# Stimuli Responsive Materials': A potential route to futuristic self-aware, adaptive Devices?

Professor Dermot Diamond

CLARITY: The Centre for Sensor Network Technologies,

National Center for Sensor Research

Dublin City University, Dublin 9, Ireland

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# Keynote Article: August 2004, Analytical Chemistry (ACS)

# 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.

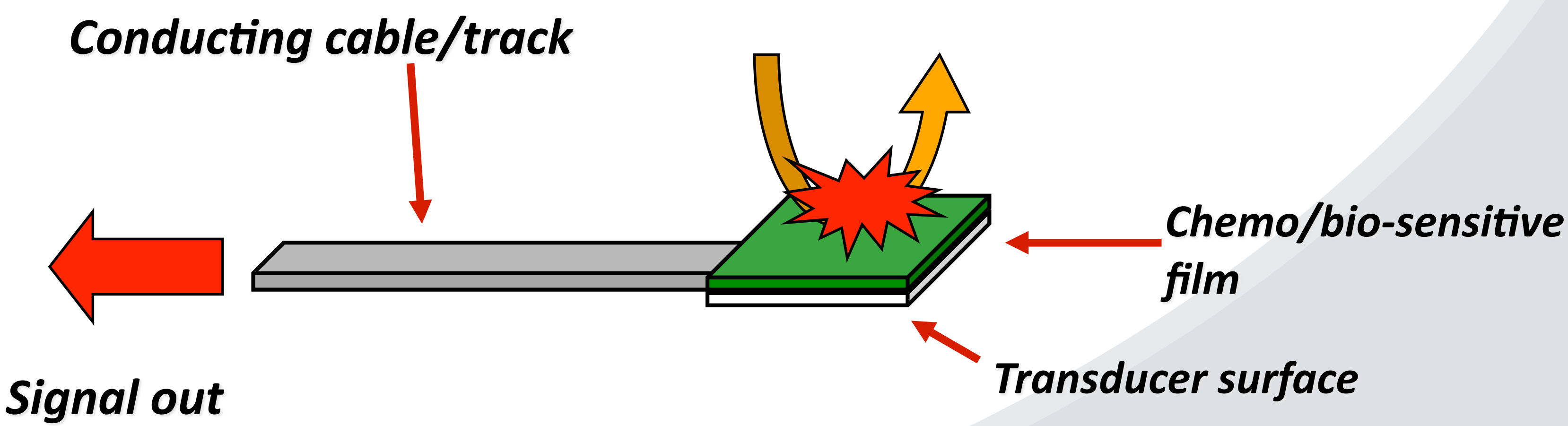
Digital communications networks are at the heart of modern society. The digitization of communications, the development of the Internet, and the availability of relatively inexpensive but powerful mobile computing technologies have established a global communications network capable of linking billions 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.

# 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'*




In contrast to transducers such as thermistors, in chemical sensors, the sensing surface **MUST** be directly **exposed** to, and **interact intimitely** with, the sample

