CLARITY
clarity-centre.org

Materials with switchable characteristics: the key to innovation and creativity in future fabrics

Professor Dermot Diamond

CLARITY: The Centre for Sensor Network Technologies,

National Center for Sensor Research

Dublin City University, Dublin 9, Ireland

Presented at

Smart Fabrics 2009

Holiday Inn West, Rome

10th-12th March 2009

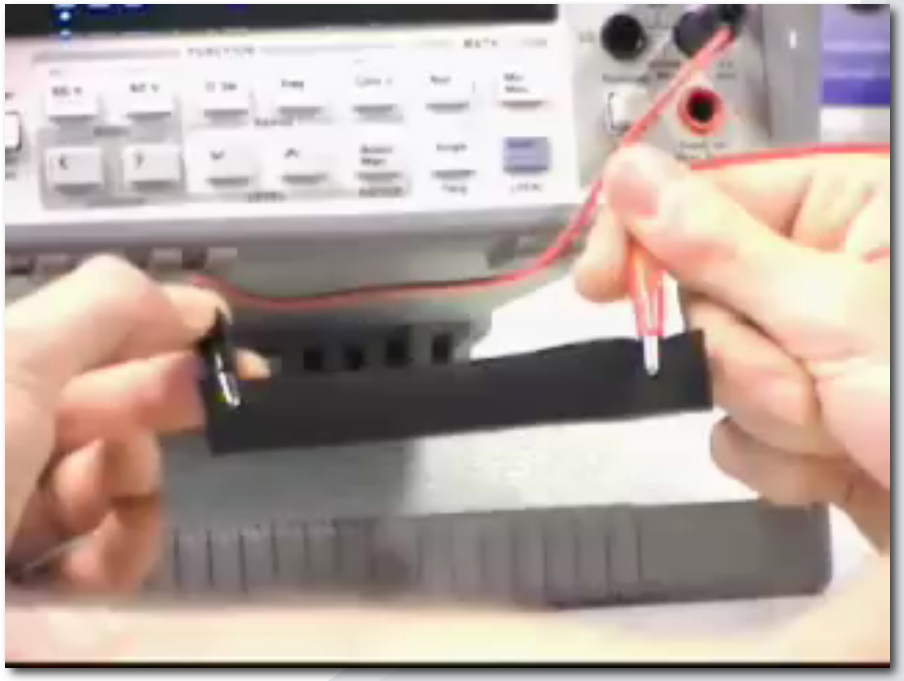
Smart Textiles – Wearable sensors

CLARITY
clarity-centre.org

- **Current Situation - Wearable sensors are usually discrete sensors and electronic components attached to the fabric**

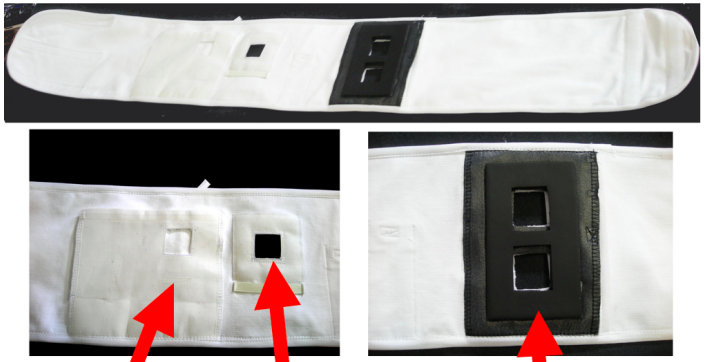
- **Move to Functionalised Fabrics, e.g. lycra coated with conducting polymer**
  - can be used to functionalise discrete locations on a garment
  - can sense stretch, bending, pressure, movements….
  - Can pick up breathing, heart function
  - Innocuous to the wearer

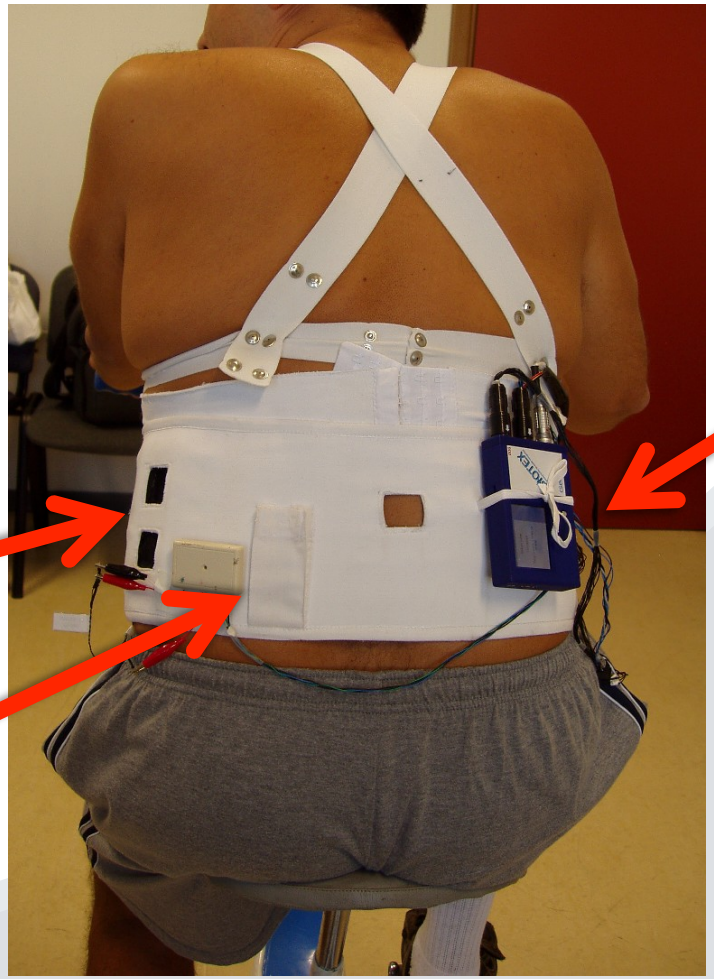
- **Close cooperation with Prof. Gordon Wallace, University of Wollongong**



