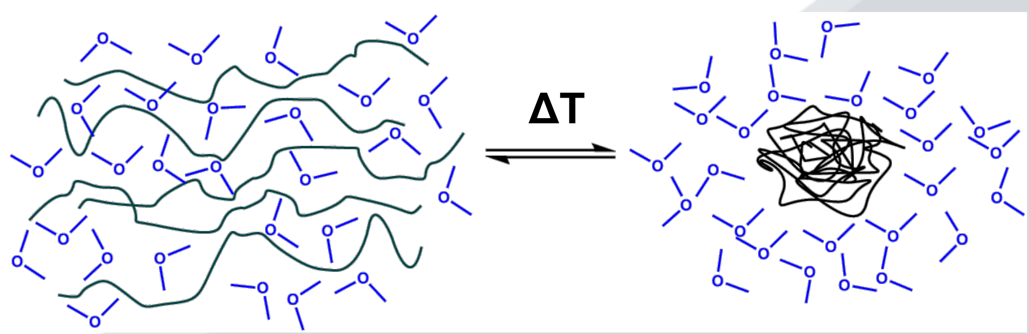
- **pNIPAAM exhibits inverse solubility upon heating**
- **This is referred to as the LCST (Lower Critical Solution Temperature)**
- **Typically this temperature lies between 30-35^{o}C, but the exact temperature is a function of the (macro)molecular microstructure**
- **Upon reaching the LCST the polymer 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

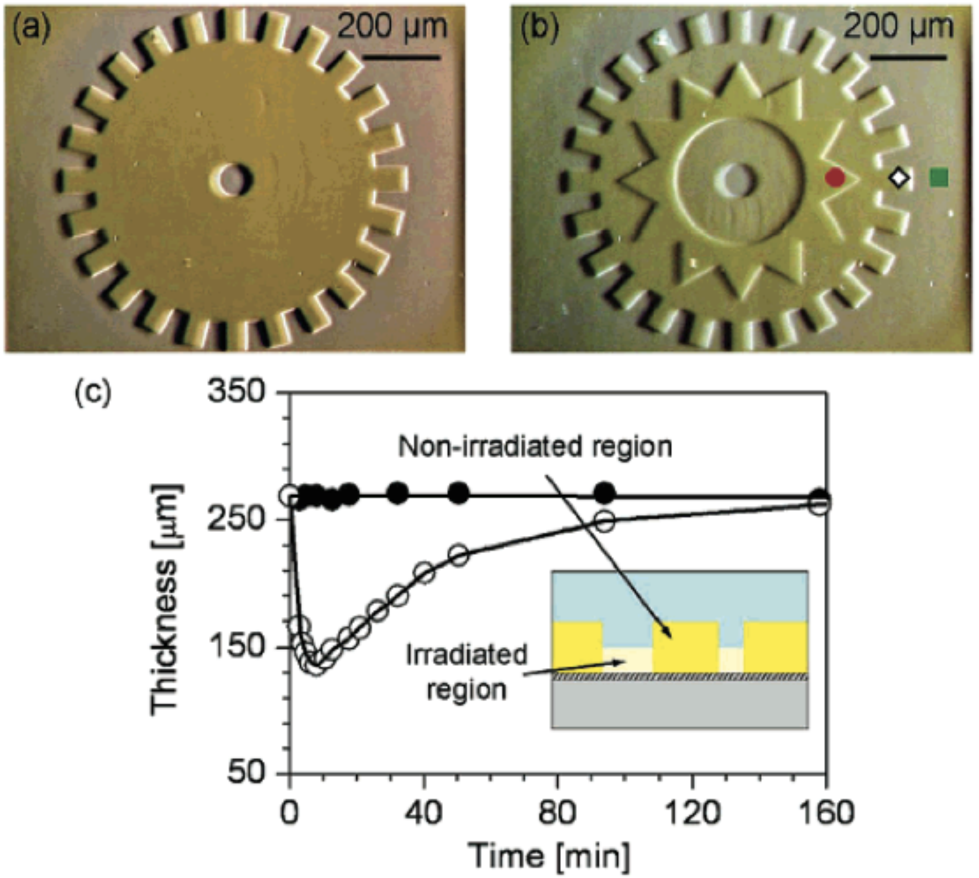
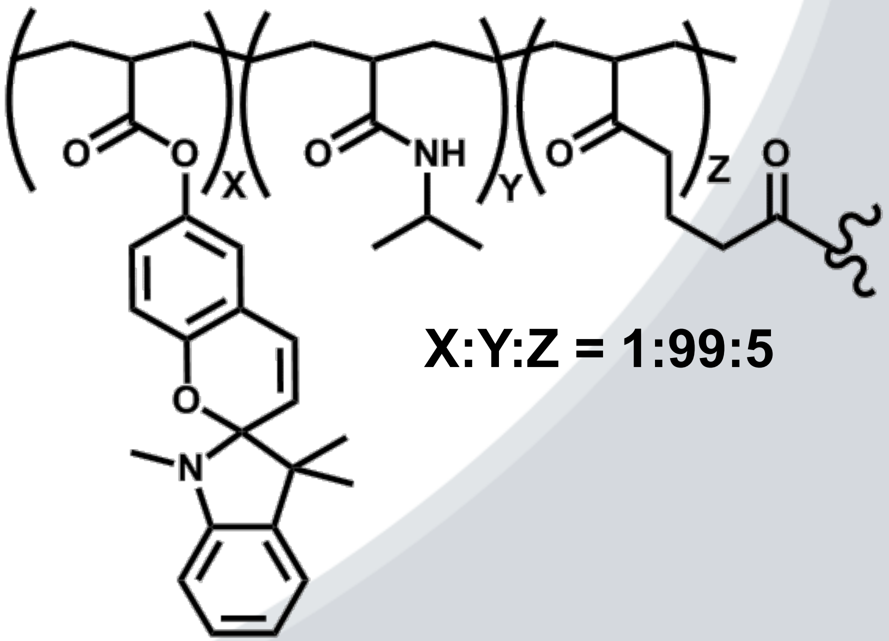


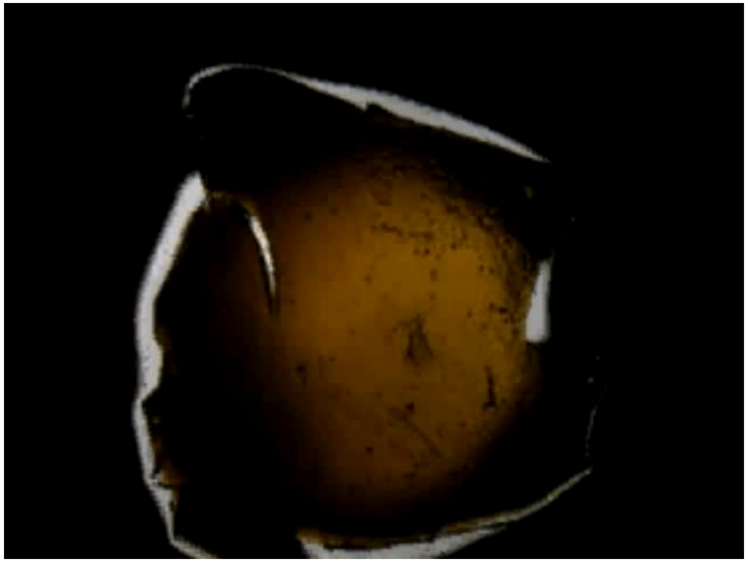
Figure 3. (a, b) Images of the pSPNIPAAm hydrogel layer just after the micropatterned light irradiation. Duration of irradiation was (●, red) 0, (◊) 1, and (■, green) 3 s. (c) Height change of the hydrogel layer in (●) non-irradiated and (○) irradiated region as a function of time after 3 s blue light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