# Fundamental Problem: Sensor surface will change with time!

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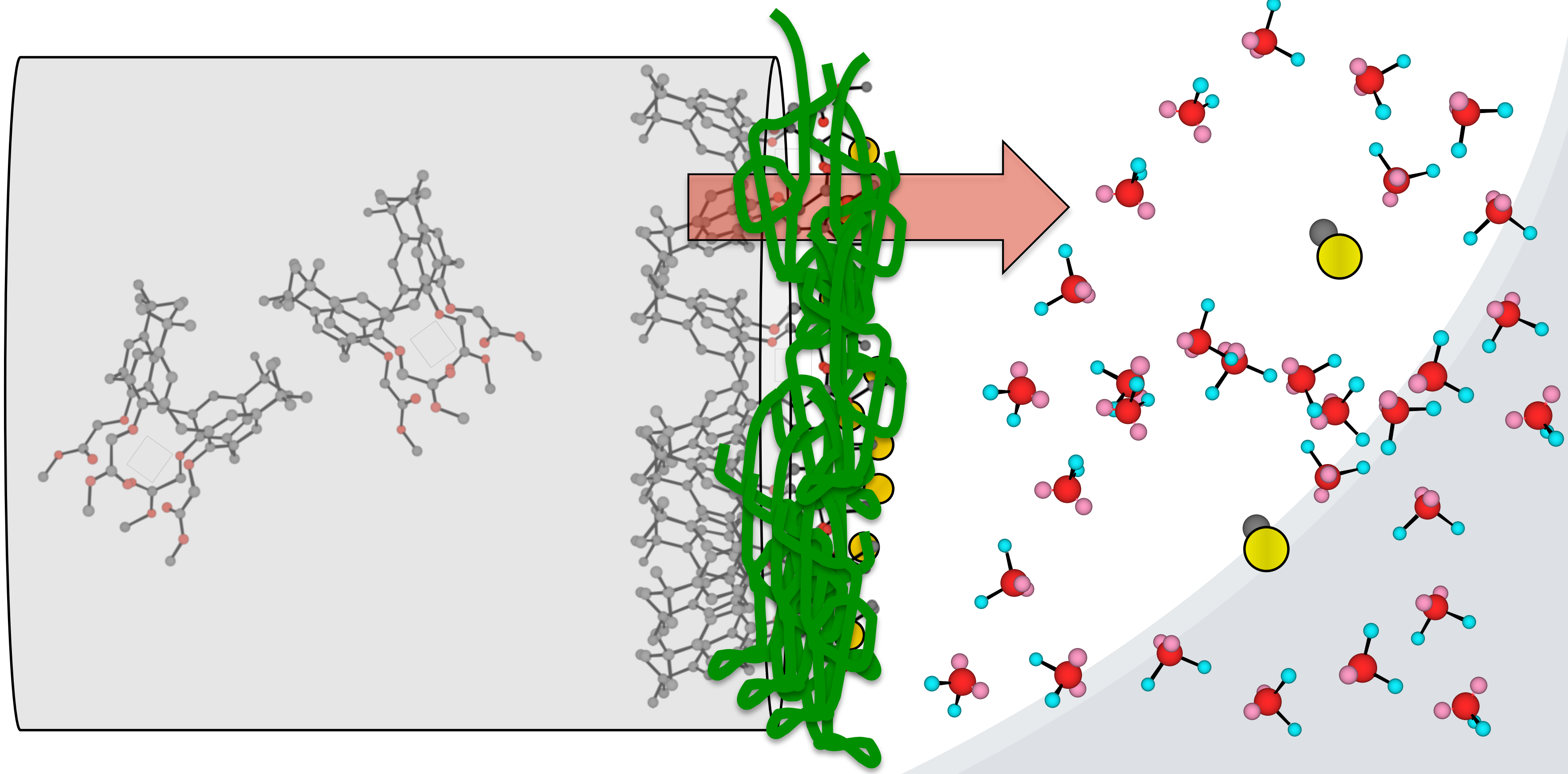

- Surface interactions are critical to signal generation – very susceptible to any process that modifies the surface condition => drift, loss of  sensitivity => regular calibration => high cost of ownership
- Leaching, biofouling, physical damage, sample interferents, …..
- Engineers expect a thermistor, we have platforms closer to a washing machine!