From Rod Shepherd, AIC, NCSR

Clinical Trials – BIOTEX

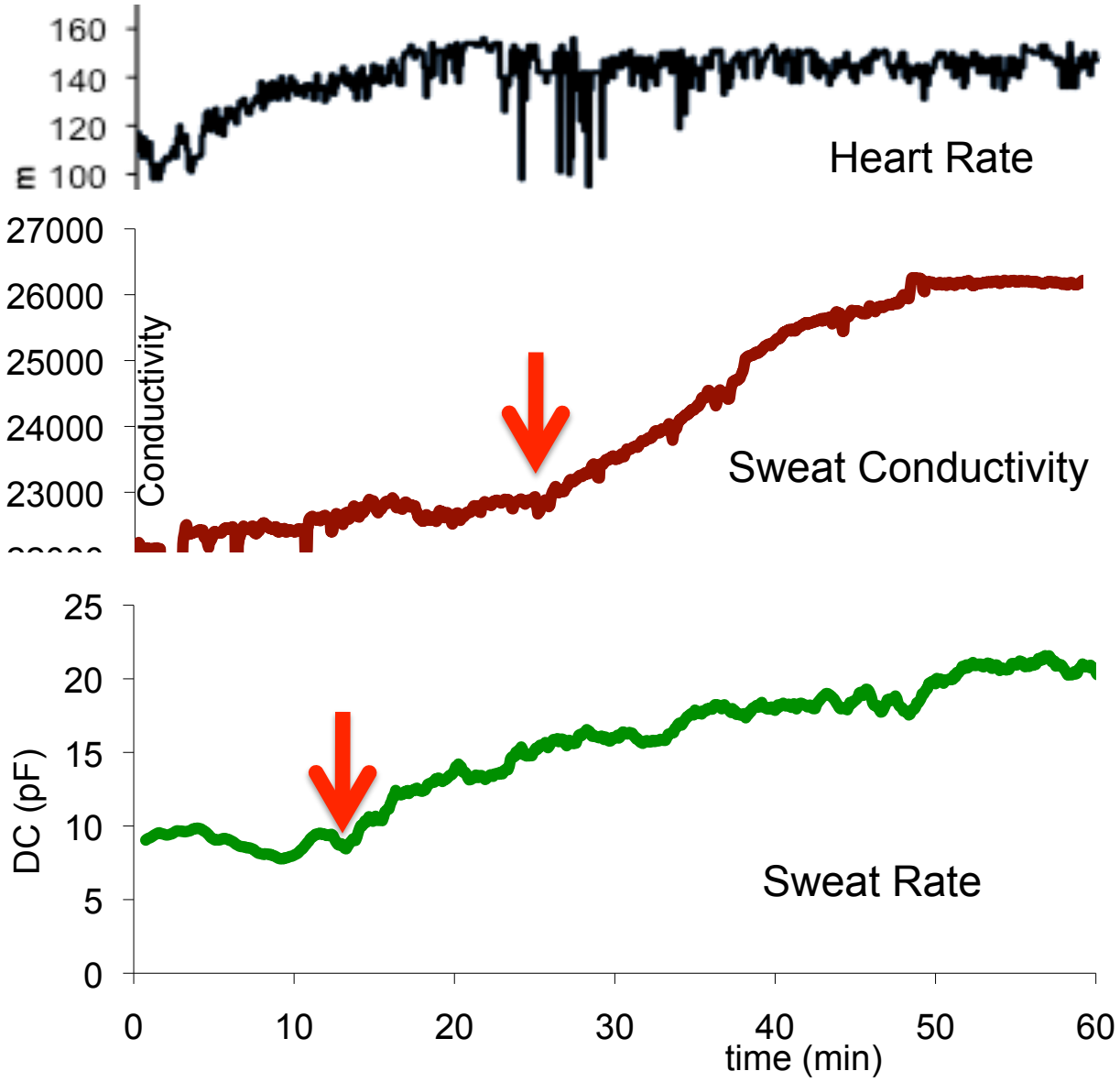




Control Unit

Sweat rate sensor

Multiparametric patch integrated into waistband



BIOTEX-Clinical Trials Female Diabetic subject

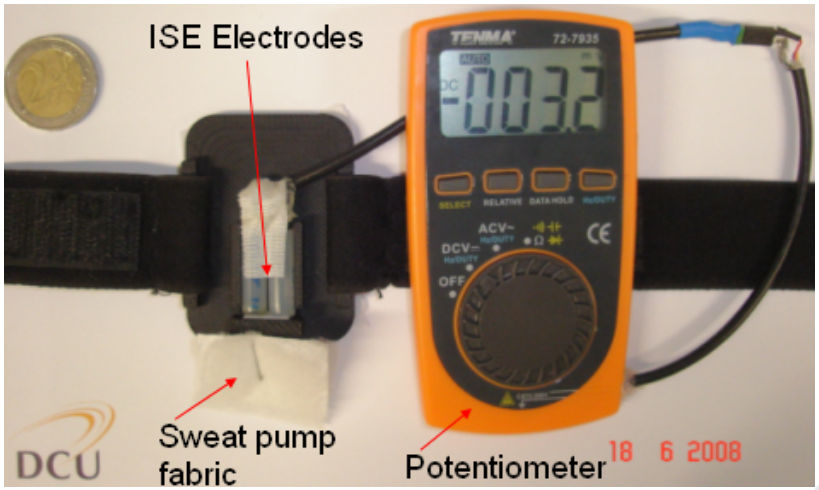
- Female Diabetic Volunteer
- Sweating begins after about 11-12 min exercise

- Conductivity rises sharply after about 25 minutes (sweat has filled the device)

- 'dead-time' is an issue – measurements can only be made when sweat is available

Na^+ Measurements in Sweat

CLARITY
clarity-centre.org

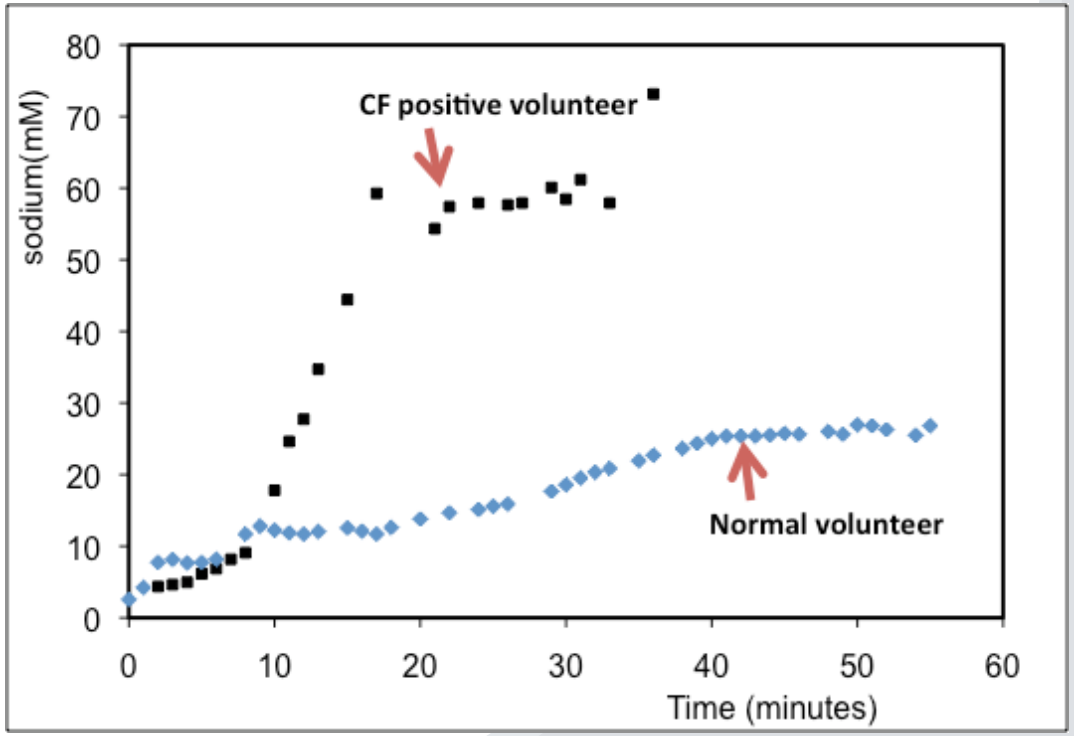


- Solid-state PVC membrane sodium ISE integrated into sweat sampling unit
- Data courtesy of Dr. Ben Schazmann, ASG, DCU

Na+ monitoring in sweat using wearable sensor

CLARITY
clarity-centre.org

- Measurements successfully made
- Clinical trials with CF-positive and normal volunteers
- Elevated levels of Na^+ found in sweat of CF+ volunteers as expected
- Enables electrolyte loss to be estimated when combined with sweat rate/volume data
- Important for rehydration
- Interesting observations
  - elevated viscosity of sweat of CF+ volunteers
  - sweat rate much lower – in some cases no sweating occurred
  - could not exercise as long as normal set



- Diagnostic CF threshold >60mM [Na^+] reached
- Issue with initial delay
  - arises from inherent delay in onset of sweating
  - contribution from 'dead-volume'

Current Status – wearable (Chemo)sensors

CLARITY
clarity-centre.org

- Functioning systems are still largely based on conventional electronic modules
- Sensors and other components are increasingly being integrated into fabrics
- Signal/Comms/power lines woven into material using wide variety of materials e.g. metallic threads conducting polymers, fibre optic cable…
- Need for fundamental breakthroughs in ways to do on-body sensing, interconnects, power, communications, liquid handling etc.

