Advances in Sensor Technologies and Applications for Monitoring

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Advances in Sensor Technologies and Applications for Monitoring

Conference with Posters and Exhibition

Programme

Organised by the Automation and Analytical Management Group
Royal Society of Chemistry

A one day meeting on
Wednesday 19th June 2013

At The Royal Society of Chemistry,
Burlington House,
Piccadilly, London W1J 0BA

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RSC | Advancing the Chemical Sciences

Advances in Sensor Technologies and Applications for Monitoring

Wednesday 19th June 2013
at The Royal Society of Chemistry, Burlington House, London

Conference Programme

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Advances in Sensor Technologies and Applications for Monitoring

Conference with Posters and Exhibition

Wednesday 19th June 2013
at The Royal Society of Chemistry, Burlington House, London

09:00 - 09:30 Registration and Coffee

Session 1: Aquatic Monitoring & Special Techniques

Chairperson: **R Narayanaswamy,** AAMG-RSC, UK

09:30 Water Quality Monitoring Using Sensors for Volatile Chemicals: Henry's Law Rules
Krishna Persaud
The University of Manchester, UK

09:55 Fit for Purpose Robust Water Sensors for use in Emergency Incident Detection: - Is this an impossible dream?
Clive Thompson,
ALcontrol Laboratories, UK

10:20 Nanostructured Electrode Arrays for Electrochemical Analyses
Neville Freeman
Nanoflex, UK

10:45 New Advances in Screen Printed Sensor Design for Electrochemical Applications
Jonathan P. Metters *and Craig E. Banks,*
Manchester Metropolitan University, UK

11:05 Tea / Coffee

11:30 Impedimetric Microsensors for the Determination of Nitrate in Aqueous Matrices
Craig Alexander
The University of Manchester, UK

11:50 Using Sensor Technology to Understand the Dynamics of Fluvial Dissolved Organic Carbon Export
Martin Coleman, *Susan Waldron, E Marian Scott, Jonathan Cooper*
University of Glasgow, UK

12:10 Multi-species Sensing using Multi-Mode Absorption Spectroscopy (MUMAS)
Paul Ewart, *J.H. Northern, A.W.J. Thompson, S.O'Hagan, B.A.O. Williams*
University of Oxford, UK

12:30 PODS: A New Diffusive Sampler Concept
Emile De Saeger, *Pascual Perez Ballesta, Annette Borowiak*
JRC-EC, Italy

12:50 Lunch - Exhibition & Poster Session

Session 2: Biological and Environmental Monitoring

Chairperson: **Alan Braithwaite,** AAMG-RSC, UK

14:00 Towards Smartphone Connected Diagnostics for Infectious Diseases
Rachel McKendry
University College, London, UK

14:25 Leaky Waveguide (LW) Imaging for Biosensing
Ruchi Gupta, *Nick J. Goddard*
University of Manchester, UK

14:45 Isothermal Nucleic Acid Sequence-based Amplification Integrated Sensor for Biological Environmental Monitoring
Maria-NefeliTsaloglou, *Hywel Morgan,*
University of Southampton, UK

15:05 The Development and Validation of a Potentiometric Biosensor Assay for the Rapid Detection of 10 Antimicrobial Growth Promoters in Feeding Stuffs
James A. Donarski, *K.Wolodko-Cierniak, K. Chapman, M. Sharman, P.Swarbrick, S. Painter, P. R. Brown, S. J. Fenwick*
Food & Environment Research Agency, UK

15:25 Tea / Coffee

15:50 A Novel Approach to Chemical Sensing Using Fibre-optic Sensors Anchored with a Functionalised Mesoporous Thin Film
Sergiy Korposh, *F. Davis, S.W.James, S.W.Lee, S.Higson, R.P.Tatam,*
Cranfield University, UK

16:10 Stand-off Spectroscopy for the Detection of Chemical Warfare Agents
Rhea J. Clewes*, Chris R. Howlea, David J. M. Stothard, Malcolm H. Dunn, Gordon Robertson, William Miller, Graeme Malcolm,Gareth Maker,*
DSTL, UK

16:30 Highly Sensitive Hydrocarbon and Biogenic Odour Sensors
Hadi AlQahtani *and Martin Grell*
University of Sheffield, UK

16:50 Exhibitors Presentations

17:15 Concluding Remarks and End of Conference

ABSTRACTS

Water Quality Monitoring Using Sensors for Volatile Chemicals: Henry's Law Rules

Krishna C. Persaud

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Many water treatment plants rely on river intakes or ground water as a source of raw water that is treated for potable supplies to the neighbouring population. For many river water intakes, diesel fuel or petrol spills, mainly from road traffic accidents, represent one of the greatest risks of contamination. For ground waters, the likely concentrations are lower but the risks remain. Many different methods have been developed for detecting oil in water and water in oil; these have predominantly been designed for the offshore oil industry and are targeted towards percent and high ppm detection levels. The suitability of these techniques for low ppb detection is uncertain. Of great importance is the detection of fuel oils when a pollution event occurs, without frequent false alarms.