# Using LEDs as Chemo-Sensors!

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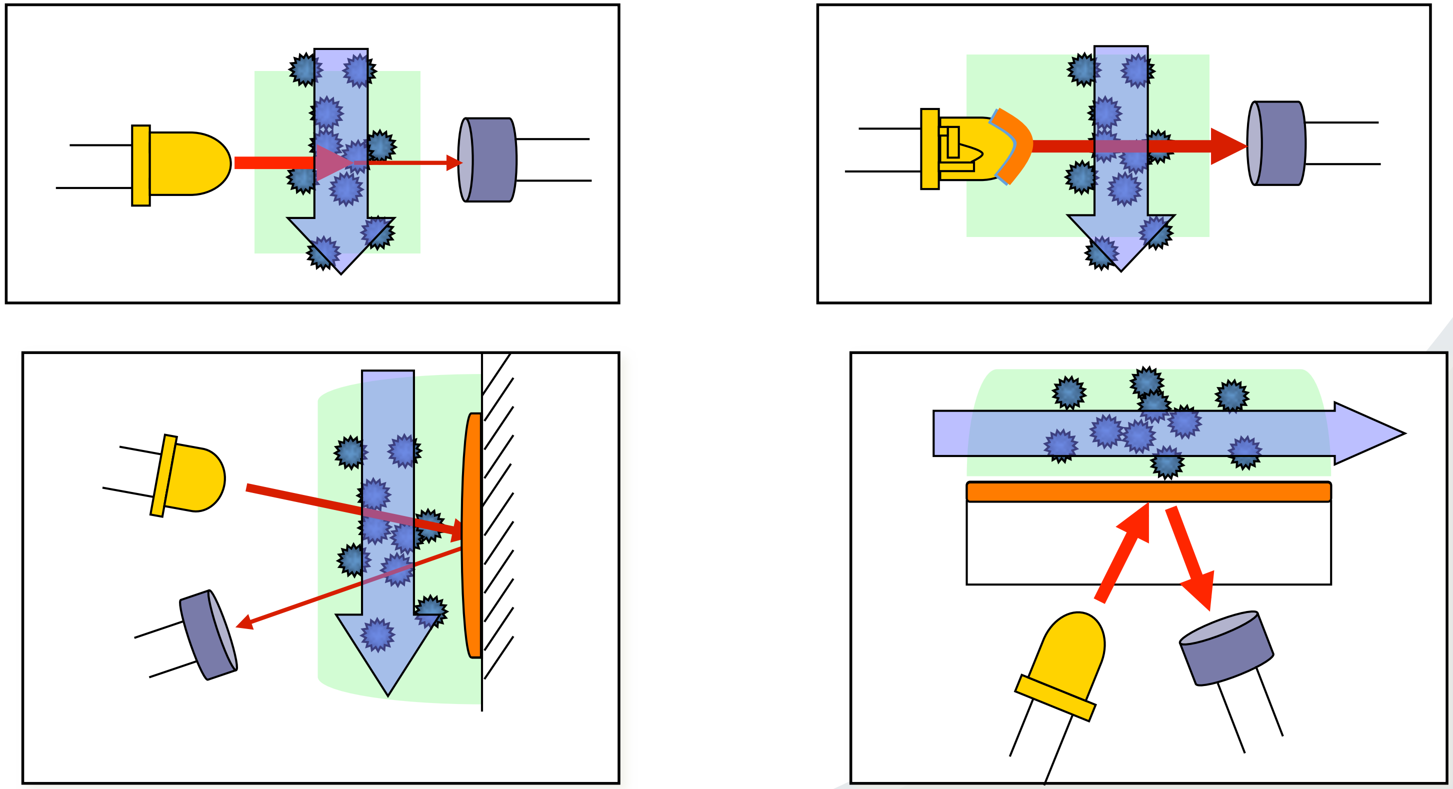
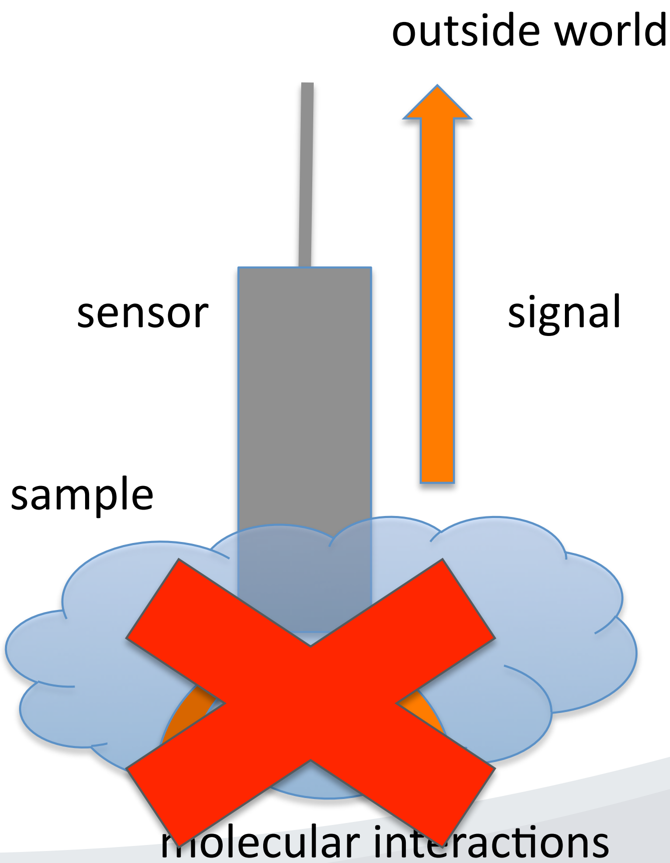
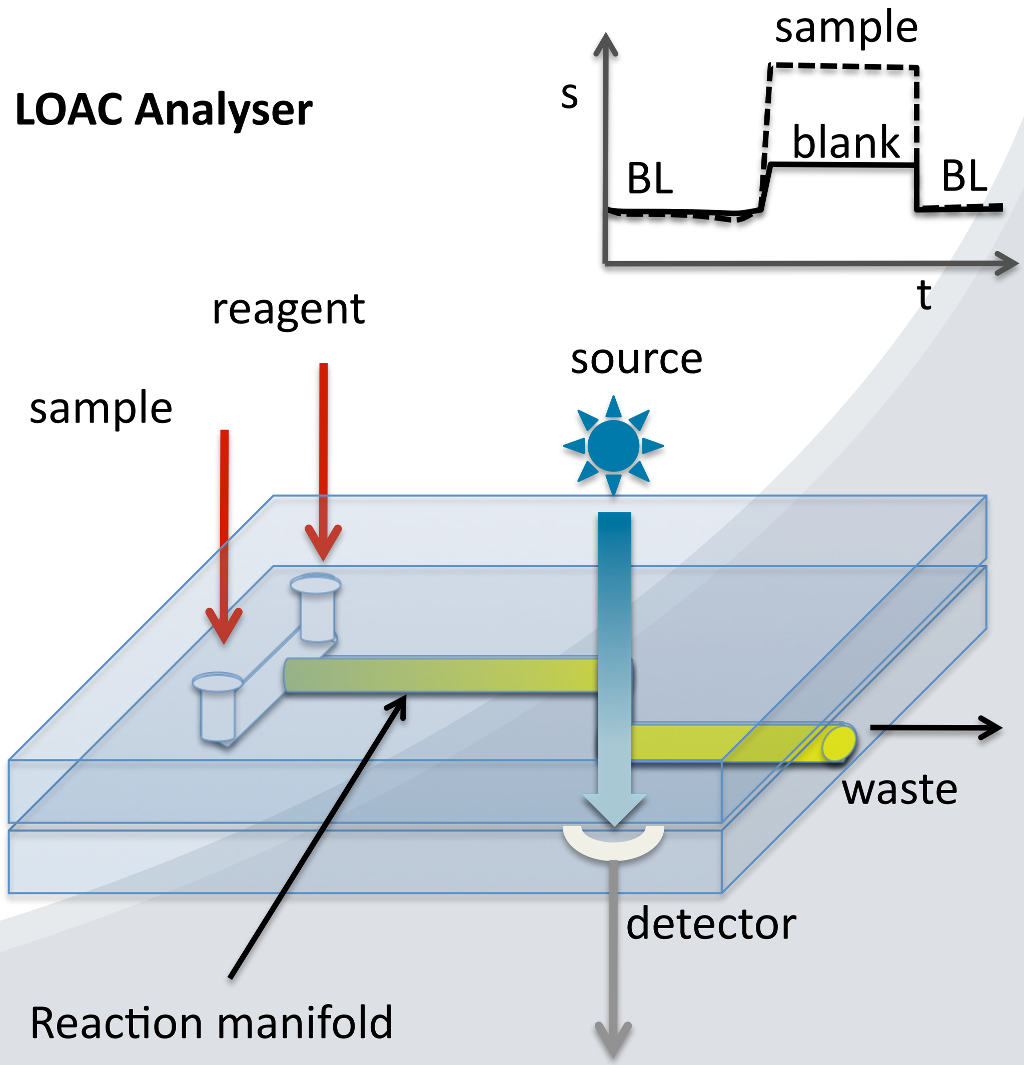