Need to build on linkages between fundamental materials science, platform development, manufacturers, end users

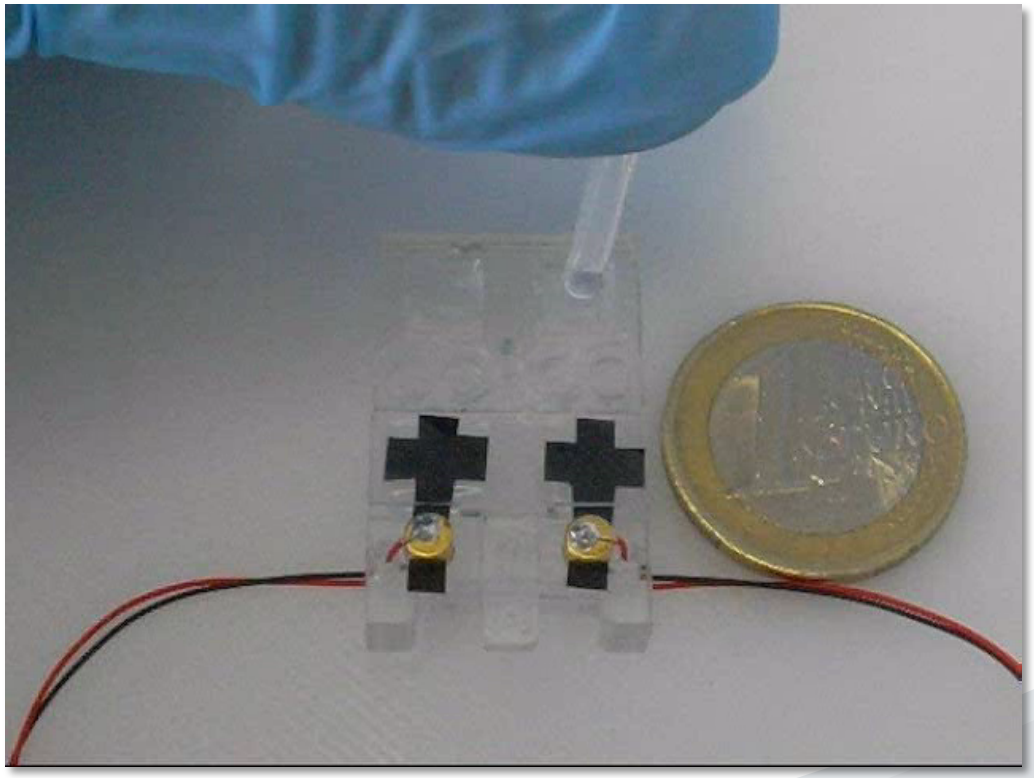
CLARITY
clarity-centre.org

Next Generation ‘stimulus responsive’ or ‘Adaptive’ Materials

Adaptive (Stimulus-Responsive) Materials

- Materials that possess ‘multiple personalities’ or characteristics
- Can switch reversibly between these via a stimulus (chemical, electrochemical, photochemical…..)
- Properties change dramatically e.g. chemical binding behaviour, surface charge/polarity, porosity, permeability, dimensions, colour…..