A practical problem faced by the water industry is that probes placed in running water tend to foul very rapidly and so a non-contact method is required for monitoring traces of hydrocarbons in water at ppb levels. Henry's law is one of the gas laws formulated by William Henry in 1803. It can be formulated that the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid. We can utilise this concept to create a non-contact method for monitoring hydrocarbons in water, as the concentration of volatiles in the headspace is directly proportional to the concentration in water at a particular temperature. By creating a sampling system consisting of a flow through tank whereby raw water flows, a headspace is produced representing a dynamic equilibrium between dissolved hydrocarbons and the vapour above it. By placing a gas sensor array in that headspace, it is possible to directly measure in real time the concentrations of hydrocarbon vapours and signal an alarm if this exceeds a threshold. We present data showing how this concept can be implemented in real-time monitoring of river intakes.

Fit For Purpose Robust Water Sensors For Use In Emergency Incident Detection: - Is This An Impossible Dream?

K. Clive Thompson
Chief Scientist ALcontrol Laboratories

ABSTRACT

There has been a very considerable amount of effort and expenditure incurred over the last 20 years on developing water sensors for use in emergency incident early warning detection and for indicating the subsequent transmission of the resulting polluted water through the water distribution system. Various specific parameter and holistic detection systems have been developed over the years. In the author's opinion, very few have been found to be fit for purpose for long-term robust reliable operation with minimal maintenance requirements and at an acceptable lifetime cost. However, there are a few notable exceptions

This presentation will attempt to highlight various problems that have been encountered and also in some cases the lack of full appreciation of what is required by the research group developing the sensors. Some specific examples will be cited of appropriate and inappropriate sensor systems for this very demanding application

Nanostructured Electrode Arrays for Electrochemical Analyses

Neville Freeman, Reshma Sultana, Nicola Kay
NanoFlex Ltd

ABSTRACT

Nanoelectrode structures have been of considerable interest in electrochemistry for more than a decade. The benefits accruing from the use of such electrodes have been examined in detail from a theoretical perspective. Such benefits include low capacitance, enhanced kinetics, high signal to noise ratios and immunity to hydrodynamic perturbations to name but a few. However the challenges associated with the fabrication of structures are probably responsible, at least in part, for significant variations in their reported behaviours. In this paper we examine a fabrication approach to obtain a model nanostructured electrode array system to assess some key performance characteristics which are readily accessible for use in electrochemical analysis. We report on the performance of the electrode using voltammetry and amperometry and we also discuss potential benefits using 'extended' interrogation methodologies and implications in terms of:

1) Enhancement of electrode lifetimes;
2) Limits of detection;
3) Susceptibility to stirring.

The practical ramifications of these characteristics will also be considered.

New Advances in Screen Printed Sensor Design for Electrochemical Applications

Jonathan P. Metters[1] and Craig E. Banks*

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ABSTRACT

With an ever intensifying prerequisite for newly developed sensors to be not only highly reliable and cost effectivewhilst allowing ultra-low limits of detection but also easily utilised away from the laboratory at a given site, it is easy to understand why so few viable sensing solutions have been proposed. Electrochemical sensors fabricated via screen-printing technologies can profilera potential solution to such problems.

This talk will demonstrate the importance of screen printed electrochemical sensor design and the benefits which the control over such parameters can yield when utilised for analytical purposes. Insights are provided into the potential manipulation of screen printing for the creation of novel sensors such as recessed and microband electrodes in addition to microelectrode arrays fabricated entirely through screen printing. Similarly we explore the exciting potential utilisation of paper based substrates for the fabrication of ultra flexible screen printed sensors, which are determine to be analytically useful. Further to this the enhancements offered through the utilisation of such sensors is further demonstrated through application towards the sensing of key analytes which require monitoring in water analysis.

Impedimetricmicrosensors For The Determination Of Nitrate In Aqueous Matrices

Craig Alexander

Manchester Institute of Biotechnology, School of Chemical Engineering and Analytical Science, University of Manchester, UK.

ABSTRACT

Due to its environmental importance, the need for *in situ*analysis techniques for nitrate determination has seen much research published in the field of nitrate-selective chemical sensors. This paper describes the development of gold interdigitated electrode (IDE) sensors,prepared via a mask-less, lift-off photolithography method, for the selective quantification of the nitrate anion in aqueous samples. The sensing area of the electrodes was spin-coated with a nitrate-selective membrane containing one of two commercially-available ionophores, tetradodecylammonium nitrate (TDAN) and Nitrate Ionophore V (Selectophore™). Both poly(vinyl) chloride (PVC),as is often used in traditional ion-selective electrodes (ISE), and silica-based sol-gels (methyltriethoxysilane and diethoxydimethylsilane) were used as the membrane material. A change in the electrical propertiesof the membrane, such as conductance and capacitance, were monitored as a function of nitrate concentration using an Agilent E490A LCR meter. A comparison of membrane material and ionophore could then be drawn over a variety of performance characteristics such as linear range, selectivity against interfering ions and working lifespan. All of the sensors performed adequately in these areas when compared to many conventional ISEs found in the literature.Membranes containing no ionophore were also tested as a control. Further investigation in to long-term performance and effects of biofouling are currently on-going. Such a device provides a route for producing low-cost, simple to fabricate ion sensors which do not require additional reference electrodes, as is the case with traditional potentiometric sensors.