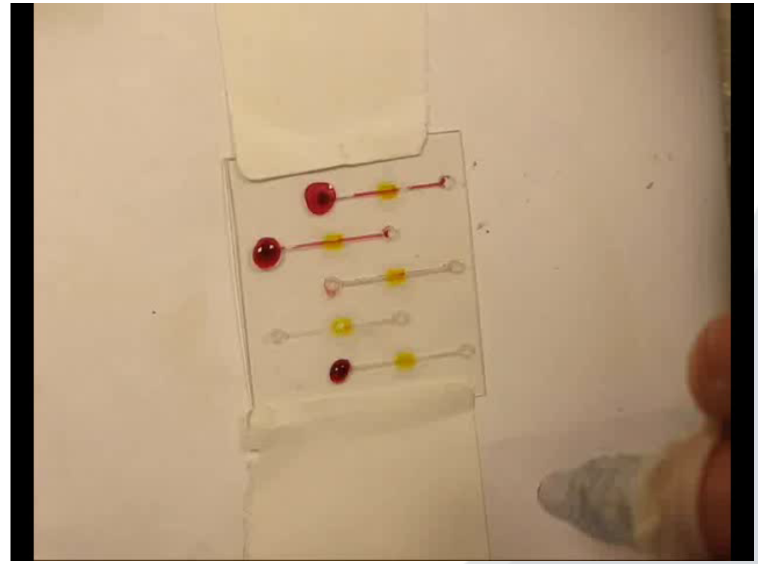


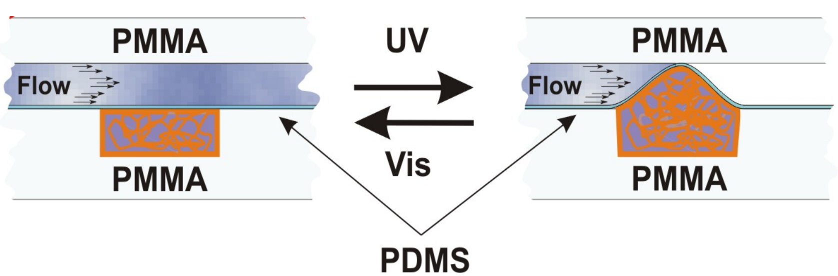
X:Y:Z = 1:99:5

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

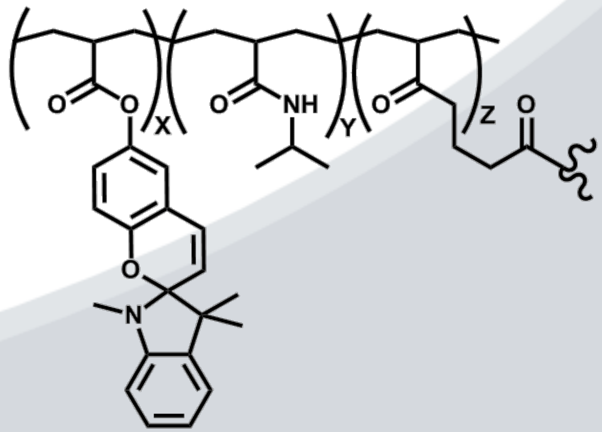
Photo-actuator polymers as microvalves in microfluidic systems