- LEDs are superb platforms for building optical sensors!
- Colour based measurements can be used for a wide variety of assays – chemo, bio (enzyme, antibody)

# Direct Sensing vs. Reagent Based LOAC

# Autonomous Chemical Analyser

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- Flow System
  - Reagent (yellow method)
  - Sample (phosphate)
  - Wash/clean
  - Standards (x2) 5, 20 ppm
  - Waste (stored)
  - Low powered pumps (x6)
- Detector – low power, based on LEDs
- Microfluidic manifold for sampling, reagent mixing, presentation to detector
- Can function autonomously (in principle) for up to one year (depends on duty cycle) on ca.50 mL of reagent
- Performs 2-point calibration between each measurement
- Electronics
  - signal acquisition & processing
  - Communications (wireless GSM-SMS)
  - GPS to track location
  - Battery (12 V; lead acid)
  - Solar panel
- Component cost ca. €2,000

# Autonomous Wet-Chemistry Analyser

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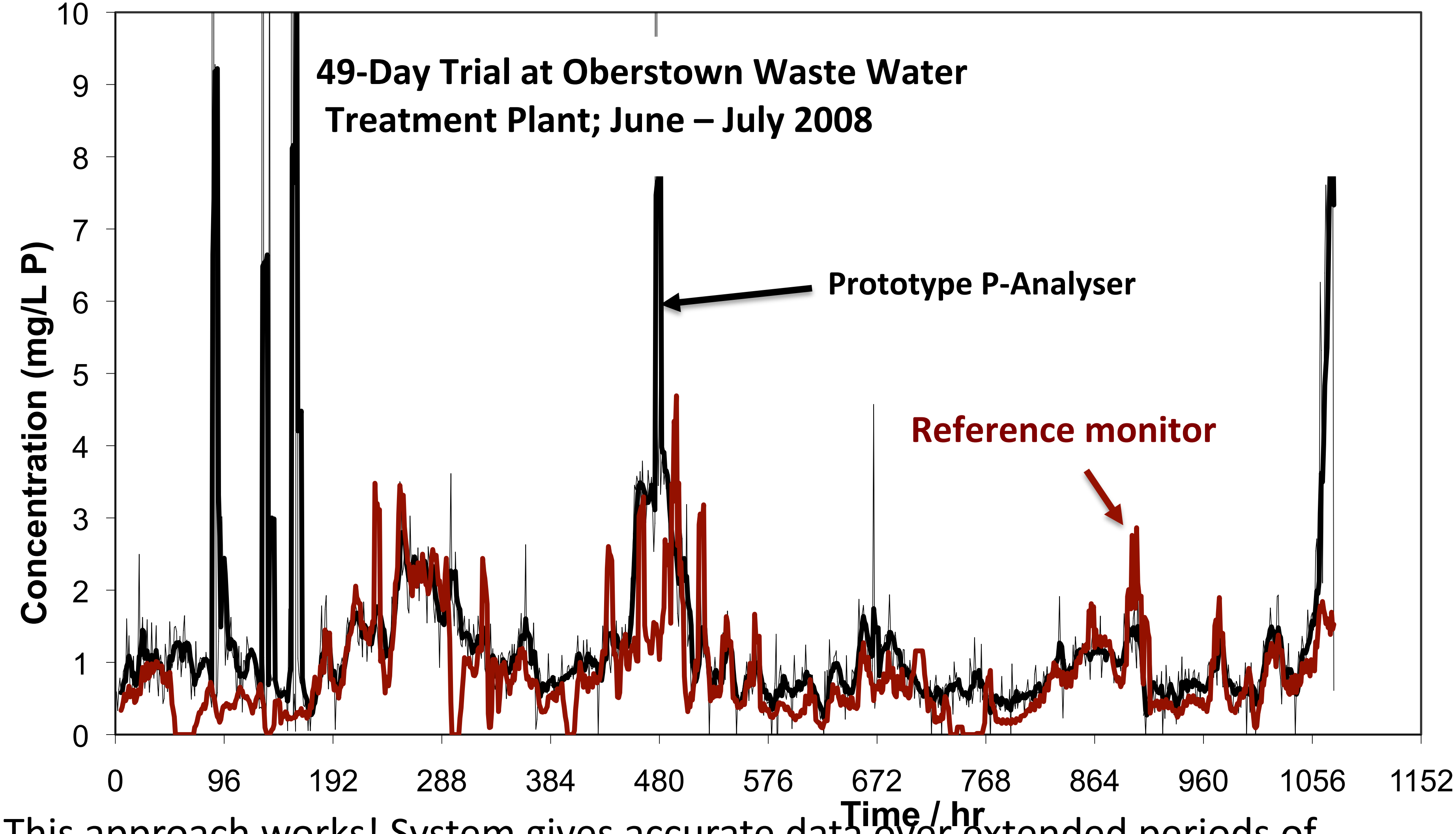