Using Sensor Technology To Understand The Dynamics Of Fluvial Dissolved Organic Carbon Export

***Martin Coleman*[1],** Susan Waldron[1], E Marian Scott[2], Jonathan Cooper[3]

School of Geographical and Earth Sciences[1],
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School of Mathematics and Statistics[2],
University of Glasgow, Glasgow G12 8QQ, Scotland, UK
School of Engineering[3],
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ABSTRACT

Dissolved organic carbon concentrations, [DOC], are of interest to water companies as purification requires removal of this pool. Additionally [DOC], in freshwaters are increasing [1]. Furthermore respiration of this C pool can lead to an increased atmospheric CO_2 flux.

Hydrological events result in the highest DOC exports [2] and here [DOC] rapidly changes over short time periods such that manual sampling is inadequate for characterising. The transition from base flow to surface run-off dominated events cannot easily be monitored by manual sampling; such insight can only be gained through the use of continuous monitoring equipment [3]. Thus, the deployment of automated sensor technology could aid our knowledge of dynamic natural habitats.

Since autumn 2010 we have deployed a S::CAN Spectro::lyser in a 7.5km^2 catchment draining part of Europe's largest windfarm, Whitelee. Every 30 minutes the Spectro::lyser uses absorbance readings to calculate [DOC].

Here we present the Spectro::lyser [DOC] time series from June 2012 to May 2013; which ranges from ~ 10 and 60mg/l. Logged stage height, pH, conductivity and temperature data from an In-Situ MD Troll 9000 at the same location are also presented. I will consider the complex relationships that exist between these different variables and the benefits that high resolution data collection can provide. For example, it appears that events trigger an initial dilution of [DOC] prior to an increase.

References

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3. Kirchner, J.W., et al., *The fine structure of water-quality dynamics: the (high-frequency) wave of the future.* Hydrological Processes, 2004. **18**(7): p. 1353-1359.

Multi-Species Sensing Using Multi-Mode Absorption Spectroscopy (MUMAS)

J.H. Northern, A.W.J. Thompson, S. O'Hagan,
B.A.O. Williams and ***P. Ewart***

Physics Department, Oxford University, Parks Road, Oxford OX1 3PU U.K.

ABSTRACT

The detection of multiple species using a single laser and single detector employing multi-mode absorption spectroscopy, MUMAS, is reported. MUMAS uses a single multi-mode laser with each mode scanned across the frequency interval between adjacent modes so that absorption may be detected, by a decrease in total transmitted intensity, when any mode encounters a molecular resonance. Thus MUMAS achieves high spectral resolution and wide spectral coverage of multiple transitions or species using only a single laser and single detector and needs no multiplexing and de-multiplexing, spectral dispersion, complex or expensive laser sources nor reference cells.

An in-house constructed, diode-pumped, Er:Yb:glass micro-laser operating at 1565 nm with 10 modes separated by 18 GHz was used to record MUMAS signals in a gas mixture containing C_2H_2, N_2O and CO. The components of the mixture were detected simultaneously by identifying multiple transitions in each of the species. By using temperature and pressure dependent modelled spectral fits to the data, partial pressures of each species in the mixture were determined with an uncertainty of ±2%.

Application of the technique to simultaneous detection of CO and CO_2 in the exhaust of a SI engine has been demonstrated. The ratio of CO/CO_2 has been determined with a precision of better than 0.4% allowing monitoring of completeness of combustion. Extension of the technique to the mid-IR has also been demonstrated using difference frequency generation (DFG) with a cw Nd:YAG laser to shift the multi-mode spectrum to 3.3 μm allowing simultaneous detection of CH_4 and NH_3.

PODS: A New Diffusive Sampler Concept

Pascual Perez Ballesta, Annette Borowiak, ***Emile De Saeger***
Joint Research Centre, Institute for Environment and Sustainability, Ispra

ABSTRACT

Diffusive sampling is strongly associated with the history of air pollution monitoring. The use of this simple and cost-effective methodology has allowed to extend the measurement from a single point to the mapping over a larger area, adding a new dimension to air quality monitoring.

JRC has in past years devoted substantial efforts to the validation, standardization and promotion of this methodology. From the Palmes tube to the more sophisticated Perkin-Elmer and Radiello samplers, this methodology has gradually gained wide recognition, in particular since CEN standardization.