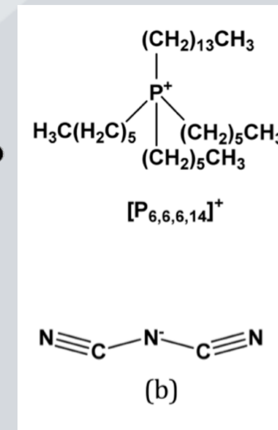






trihexyltetradecylphosphonium dicyanoamide $[P_{6,6,6,14}]^{+}[dca]^{-}$

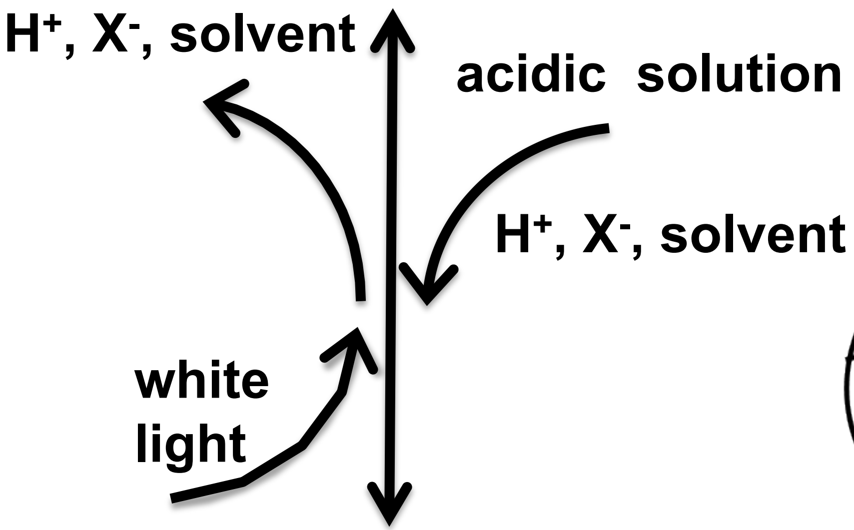




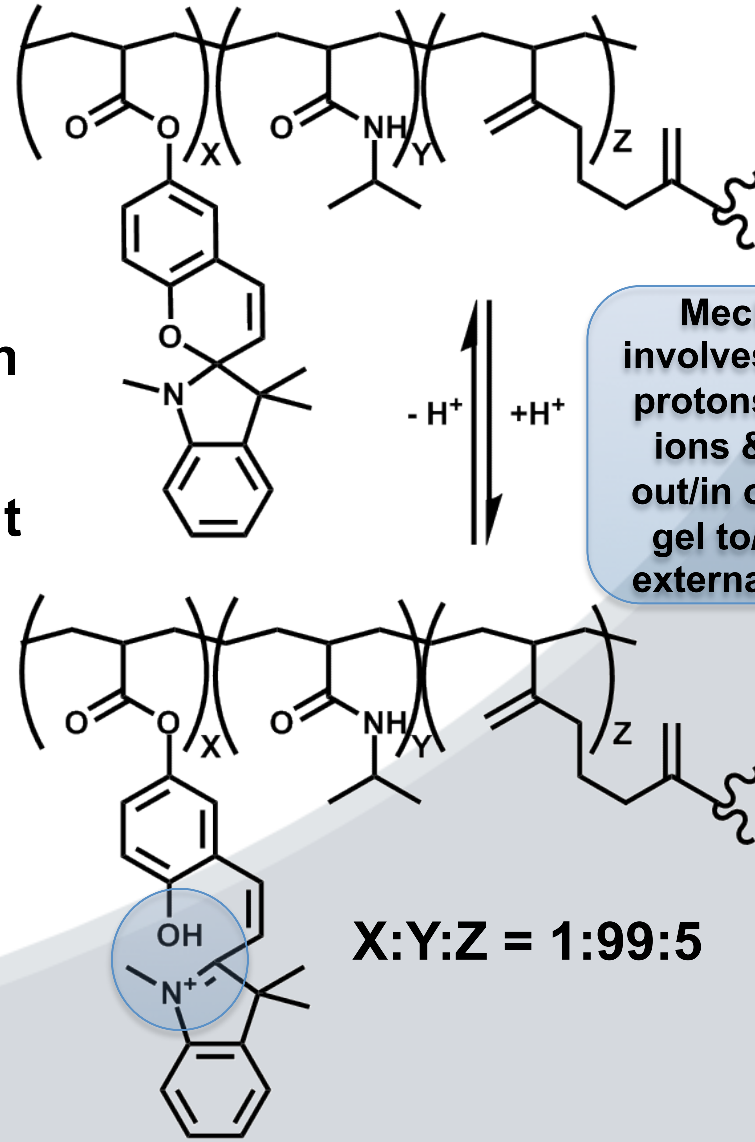
Ionogel-based light-actuated valves for controlling liquid flow in micro-fluidic manifolds, Fernando Benito-Lopez, Robert Byrne, Ana Maria Raduta, Nihal Engin Vrana, Garrett McGuinness, Dermot Diamond, Lab Chip, 10 (2010) 195-201.

Actuation Mechanism

SPIRO (contracted)



MERO-H+ (expanded)



Mechanism involves diffusion protons, counter ions & solvent out/in of the bulk gel to/from the external solution

X:Y:Z = 1:99:5

So far, so good: but what are the limitations?

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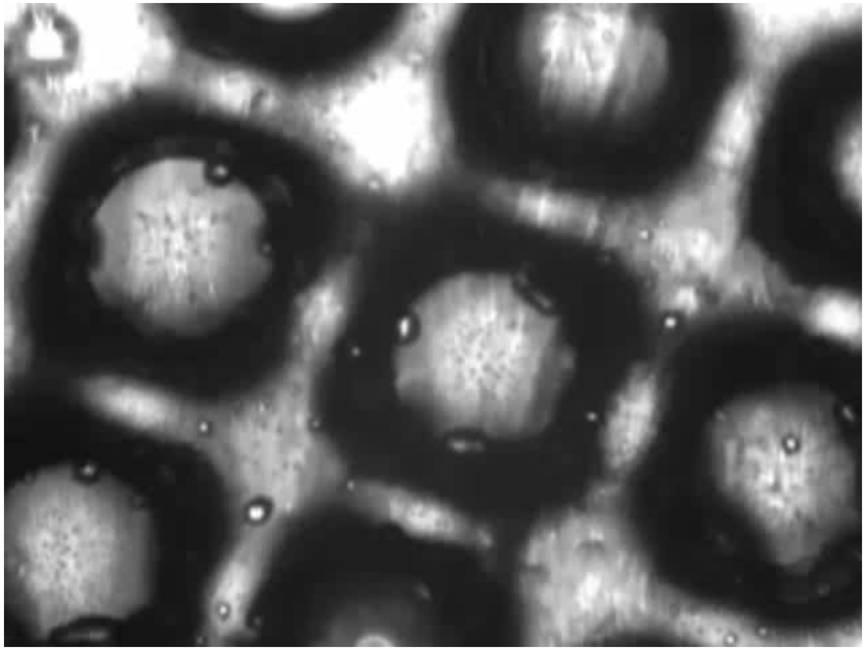
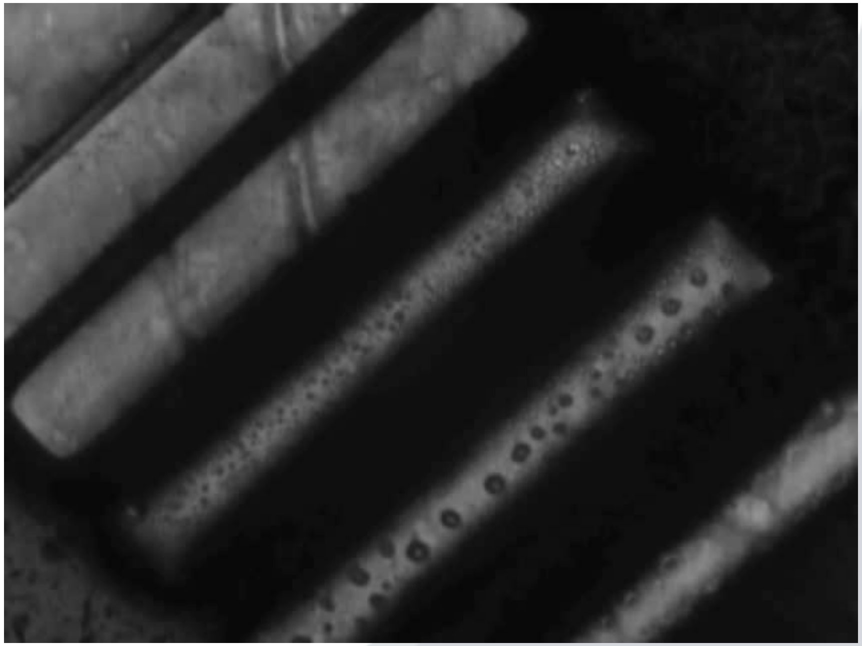
- Response time for re-swelling is slow - 10's of minutes due to diffusion mechanism
- Swelling requires protonation of the MC to $MC\text{-}H^+$ within the ionogel by the external bathing solution
- These issues more or less limit the applicability of the valves to single use