Polymer Micropumps and Valves

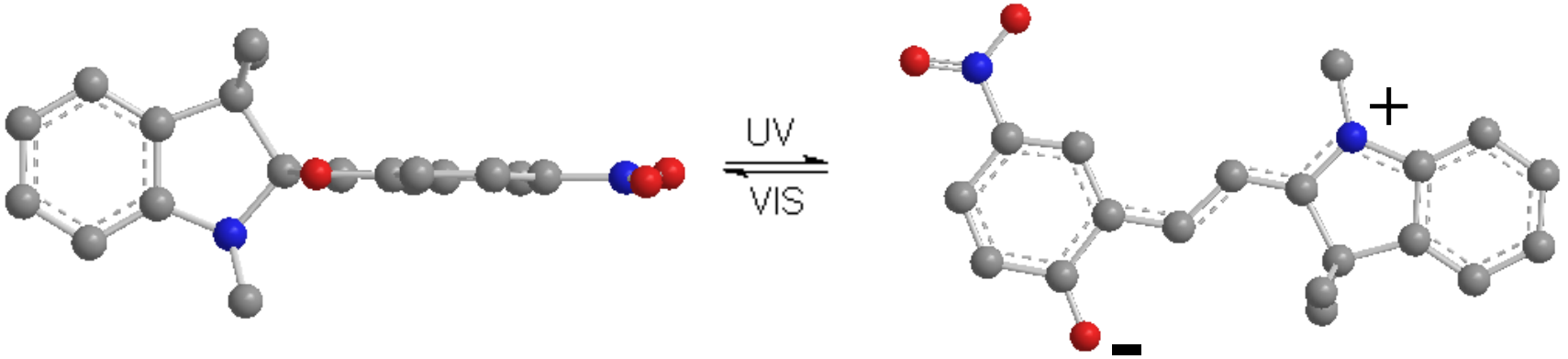


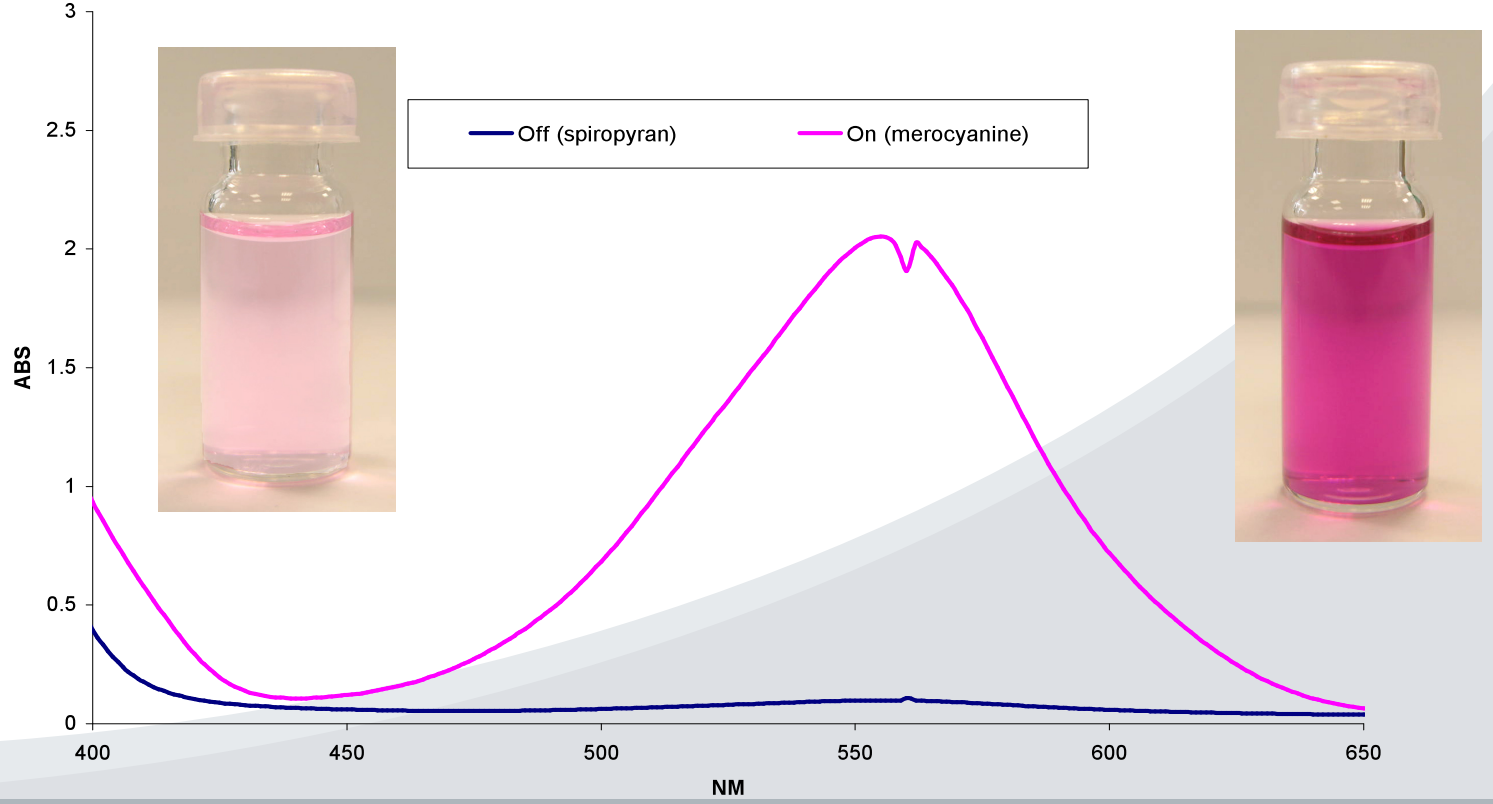
- Low power, low cost components are vital for realisation of next generation micro-dimensioned analytical platforms
- Based on polypyrrole CP ‘benders’
- Soft polymer actuators more attractive for integrated ufluidics manifolds
- ‘lego’ approach – detector block will slot in

What about photoresponsive materials?