However, shortcomings linked to the design of current samplers still limit their use to indicative measurements. Recent technological developments have allowed JRC to develop a new versatile diffusive sampler concept (PODS: Pocket Diffusive Sampler), with the following advantages:

- greater relative diffusion surface vs. adsorbent ratio
- Interchangeable diffusion body (range of different porosities, pore sizes, and materials) to provide appropriate diffusion resistance according to the application (outdoor, indoor, exposure), pollutant and sampling time
- reduced amount of adsorbent resulting in lower blank level and sampler cost
- easy and performing chemical/thermal clean-up procedure, improving life cycle, blank level and sampling rate drift
- adsorbent body adapted to existing thermal desorption systems
- hermetically closing of device allows for sampling interruption/activation without blank level increase from external contamination

The sampler validation for VOCs and gaseous PAHs in outdoor air have demonstrated the exceptional performances of the sampler for these compounds. Further validation work including also gaseous POPs is planned for the future.

Towards a Smartphone Connected Test for HIV

Rachel A. McKendry[1], Valerian Turbe[1], Eleanor Gray[1], Ezra Linley[1], Ben Webb,[2] Robin Weiss, Deenan Pillay[2], Vince Emery[2], Eleni Nastouli[2], Vicki Lawson[3], Hiromi Yatsuda[3], Dale Athey[3].

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3. OJ-Bio Ltd, Bioscience Centre, International Centre for Life, Times Square, Newcastle Upon Tyne NE1 4EP.

ABSTRACT

The devastation caused by HIV is driving the development of new diagnostics. We aim to develop a new generation of smart-phone connected HIV tests to address the unacceptably high levels of undiagnosed HIV-infected individuals by widening access to HIV testing to GP surgeries, pharmacists and developing countries. Our low cost device works in a similar way to a pregnancy test, but with quantitation and the ability to wirelessly and securely transmit results to healthcare provider electronic systems. The sensor microchip is coated with proteins that capture HIV markers. Here we show that when HIV biomarker antibodies and antigens specifically adhere to the chip they alter its electrical signal and the device displays a simple message on a screen within minutes. This early-warning test has the potential to bring major economic and human benefits – benefiting patients by empowering them to gain faster access to treatment, protecting the public from the spread of HIV, offering a more cost-effective model of community based HIV care and generating new commercial opportunities for British industry.

The next generation mobile diagnostics for HIV project is funded by the National Institute for Health Research's Invention for Innovation Programme

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NHS
National Institute for Health Research

Leaky Waveguide (LW) Imaging For Biosensing

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ABSTRACT

Leaky waveguides (LW) are a subcategory of optical waveguides where instead of total internal reflection (TIR), either frustrated total internal reflection or Fresnel reflection is used to partially confine light. Some examples of LW devices consist of resonant mirror (RM) and metal or dye clad leaky waveguide (MCLW/DCLW) [1,2]. The angle at which light couples in RM and MCLW/DCLW (i.e. resonance angle) depends on the refractive index of the waveguide and the surrounding medium. Hence, these devices have been used for label-free target specific sensing and bulk refractive index monitoring [3,4]. Imaging is beneficial because it enables real-time monitoring of multiple analytes simultaneously. To the best of our knowledge, however, the suitability of these devices for imaging has not been demonstrated. This work for the first time investigates the feasibility of RM and MCLW/DCLW devices for imaging to monitor biological interactions. The structures studied and the instrumentation used in this work is shown in Figure 1 (a) and (b) respectively.

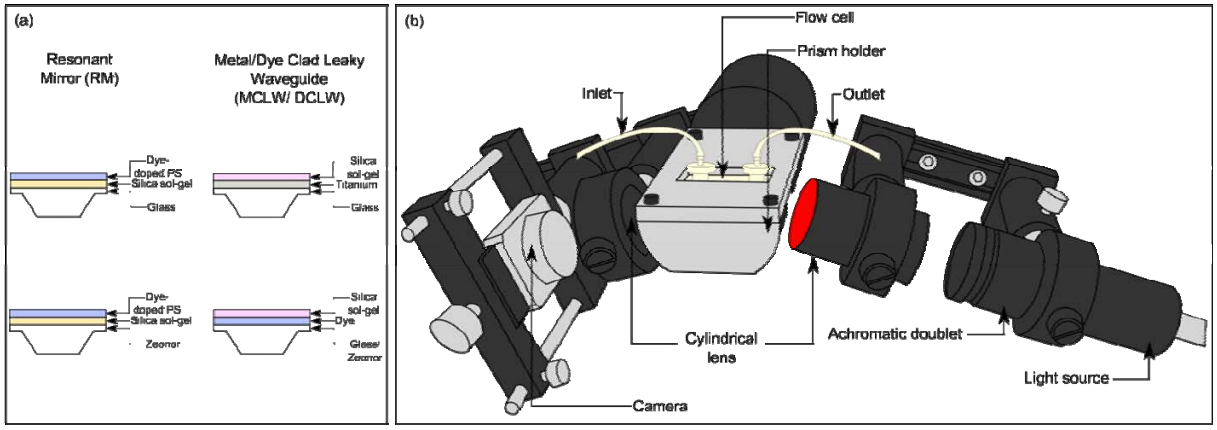

Figure 1: (a) RM and MCLW/DCLW structures and (b) instrumentation used in this work (where PS is polystyrene and diagrams are not to scale)