This approach works! System gives accurate data over extended periods of autonomous operation in real scenarios – moderate scale up possible

**But still relatively expensive!**

# $CO_2/CH_4$ Monitoring System

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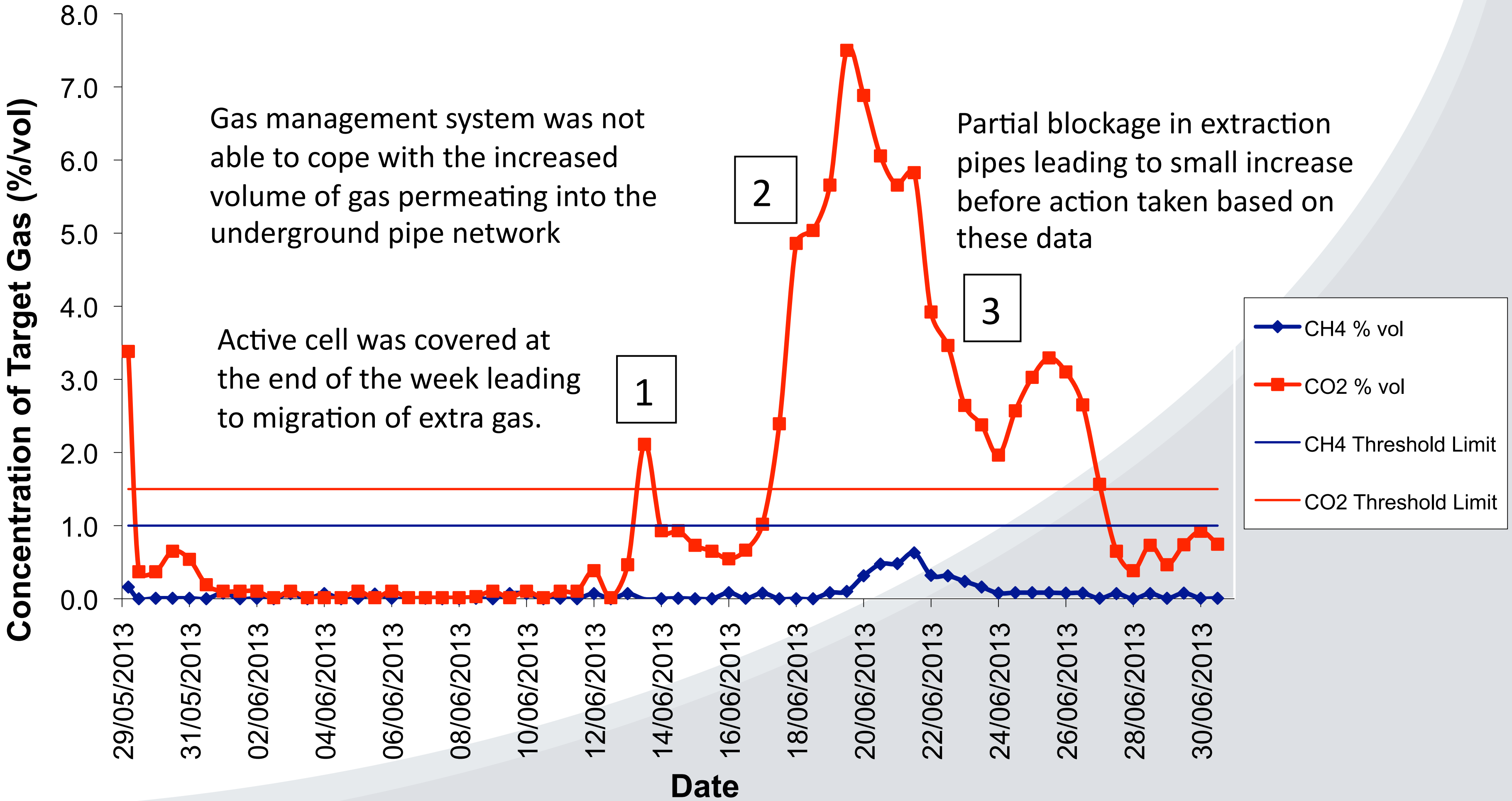
Figure 1. Annotated representation of an assembled autonomous landfill gas monitoring platform. (1) Control board, (2) Bluetooth module, (3) GSM module, (4) Battery, (5) Extraction pump, (6) Inlet/Outlet selection valves, (7) Sample chamber.