Photoswitchable Materials

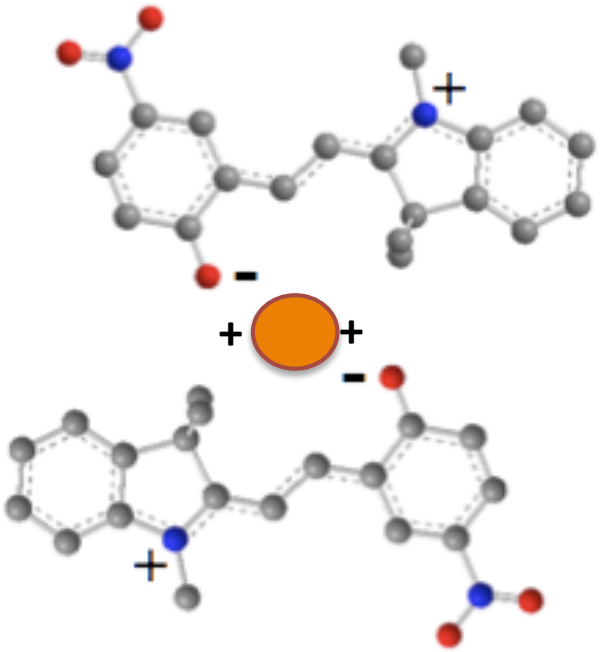
CLARITY
clarity-centre.org

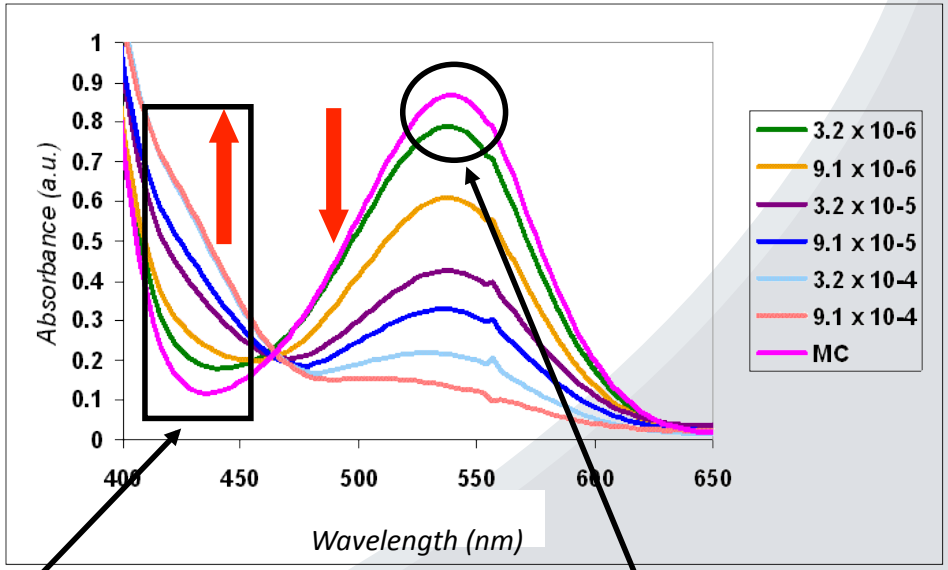




Spiropyran and Metal Ions

The binding of many metals, such as Cu^{2+} and Co^{2+}, to the phenolate of the MC form has been demonstrated



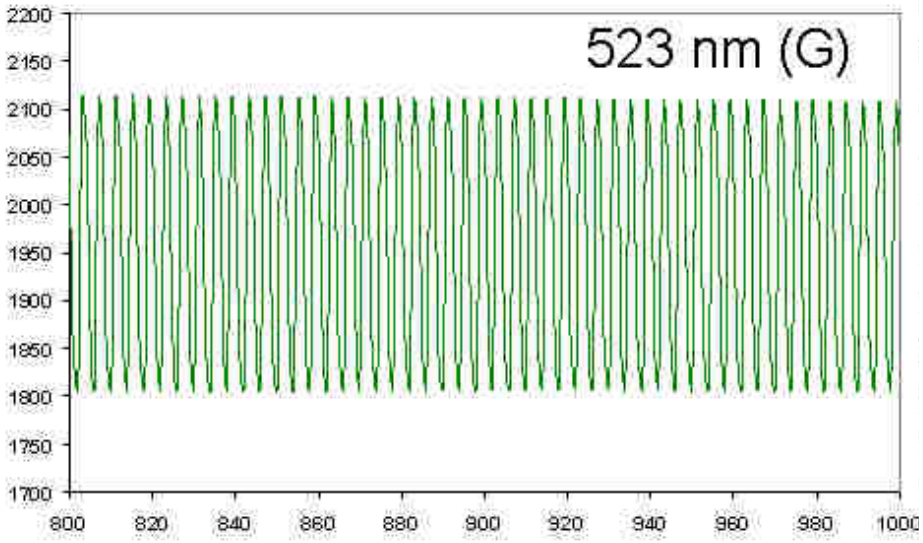


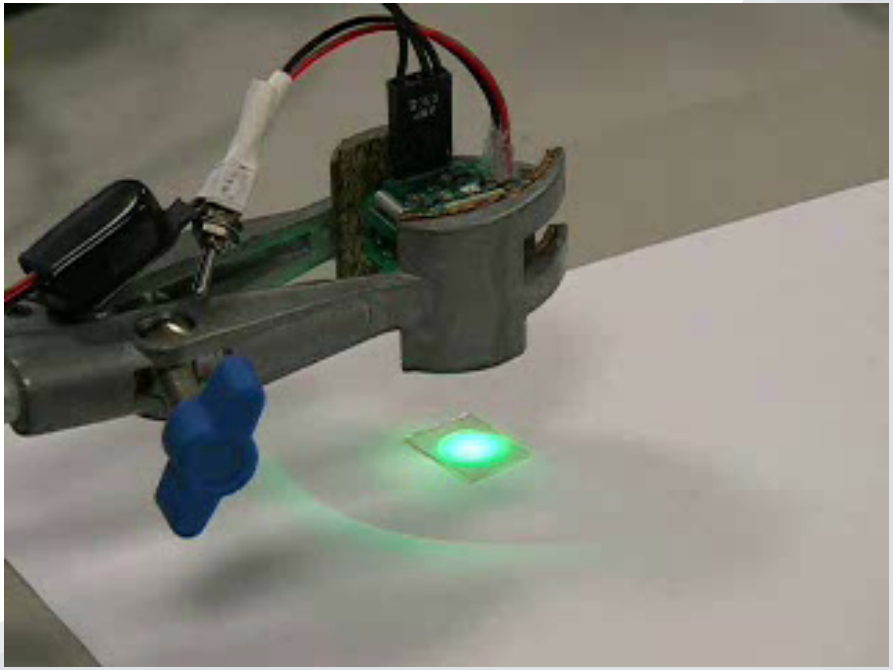
Increase in absorbance below ~460 nm due to formation of MC-Cu^{2+} complex