References:

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Isothermal Nucleic Acid Sequence-Based Amplification Integrated Sensor For Biological Environmental Monitoring

Maria-NefeliTsaloglou & Hywel Morgan

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ABSTRACT

Biological environmental monitoring is a multi-disciplinary field which combines bio-analytical sciences, microfluidics, as well as system integration and automation. Field applications include: point-of-care diagnosis of norovirusinfectionsto prevent wider spread; genotyping of microbial infection in blood; water monitoring for biotoxins and their producers, as well as for emerging pollutants in the aquatic environment.

We have developed an integrated microfluidic system for cell concentration and lysis, RNA extraction/purification and quantitative RNA detection for environmental applications (Tsaloglou*et al* 2013). An 87 base-pair region ofthe *rbcL* mRNA for toxic microalga *Kareniabrevis* was detected using real-time nucleic acid sequence based amplification (NASBA). This is an isothermal alternative to PCR which operates at 41°C, preceded by a two-minute incubation at 65°C for primer annealing. The system uses disposable cartridges with preserved reagents for long-term periods. Our drying method in the presence of di-saccharides significantly extended reagent life-time from one hour to eight months. Quantitation was performed in reference to an internal control, co-amplified with the wild-type target in a competitive fluorescence assay. The sensor was demonstrated for 500 cell equivalents of *K. brevis*.

These results are significant for field applications where rapid speciation and quantitation of micro-organisms is required. Current and future work includesintegrationof this technology into simpler low-cost digital and paper microfluidic devices for fast field-based applications.

Tsaloglou, M. N., F. Laouenan, et al. (2013). "*Real-time isothermal RNA amplification of toxic marine microalgae using preserved reagents on an integrated microfluidic platform*." RSC Analyst**138**(2): 593-602.

The Development And Validation Of A Potentiometric Biosensor Assay For Therapid Detection Of 10 Antimicrobial Growth Promoters In Feedingstuffs.

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ABSTRACT

Antibiotics have been routinely used worldwide in animal production for decades. Various antimicrobial compounds were found to be effective growth promoting agents when added in sub-therapeutic doses to the feed of farm animals [Wegener 2003; Schwarz *et al*., 2001]. As from 1st January 2006 an EU-wide ban on the use of antibiotics as growth promoters in animal feed became effective [EC 2003]. In order for this ban to be applied effectively, analytical systems are required to detect potential abuse.

Commercial potentiometric biosensor instruments are available that provide a reproducible platform on which sensitive and robust assays can be developed [Purvis *et al*., 2003]. In such devices, enzyme labelled antibody/ antigen complexes are formed at the surface of a polypyrrole-coated electrode. The analyte detection is mediated by a secondary, enzyme-linked reaction resulting in the formation of electrically charged products. The charged products of the enzymatic reaction can be rapidly and accurately measured as a change in potential at the electrode surface [Tudoraches*et al*., 2007].

The aim of the research presented here was to carry out a feasibility study to assess the applicability of a commercially available potentiometric biosensor (using the Vantix™ Research system) for the rapid qualitative analysis of multiple AGP compounds in animal feedingstuffs.

A potentiometric biosensor assay for the simultaneous detection of Avilamycin, Bacitracin, Carbadox, Flavomycin, Monensin, Olaquindox, Salinomycin, Spiramycin, Tylosin and Virginiamycin residues in animal feedstuffs was developed. Relevant detection limits in feedingstuffs for the named antimicrobial growth promoters were achieved (1 – 10 mg kg^{-1}). The validation of this system to Commission Decision 2002/657/EC is presented.

References

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Schwarz S. and Chaslus-Dancla E. (2001) Use of antimicrobials in veterinary medicine and mechanisms of resistance. Vet Res 32, 201-225.

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Wegener H.C. (2003) Antibiotics in animal feed and their role in resistance development.CurrOpin on Microbiol 6, 439-445.