# Data events June 2009



# Remote Access to field Deployment data

Air Quality: Data from the real-time greenhouse gas emissions monitoring deployment at a local landfill site are available at: http://kspace.cdvp.dcu.ie/public/colum/gasMonitor/

Data from the real-time energy monitoring deployment is available at: http://kspace.cdvp.dcu.ie/public/colum/aalD/index.php

Water Quality: Data from the real-time phosphate analyser deployed at the Broadmeadow/Swords Estuary is available at: http://kspace.cdvp.dcu.ie/public/colum/phosphateMonitoring/

# Strategy, Ideas???

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- **Take what works best from printed electronics**
- **Combine to give a new functional platform with CLEAR ADVANTAGES OVER EXISTING APPROACHES**
- **Demonstrate this new platform functioning in REAL FIELD DEPLOYMENTS**
- **What components are available?**
  - Solar cells
  - batteries
  - O-LEDs
  - O-PDs
  - ........

Combine these to provide a new platform & **choose the right application**

# Very Low-Cost Chemical Sensing and Wireless Communications

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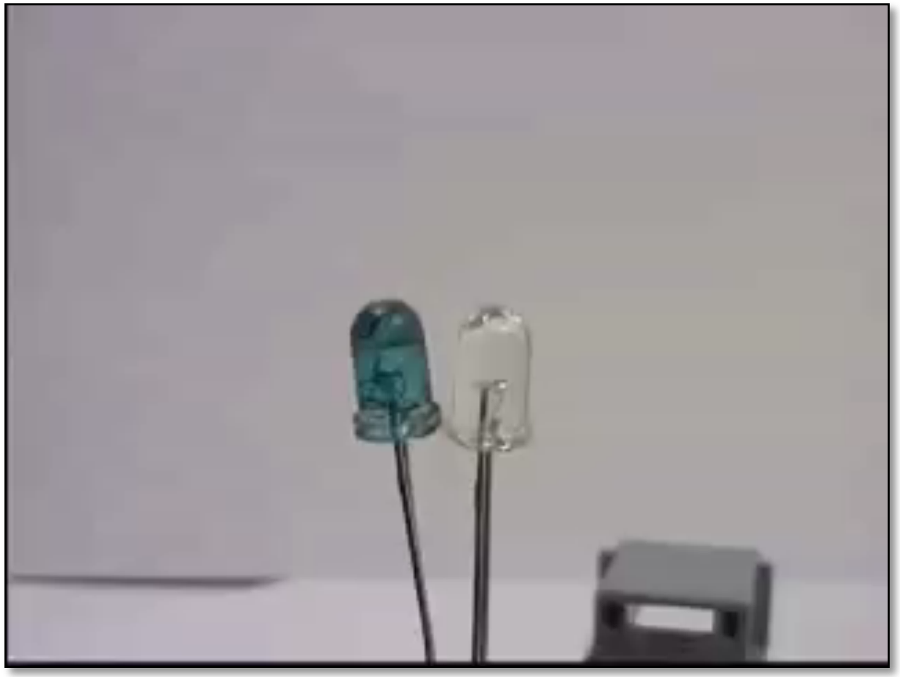