Decrease at 540 nm as free MC concentration decreases

Multiple Switching of SP-MC using LEDs

CLARITY
clarity-centre.org





- Take measurements R,G,B (flash <1s)
- UV LED ‘on’ 10 s; wait 10 s; repeat measurements
- Green LED ‘on’ 10 s; wait 10 s; repeat measurements
- Green channel more sensitive as expected
- >2,000 repeat switches performed on a single surface

Photocontrolled DNA Binding

CLARITY
clarity-centre.org

J|A|C|S COMMUNICATIONS

Published on Web 08/13/2008

Photoswitched DNA-Binding of a Photochromic Spiropyran

Johanna Andersson, Shiming Li, Per Lincoln, and Joakim Andréasson*

Department of Chemical and Biological Engineering, Physical Chemistry, Chalmers University of Technology, SE-412 96 Göteborg, Sweden

Received March 17, 2008; E-mail: a-son@chalmers.se

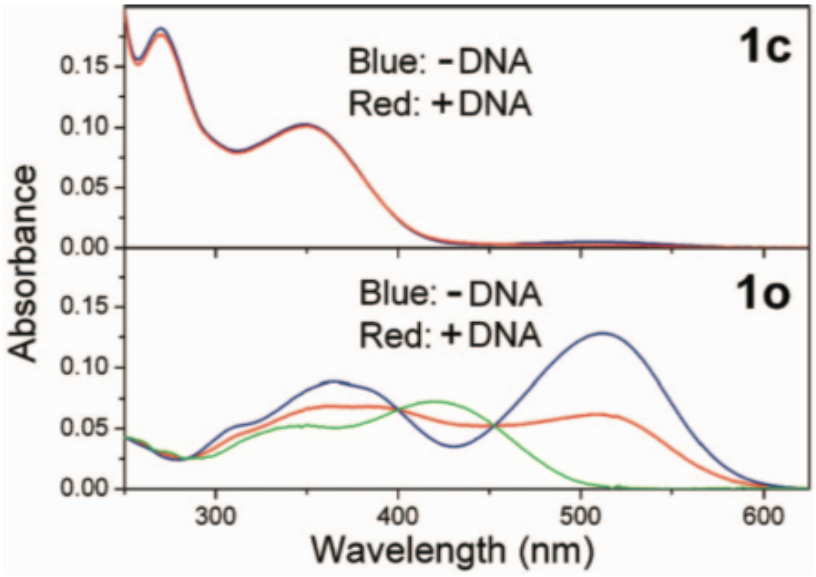


Figure 1. Absorption spectra of **1c** (top panel) and **1o** (lower panel) in the absence (blue lines) and presence (red lines) of calf-thymus DNA. The contribution from DNA to the overall absorption has been subtracted for ease of comparison. Likewise, the contribution from **1c** has been subtracted from the spectra of **1o** shown in the lower panel. The green line corresponds to a sample of 100% **1o** bound to DNA as the contribution from unbound **1o** has been corrected for (see Supporting Information for details). The total concentration of **1** was $\sim 1.5 \times 10^{-5}$ M. The concentration of DNA was 11.6×10^{-5} M, and the NaCl concentration of the solution was 8.6×10^{-3} M.