A Novel Approach To Chemical Sensing Using Fibre-Optic Sensors Anchored With A Functionalised Mesoporous Thin Film

***S. Korposh*[1],** F. Davis[2], S. W. James[1], S.-W.Lee[3], S. Higson[2]and R. P. Tatam[1]

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ABSTRACT

A new approach tooptical fibre based chemical sensing, exploiting functional coatings deposited onto a long period grating (LPG), is reported. LPGs are devices that facilitate the coupling of light between different modes of the optical fibre, with the coupling conditions, and thus the transmission spectrum of the device, being sensitive to the refractive index (RI) of the medium surrounding the optical fibre.A novel 2 stage approach to the development of the sensor is explored. The first stage involves the deposition of the mesoporous coating onto the LPG. In the second stage a functional material, chosen to be sensitive to the analyte of interest, is infused into the base mesoporous coating. The mesoporouscoating consists of a multilayer film of SiO_2 nanoparticles (SiO_2 NPs) deposited using the layer-by-layer technique. The operation of the sensor was characterised using several functional materials, tetrakis-(4-sulfophenyl)porphine (TSPP),polyacrylic acid (PAA) and p-sulphonatocalix[4]arene (CA[4]). TSPP is a porphine compound that changes its optical properties in response to exposure to ammonia, while PAA has been employed previously as a functional compound for ammonia binding. In the case of the PAA it is assumed that direct binding of ammonia to the COOH moiety will change the RI of the mesoporous coating, while in the case of TSPP its desorption will result in an RI change. CA[4] is capable of host-guest interaction with various guest ions and small molecules, such as VOCs. It will be demonstrated that various functional compounds can be infused into the same mesoporous film.

Stand-off Spectroscopy for the Detection of Chemical Warfare Agents

Rhea J. Clewes*[a],** Chris R. Howle[a], David J. M. Stothard[b], Malcolm H. Dunn[b], Gordon Robertson[c], William Miller[c], Graeme Malcolm[c] and Gareth Maker[c].

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[b]Photonics Innovation Centre, The J. F. Allen Physics Research Laboratories, School of Physics and Astronomy, University of St. Andrews, St. Andrews, Fife, KY16 9SS, U.K.
[c]M Squared Lasers Ltd, 1 Technology Terrace, Todd Campus, West of Scotland Science Park, Maryhill Road, Glasgow, G20 0XA, U.K.

ABSTRACT

The most desirable configuration for detection of toxic chemicals utilises the optimum distance between detector and hazard. This approach ensures that no contamination of equipment or personnel occurs. Where the target chemical is an involatile liquid, indirect detection of the liquid contamination is precluded by inherently low vapour pressure. Direct detection of the chemical hazard is the only viable approach. Recent technology developments have allowed spectroscopic systems to provide multiple options for the stand-off detection of involatile CWAs. The Negative Contrast Imager (NCI) from M Squared lasers is based on an optical parametric oscillator (OPO) source comprising a Q-switched intracavity MgO:PPLN crystal. This crystal has a fanned grating design and wavelength tuning is achieved by translating the PPLN crystal within the 1064 nm pump beam. This approach enables the production of shortwave and midwave IR (1.5 – 1.8 μm and 2.6 up to 3.8 μm, respectively) radiation, which is scanned across the scene of interest. Target materials that have an absorption feature commensurate with the wavelength of incoming radiation reduce the intensity of returned signal, resulting in dark pixels in the acquired image. This method enables location and classification of the target material.

Highly Sensitive Hydrocarbon and Biogenic Odour Sensors

Hadi AlQahtani and Martin Grell

Department of Physics and Astronomy, University of Sheffield, Sheffield, UK.

ABSTRACT

Alkane odours represent an explosion hazard, but the sensing of alkane odours with chemical sensors is difficult, because they do not engage in specific interactions at ambient temperatures. Here, we explore physical sensors instead, based on the swelling of an alkane matrix in a similar odour. Response is a rapid resistance increase due to swelling, and is strongest for alkane odours where the alkane chain is similar in length to the dodecane shell. For decane odours, we find a response to concentrations as low as 15 ppm, about 600 times below the lower explosive limit. Response is weaker, but still significant, to aromatic odours (e.g. Toluene, Xylene), while potential interferants such as polar and/or hydrogen- bonding odours (e.g. alcohols, ketones) are rejected. Resistance does not depend on humidity, depends only weakly on temperature, and recovers rapidly and completely to its original value within the error margin of measurement.

Moreover, the sensitivity of swelling-based gold core–organic shell nanoparticle vapor sensors is improved manifold by cooling sensors below ambient temperature. This is due to the reduced volatility of the analyte. Sensitivity to a particular analyte scales with temperature like that of analyte's saturated vapor pressure, thus allowing quantitative prediction of sensitivity enhancement. We believe our conclusions apply to all swelling-based sensors.

Finally, we demonstrate the detection of 1-decanol, a vapour released by E. coli bacteria, at a partial pressure in the order 100 ppb by just attaching different ligands, undecanolthiol, to CSNPs. This is an exceptionally low limit of detection for swelling-based sensors, and relies firstly, in the careful matching of the CSNPs ligands to the targeted odour, and secondly, in the very low volatility of this odour.

References:

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POSTER ABSTRACTS

Next Generation Chemical Sensors: Detecting Nitrate and Ammonia in Water

Deirdre Cogan, John Cleary, Thomas Phelan and Dermot Diamond*

CLARITY: Centre for Sensor Web Technologies, National Centre for Sensor Research, Dublin City University, Dublin 9, Ireland.