Build Dynamic Structures within Microchannels



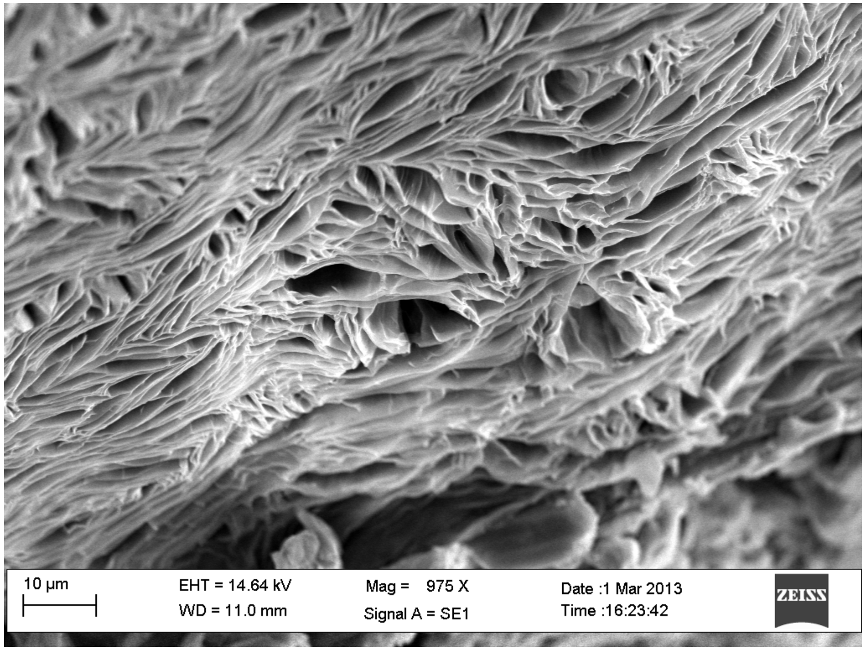
Ntf2 pillars speed x3

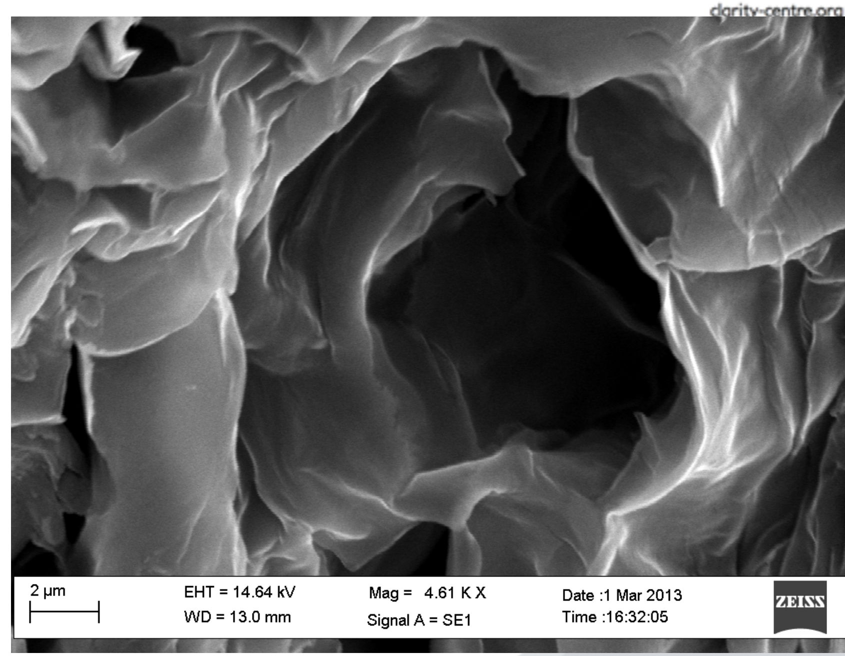


DCA lines speed x4

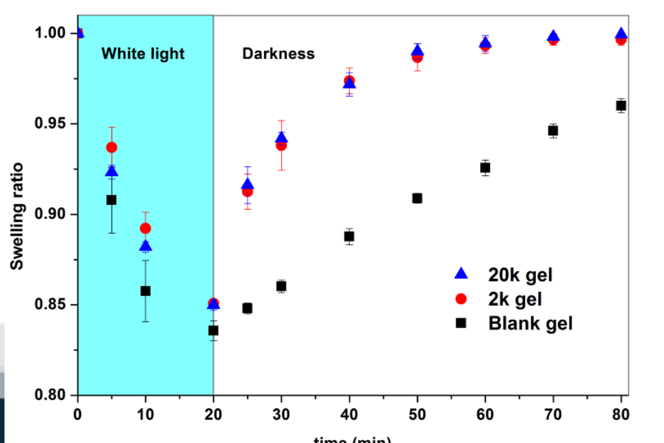
With Dr Peer Fischer, Fraunhofer-Institut für Physikalische Messtechnik (IPM), Freiburg

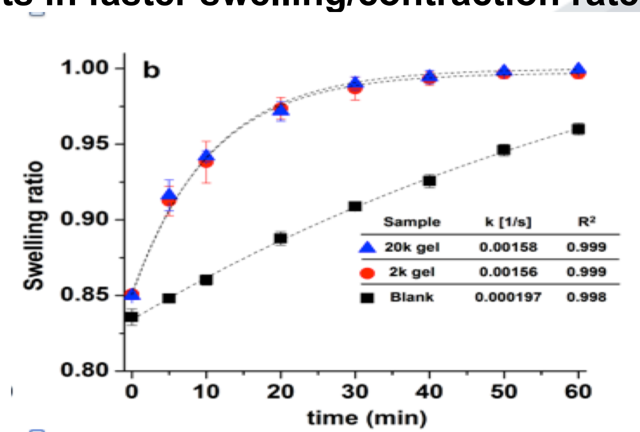
Porous Gels





Highly porous pNIPAAm gel structures generated using PEG as the porogen. This dramatically increases the surface area to bulk ratio, reducing the diffusion pathlength for water to penetrate to the gel interior, which in turns results in faster swelling/contraction rates

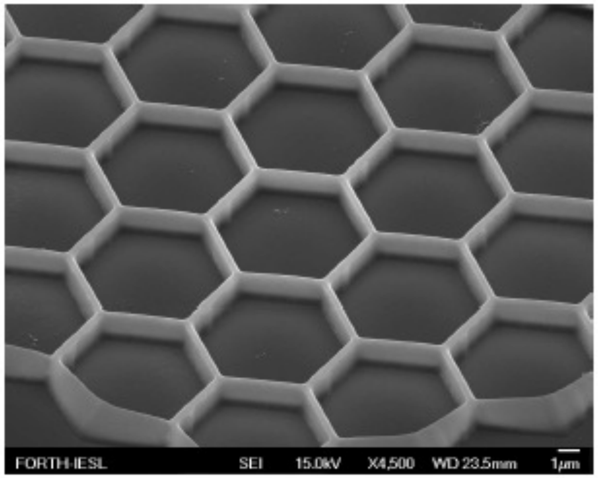




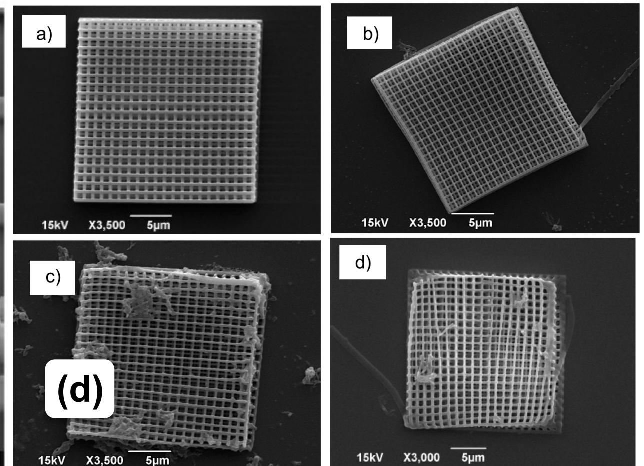
On the re-swelling side; highly porous gels now recover ca. an order of magnitude faster;