Chart 1. Structures of Photochromic Spiropyran **1**

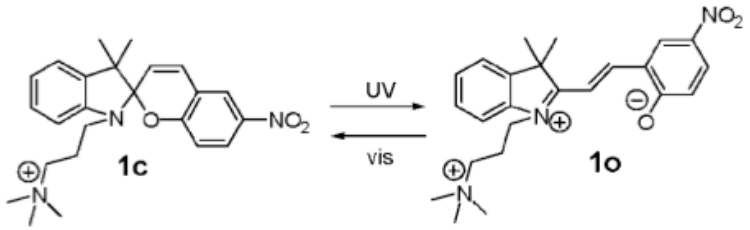
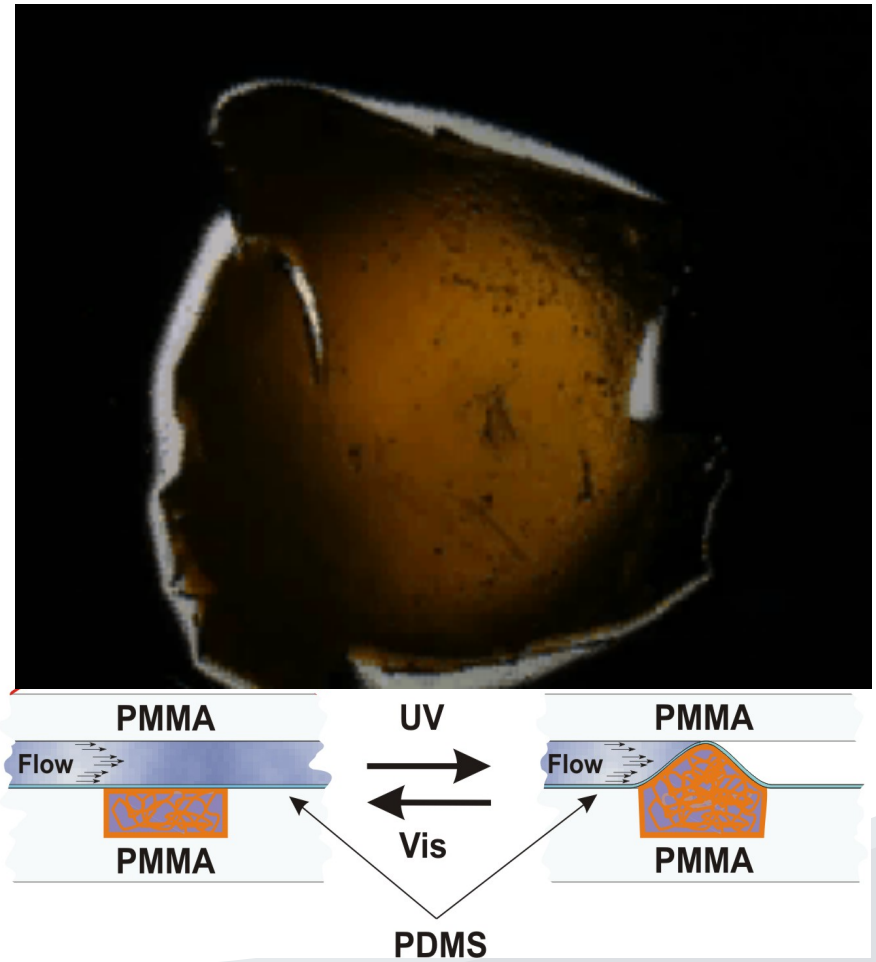
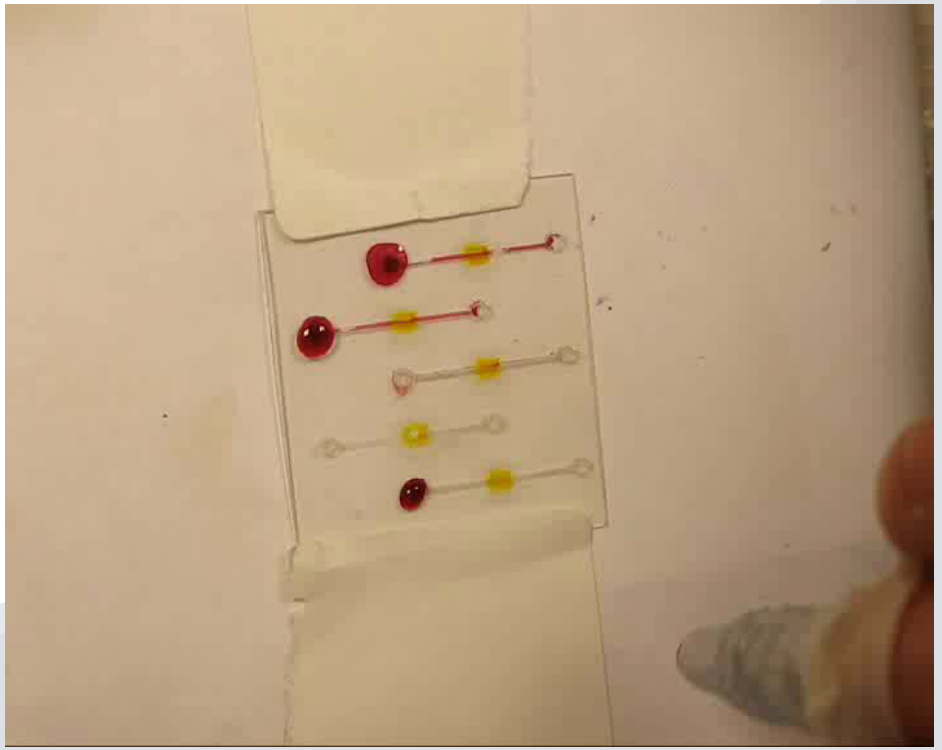


Photo-actuator polymers as microvalves in microfluidic systems





Conclusions

- **Great potential for platforms capable of sophisticated multi-functional behaviour**
- **Stimulus-responsive function can be fully integrated into fibres, textiles, fabrics**
  - Control of liquid movement – polymer pumping & valving function, dramatic changes in surface energy
  - Controlled uptake and release of range of a range of guest species
  - Integrated sensing and actuation capabilities
- **Need for joint academic & industry research effort**
  - Need to establish better links between fundamental materials chemistry, emerging platform technologies, and the needs/markets to realise applications