POSTER ABSTRACT

There is a growing need for low cost, remote sensing systems which can be deployed in sufficiently large numbers to ensure that data on key water quality parameters is readily available. We are investigating the development of sensing platforms for nitrate and ammonia in water and wastewater using microfluidics combined with colorimetric chemical assays. With integrated low cost LEDbased optical detection and wireless communications, autonomous chemical sensing platforms can be produced at a price level that creates a significant impact on the existing market.

An analysis platform for the direct determination of nitrate in water using a modified chromotropic acid methodfor direct nitrate determination has been developed. This eliminates several steps from the literature method, and facilitates development of and autonomous sensing platform whereinnitrate is mixed with chromotropic acid in sulphuric acid and detected at 430 nm. Colorimetric determination of ammonium has also been investigated based on a variation on the Berthelot method, detected at a wavelength of 630 nm. Similarly to the chromotropic acid method, the Berthelot method was modified in order to simplify the fluidic handling requirement implemented on the microfluidic platform, which in turn drives down cost and improves reliability. We are in the process of further integrating these methods into fully functional autonomous devices for field deployments.

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Disposablepotentiometric Strips: A Versatile Tool For Low-Cost Sensing

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POSTER ABSTRACT

The integration of sensors within wireless networks represents a pivotal step for remote analytical monitoring, not limited to pollutants in the environmentbut also suitable for diagnostics and personal health monitoring.For instance, higher spatial and temporal resolutions for toxic metals are fundamental for epidemiology studies,where they would help to establish definitive associations between the exposure to specific chemicals and the health of individuals and communities.In addition, accessible body fluids such as saliva and sweat represent an interesting medium for the realization of wearable sensors. These fluids contain important personalized physiological information. For example, acontinuous monitoring ofpHin saliva and electrolyte concentrationsin sweat would be beneficial for controlling healthy mouth conditions orto improve endurance performances and avoid critical situations, e.g., dehydration and hyponatremiain athletes.

Low-cost potentiometric stripsbased on screen printed substrates consisting ofa solid-contact ion-selective electrode (SC-ISE)combined toa solid-contact reference electrode (SC-RE) may offer a versatile tool in sensing technology. These strips can be readily adapted for the detectionofseveral ionic species. Here, as an example, we present on the monitoring of pH in saliva, Na^{+} in sweat and Pb^{2+} in water.Thestrip is plugged into an electronic platform of reduced dimensionswhich converts the chemical information into an electric signal,wireless transmitted to a base station. This technology may have an impact in remotemonitoring but also in wearable sensing thanks to the device miniaturization.

Detection of Biologicals using Novel Sensors Based on Hydrogel-based Molecularly Imprinted Polymers.

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POSTER ABSTRACT

On-site diagnostic tools are an essential part of emergency management given that early detection of an environmental hazard leads to rapid containment and corrective action. However, current diagnostic devices for on-site testing are lacking or require multiple step protocols and technical expertise. We have developed a range of hydrogel-based molecularly imprinted polymers (MIPs) for biological memory imprinting in biosensor development.We have characterized the imprinting capability of a family of acrylamide-based MIPsfora range of proteins, bacteriophages, and disease markers, such as engrailed-2 and prostate specific antigen. Selectivities of up to 128:1 when compared with a non-imprinted polymer NIP through various buffer manipulations have been possible, measured using spectrophotometry. Initial cyclic voltammetry and quartz crystal microbalance (QCM) sensors demonstrate optimistic results in terms of sensitivity and MIP integration compatibility. QCM studies of thin film acrylamide (AA), N-hydroxymethylacrylamide (NHMA), and N-isopropylacrylamide (NiPAM) MIPs exhibit discrimination between cognate/non-cognate protein loading in MIP and NIP in the order NiPAM< AA < NHMA. Initial responses illustrate the extent of specific and non-specific analyte binding. A clear discrimination between different size proteins and theirmetallo properties has been achieved. The possibilities for this MIP technology are vast including uses in bio-sample clean-up or selective extraction, replacement of biological antibodies in immunoassays and biosensors for medicine, food and the environment.

Diagnosing Hospital Acquired Infections Using Sensor Technology And Headspace Analysis

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POSTER ABSTRACT

C.difficile is a significant cause of morbidity and mortality in hospitals, withcirca 18000 cases in England in 2011[1]. Current diagnosis methods for *C.difficile* can be slow, involving time consuming culture of samples. Alternative ELISA based approaches are faster but can be inaccurate and still require samples to be sent from the ward to the lab[2].Our proposal was to develop a diagnosis approach which reduced that diagnosis time to within an hour, and has the potential to be undertaken in a ward or GP setting.

The combination of gas chromatography(GC) and heated metal oxide semiconductor (MOS) sensor was investigated. GC analysis is relatively fast and a MOS sensor, along with high sensitivity, enables a degree of miniaturisation of the device. Headspace analysis of stool samples was considered because of anecdotal evidence that distinctive odours emanate from certain diarrhoeas such as C.difficile and cholera.