k = 1.6×10^{-3} S^{-1}
vs. 2.0×10^{-4} S^{-1}

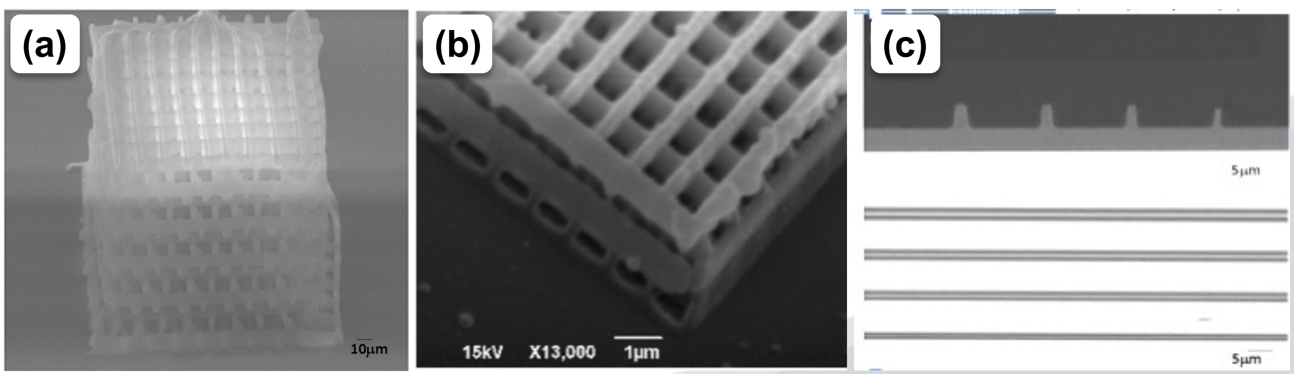
Reduce scale – increase response time
3-d Spiro-doped sol-ionogels



SEM of surface pattering produced by multi-photon polymerisation of hybrid graphene-doped ionogels



SEM images of woodpiles fabricated from material D containing a) 0%, b) 20%, c) 40% and d) 50% IL



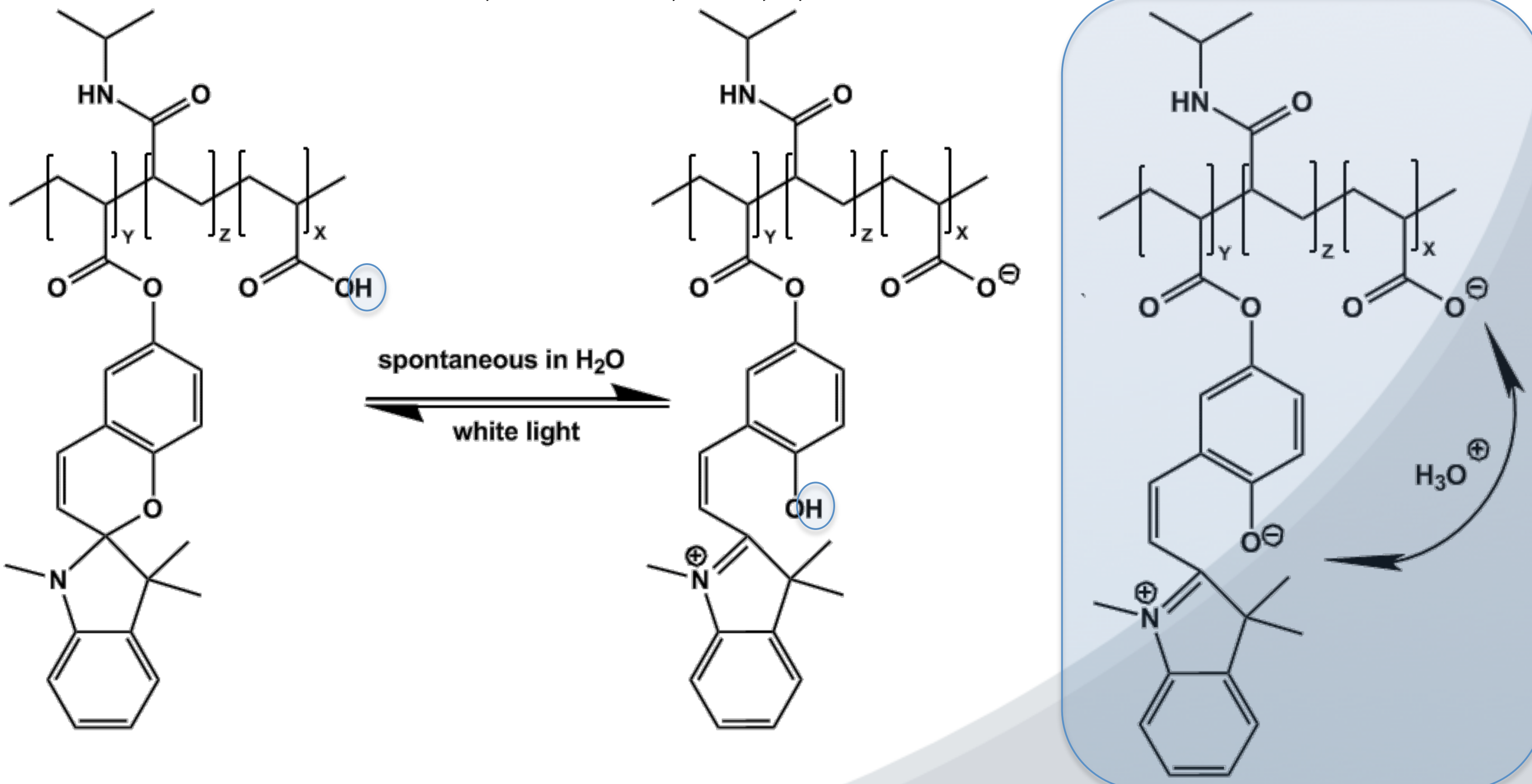
Two photon polymerised (2PP), patterned ionogels (a) and (b), and (c) feature resolution down to 150 nm or less; (d) spiropyran co-polymerised in a gel 'woodpile' structure.

The ionogels were based on photo-curable silicato-zirconate hybrid sol-gel materials and phosphonium (trihexyltetradecylphosphonium dicyanamide [$P_{6,6,6,14}$] [DCA] ionic liquid (IL). To optimise the dispersion of graphene within the ionogel matrices, aqueous solutions of graphene were prepared, as opposed to the conventional graphene powder approach, and employed as catalysts for the hydrolysis and condensation reactions occurring in the sol-gel process.