- LED on LHS reverse biased – photodiode
- Uses ambient light as incident photonic energy to discharge the diode junction (+5V)
- Coated with Chemochromic film – changes colour if local chemistry changes
- LED on RHS is used to signal that ‘an event’ has happened
- Can be pulsed to communicate more detailed information

# Low-Cost Optical Sensors based on LEDs

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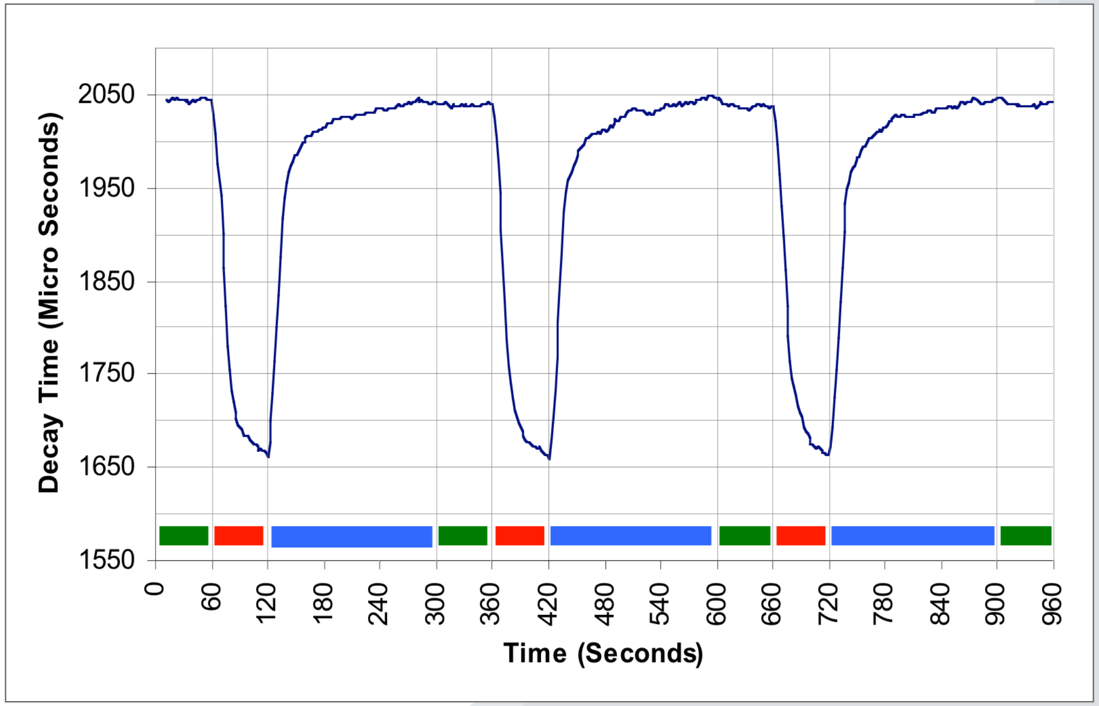


**Fig. 5.31 Smoothed Response Data of Wireless Chemical Sensor Node Exposed to Three Consecutive Plumes of Acetic Acid Laden air**

# What improvements can we make using plastic electronics?

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- We have a way to provide self-sustainability in power demand/supply (**but keep the power demand as low as possible!**)
- We can generate light using O-LEDs
- We can perform measurements
- We can control photoswitchable properties
  - liquid flow through channels
  - binding and release of guest molecules on surfaces
  - transmit information over distances
  - ………

# Conclusions

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- **Many critical processes can be controlled using light**
  - Uptake and release of molecular guests
  - Binding and release optically transduced - e.g. colour changes
  - Colour change can be detected optically using multiple detection modes
  - Liquid flow in microfluidic channels can be controlled using optically triggered valve structures
  - Flow rates can be varied through changes in surface charge or changes in viscosity of the liquid phase

**Combining printed photovoltaics, with printed batteries, printed OLEDs, printed PDs with photoswitchable materials could provide the basis for inherently scalable (self-sustaining) sensing platforms**