The sensor was operated at 450°C and responded to compounds as they eluted from the column. The sensors responded well to our gas standard of 50ppm ethanol and 50ppm methanol. Injection of the headspace of stool samples produced a series of peaks with fast response and recovery.

Studieswere undertaken using 400 diarrhoea samples obtained from hospital patients, with and without *C.difficile* infections. Artificial neural networks (ANN) were trained to predict diagnosis based on the chromatograms. ANNs could correctly identify chromatograms from *C.difficile* positive and *C.difficile* negative samples with 73% sensitivity and 79% specificity (average).

[1]ONSStatistical Bulletin. Deaths Involving Clostridium difficile, England and Wales, 2011.report August 2012.http://www.ons.gov.uk/ons/rel/subnational-health2/deaths-involving-clostridium-difficile/2011/stb-deaths-involving-clostridium-difficile-2011.html
Accessed 30/11/2012 14:00

[2] Wilcox, M.H. (2011) Laboratory diagnosis of *Clostridium difficile* infection: in a state of transition or confusion or both? *J. hospital infection*, **79**, 1-3.

Can Gastro-intestinal Diseases be Diagnosed Using Volatile Sensor Technology?

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POSTER ABSTRACT

There is a need to diagnose the digestive diseases Inflammatory Bowel Disease (IBD) and Irritable Bowel Syndrome (IBS) which can present with similar symptoms. The two forms of IBD are Ulcerative Colitis (UC), characterized by inflammation of the mucosal layer of the colon, andCrohn's Disease (CD) with inflammation anywhere in the GI tract. Common symptoms include abdominal pain, diarrhoea or bloody diarrhoea. IBS is a functional bowel disorder, and symptoms can include abdominal pain, bloating, constipation and/or diarrhoea. Diagnosis is one of exclusion, once testing has ruled out other conditions. It is considered that around 15% of the population will experience symptoms at some time.

Diagnosis of IBD or IBS often involves costly, unpleasant and invasive colonoscopy or sigmoidoscopy procedures. There remains a need for a better, low cost, non-invasive test that can be readily performed by the GP.

There is no perfect biomarker to differentiate these conditions. A novel system composed of a headspace gas chromatogram with a single heated ceramic sensor has been used to obtain retention time/electrical resistance sensor responses. Data for 160 faecal samples from patients with IBD, IDS and healthy controls has been obtained. Statistical analysis and artificial neural network software analyses have been undertaken of the sensor profiles. Initial results of the volatile organic compounds (VOCs) emitted from the stool of the different groups shows there is promise in distinguishing these conditions from each other and from healthy volunteers. Further development of this system could lead to its use for non-invasive diagnostic testing for IBS/IBD and other gastro-intestinal conditions.

Biosensors For Continuous Monitoring

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POSTER ABSTRACT

Understanding the physiological processes happening in the body during athletic performance such as training, competition, and subsequent adaption is the main reason for development of biosensors that can track biochemical changes.

Minimally invasive (subcutaneous) biosensors for biochemical detection of analytes important for the sports monitoring and also for the health wellbeing of the person are developed. In particular oxygen supply and diffusion into tissues are necessary for survival. Oxygen partial pressure (pO_2), which is a key component of the physiological state of an organ, results from the balance between oxygen delivery and its consumption. Amperometric oxygen sensors were successfully tested *in vivo* showing very well defined trends towards exercise performance of the person. Successful validation with largely used medical device O2C machine was done. Other important analytes such as glucose is also tested successfully *in vivo* and lactate has been successfully tested in vitro and in animals and next steps of *in vivo* human studies are planned. The responsive enzyme layer is sandwiched between two polymer membranes which respectively allow high selectivity, wide linear working range and biocompatibility.

Developments of noninvasive solid contact ion selective sensors are tested on body.

Combination of all information will provide valuable information of a dogmatic nature and will increase our understanding of physiological processes in the elite athlete under extreme stress conditions.

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Towards a Smartphone Connected Test for HIV

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POSTER ABSTRACT

The devastation caused by HIV is driving the development of new diagnostics. We aim to develop a new generation of smart-phone connected HIV tests to address the unacceptably high levels of undiagnosed HIV-infected individuals by widening access to HIV testing to GP surgeries, pharmacists and developing countries. Our low cost device works in a similar way to a pregnancy test, but with quantitation and the ability to wirelessly and securely transmit results to healthcare provider electronic systems. The sensor microchip is coated with proteins that capture HIV markers. Here we show that when HIV biomarker antibodies and antigens specifically adhere to the chip they alter its electrical signal and the device displays a simple message on a screen within minutes. This early-warning test has the potential to bring major economic and human benefits – benefiting patients by empowering them to gain faster access to treatment, protecting the public from the spread of HIV, offering a more cost-effective model of community based HIV care and generating new commercial opportunities for British industry.

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(This poster is supplementary to the oral presentation by Dr R.McKendry)

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