With Gabija Bickauskait *and* Maria Farsari, Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas, N. Plastira 100, GR-70013 Heraklion, Crete, Greece

Self protonating photoresponsive gel

Ziolkowski *et al.*, Soft Matter, 2013, 9, 8754–8760



Previously proton source was external (acidic soln. required)
Protons, counter ions & solvent diffuse into/out of the gel

Now the proton exchange is 'internalised'
The proton population is essentially conserved

Spontaneous Reformation of Acidified Merocyanine during Actuation Cycling in non-acidified water

Ziolkowski *et al*., Soft Matter, 2013, 9, 8754–8760

Gel with 0 % AA

Colour gradually changing from yellow to purple as H^+ leaves the gel on each cycle

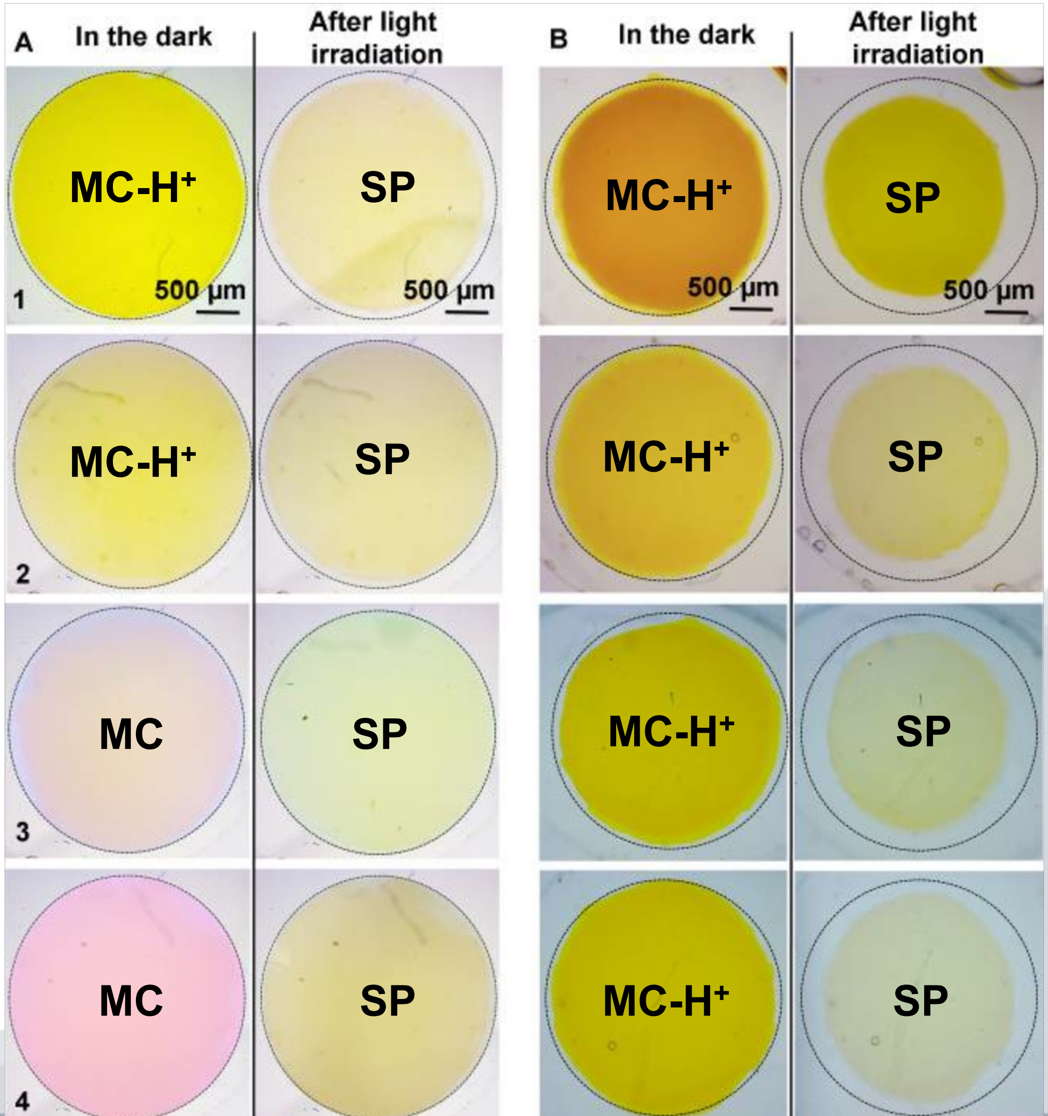
Switching changes from primarily

$MC\text{-}H^+ \rightarrow SP + H^+$

to

$MC \rightarrow SP$

Gel actuation stops



Gel with 5 % AA

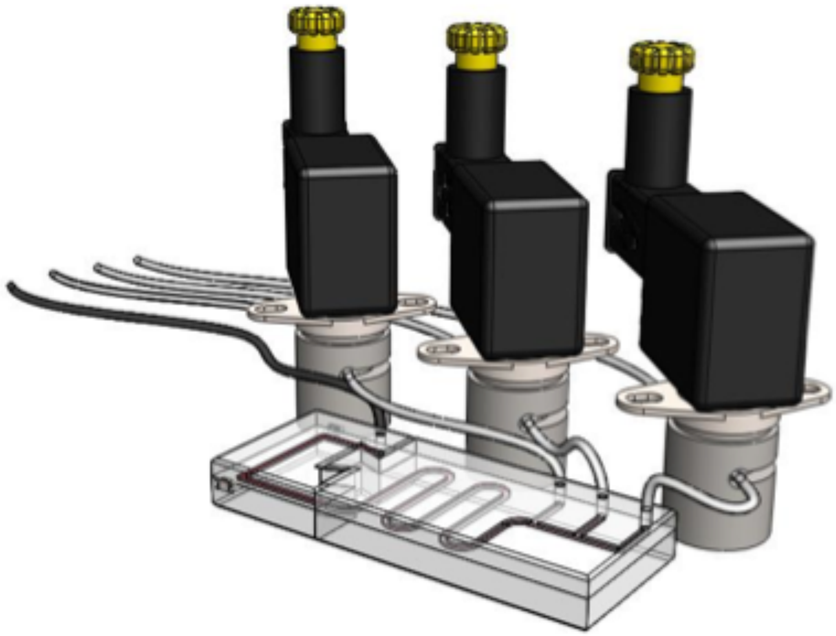
Colour remains essentially the same, as H^+ stays in the gel during cycling

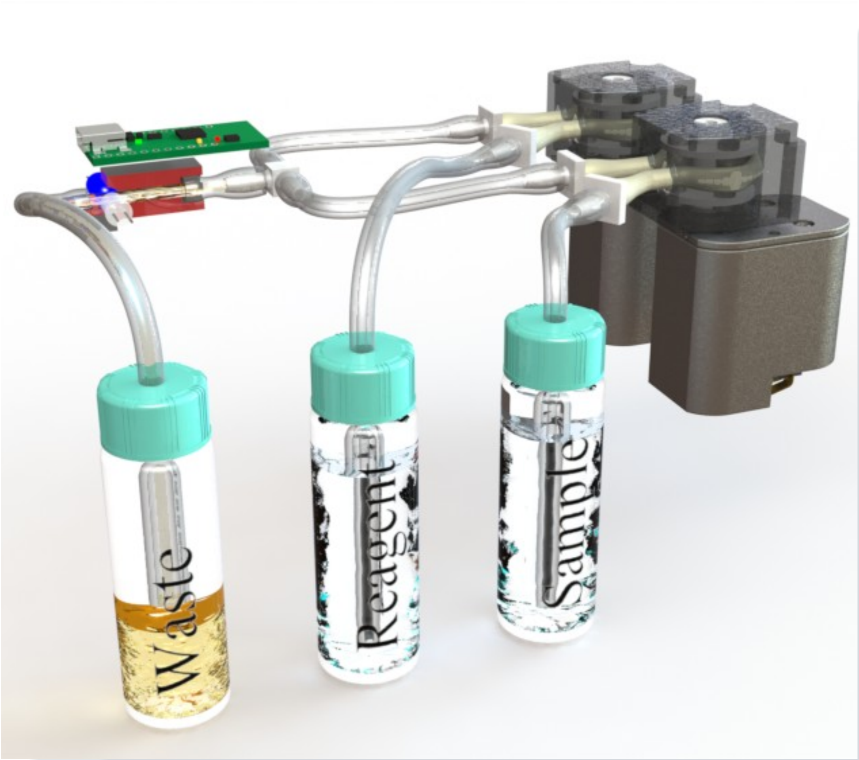
Switching stays primarily as

$MC\text{-}H^+ \rightarrow SP + H^+$

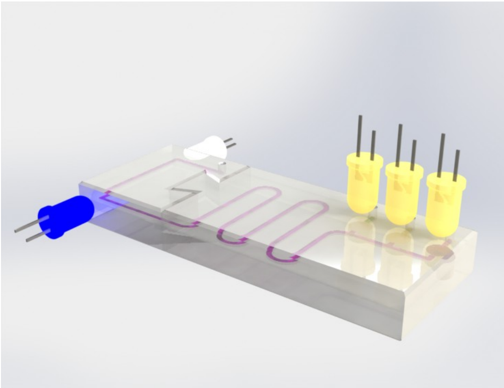
Gel actuation continues

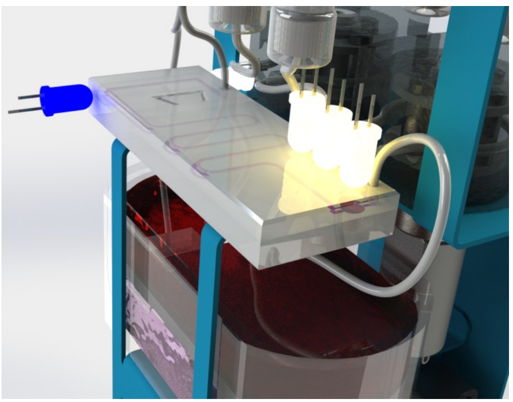
Can we go from this:

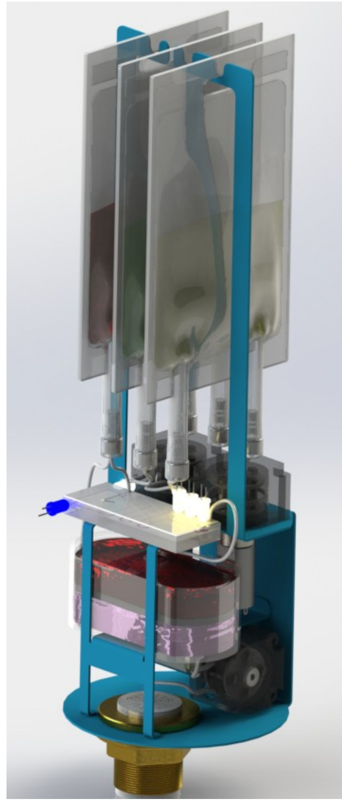


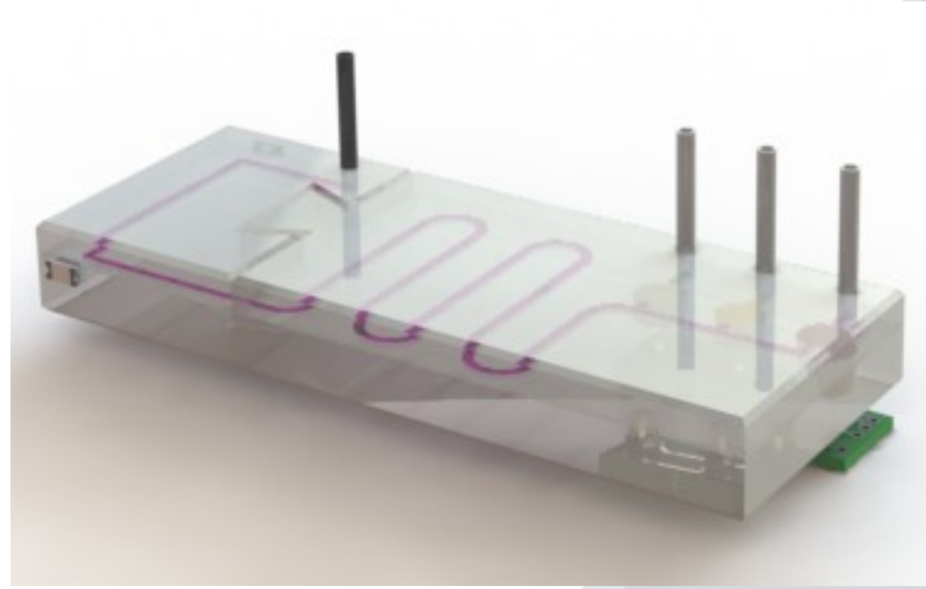


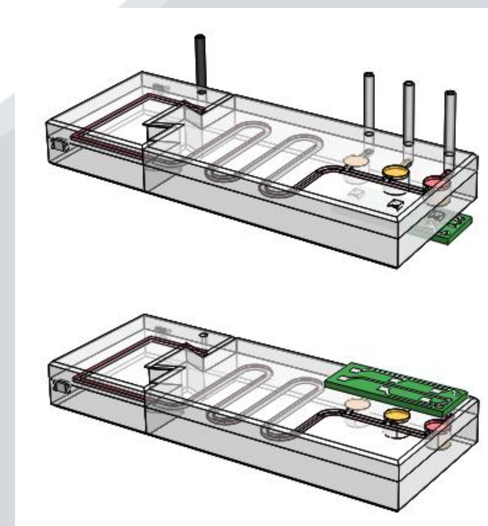
To Photo-Fluidics & Detection





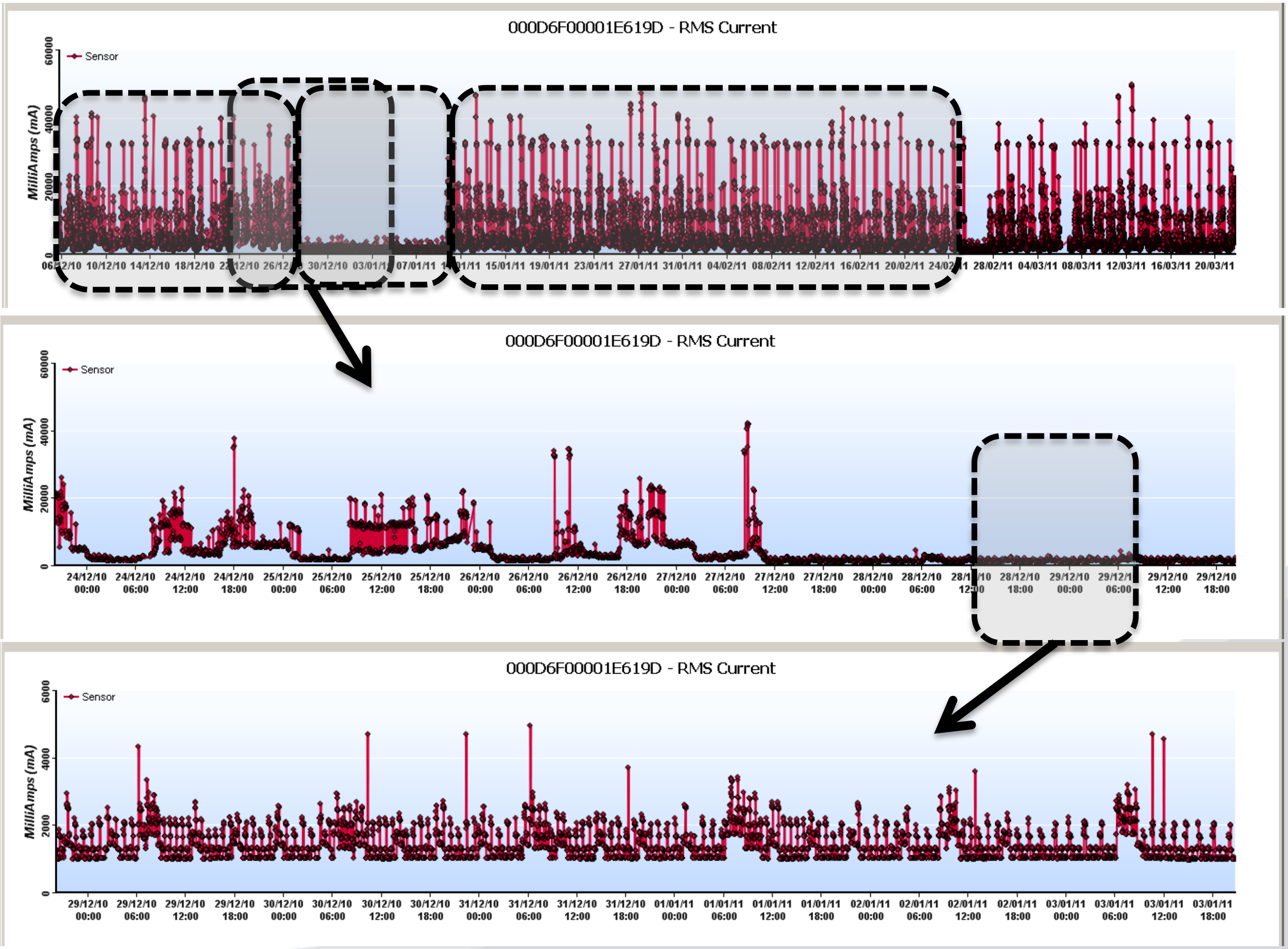






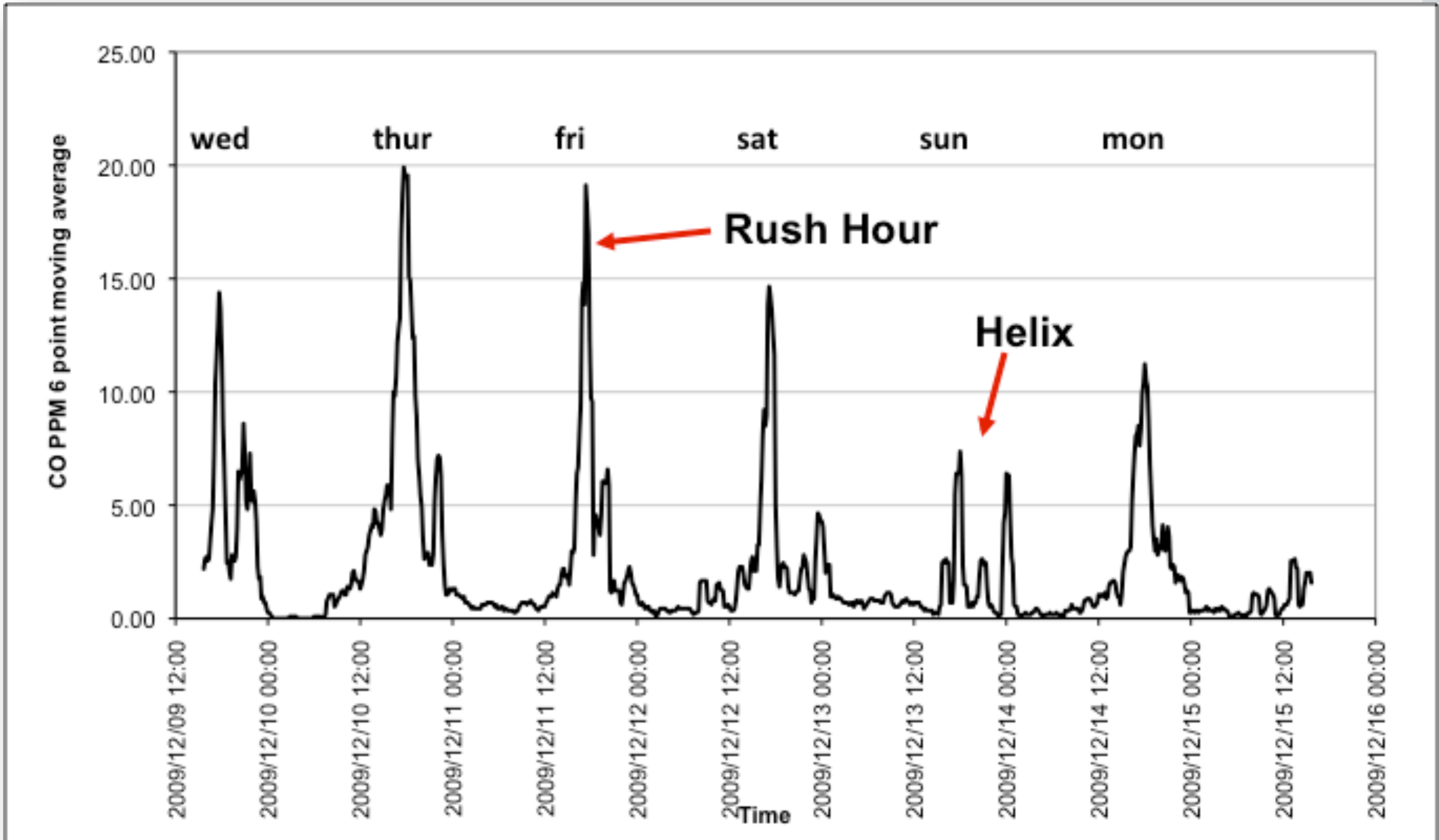
- **Fluidic handling completely integrated into the microfluidic chip**
- **Valves actuated remotely using light (LEDs)**
- **Detection is via LED colorimetric measurements**

Who owns the data? Life Patterns from Home Metering



- Home/Away
- Repetitive Patterns
- Specific Appliances
- Totally unobtrusive
- Who owns the data?

CO Emissions at DCU Car Park,



Conclusions

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- Distributed sensor networks can provide tremendous benefits to society
- Significant advances in the performance of sensors for important chem/bio-targets are required
- This will happen provided there are strong links between fundamental materials science and applied research
- Issues around ethics, trust, privacy need to be addressed

Thanks to…..

- Members of my research group
- NCSR, DCU
- CLARITY/INSIGHT
- Research Partners – academic and industry
- Funding sources – SFI, HEA, EI, MI, EPA, ARC, EU-FP7, IRCSET…

Thanks RSC for the invitation