Chemical and Biochemical Sensors, Moving from Measurement to Control

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Moving from Measurement to Control

A one day meeting

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

Wednesday 20th May 2009

**Royal Astronomical Society,
Burlington House,
Piccadilly,
London, W1J 0BQ**

Email: conference@aamg-rsc.org
Web site: www.aamg-rsc.org

RSC Advancing the Chemical Sciences

Chemical and Biochemical Sensors,
Moving from Measurement to Control

Wednesday 20th May 2009
At The Royal Astronomical Society, London

10:00 **Registration and Coffee**

Session 1 - New Directions in Sensor Technology

Chairman: Dr Alan Braithwaite, AAMG-RSC, UK

10:30 ***Chemical / Bio Sensors***
Chris Lowe
Institute of Biotechnology, University of Cambridge, Cambridge

11:00 ***Sensor Fusion***
Krishna Persaud
School of Chemical Engineering & Analytical Science, University of Manchester, Manchester

11:30 ***Nanotechnologies***
Duncan Graham
Centre for Molecular & Nanometrology, Strathclyde University, Glasgow

12:00 ***Security***
John Findlay
Institute of Membrane & Systems Biology, University of Leeds, Leeds

12:30 Lunch

Session 2 - Real World Systems and Applications

Chairman: Dr R Narayanaswamy, University of Manchester

13:30 ***The Personal Environment, Climate Control For A Healthy Environment***
Nicolae Barsan
Institute of Physical Chemistry, University of Tübingen, Germany

14:00 ***Feedback and Control in the Water Industries***
Chris Rockey
South West Water, Exeter, Devon

14:30 ***Monitoring Volatile Organic Compunds in Human Breath***
Christopher Walton
Volatiles Research Group, Cranfield University, Cranfield

15:00 Tea

15:30 ***Point of Care Monitoring***
Gary Thorpe
Queens Medical Centre, University of Birmingham, Birmingham

16:00 ***Multiple Array Sensors in the Food Industry***
Brian Birch
LIRANS, University of Bedfordshire, Luton

16:30 End of Conference

ABSTRACTS

CHEMICAL/BIOSENSORS

Christopher R Lowe
Institute of Biotechnology
Department of Chemical Engineering & Biotechnology
University of Cambridge
Tennis Court Road
Cambridge
CB2 1QT

ABSTRACT

Many extravagant claims have been made in the past two decades about the likely impact of biosensors on the diagnostics industry: In reality, the current market size represents <2% of the global diagnostics market. This presentation looks at the need for, and advantages of biosensors, the technology that has been developed over the past two decades to address these perceived needs, but, in reality, has failed to do so, and describes newer technologies which may circumvent the problems and suggests how they are likely to have a much more significant impact in the future, particularly in sectors such as medical diagnostics, genomics, proteomics and high throughput screening.

SENSOR FUSION

Krishna C. Persaud
School of Chemical Engineering and Analytical Science
The University of Manchester

ABSTRACT

If data from a variety of different sensors are combined, it is possible to measure parameters for which no single sensor exists. However many complicated multi-sensory systems fail in practical use, or require the assistance of great computing overhead. This is usually because sensor-driven control systems depends on reliable sensors. Practical sensors are less than 100 per cent reliable and are subject to drift and the effects of interferences and often sensor conflicts must be resolved. Chemical Sensors have been used to great effect to create so called "artificial noses", that are now evolving into more biomimetic systems. Biological examples of sensor fusion – eg how do dogs track scent or how do flies land on a surface give insight to engineers in designing new sensing and control systems. A practical approach to chemical sensing based on sensor fusion will be discussed. This is based on a neuromorphic principle that allows combinatorial coding, chemotopic convergence, gain control, contrast enhancement, and feedback.

NANOTECHNOLOGIES

Duncan Graham[1], Karen Faulds[1], David Thompson[1], Fiona McKenzie[1], Robert Stokes[1], Colette Dalton[1], Ross Stevenson[1], Jim Alexander[2], Paul Garside[2], Emma McFarlane[2]

1. Centre for Molecular Nanometrology, Department of Pure and Applied Chemistry, WestCHEM, University of Strathclyde, Glasgow, G1 1XL
2. Strathclyde Institute of Pharmacy and Biomedical Sciences, University of Strathclyde, The John Arbuthnott Building, 27 Taylor Street, Glasgow, UK G4 0NR.

ABSTRACT

Metallic nanoparticles can be used as basic materials for a wide variety of purposes including building blocks for nanoassemblies, substrates for enhanced spectroscopies such as fluorescence and Raman and as labels for biomolecules. Here we report how silver and gold nanoparticles can be functionalised with specific biomolecular probes to interact in a specific manner with a target molecule to provide a change in the properties of the nanoparticles which can be measured to indicate the molecular recognition event. Examples of this approach that will be discussed include DNA hybridisation to switch on surface enhanced resonance Raman scattering (SERRS) when a specific target sequence is present, the use of nanoparticles for in vivo SERRS imaging and use of nanoparticles functionalised with antibodies to provide a new type of immunoassay. These examples indicate how nanoparticles can be used to provide highly sensitive and informative data from a variety of biological systems when used with SERRS.

CELL-BASED DETECTOR AND REPORTER SYSTEM

John B.C. Findlay and Graham Whyteside, Faculty of Biological Sciences, LIGHT Laboratories, University of Leeds, Leeds LS2 9JT

ABSTRACT

Using a process akin to accelerated evolution, a detector has been created for an analyte not normally encountered in biology. By coupling the detector up to an engineered signal transduction cascade in yeast, a reporter system has been generated which possesses high specificity, high sensitivity, rapid response, reproducibility and reversibility.

The olfactory system relies on receptors which have exquisite sensitivity. They are members of the G-protein coupled receptor (GPCR) family which are the most widespread and diverse family of receptors in the genome, having evolved a wide variety of tight specificities ranging from small molecules to small proteins. They represent , therefore, an ideal template with which to create new strict specificities with high affinity. Using a process akin to accelerated evolution, the specificity of a GPCR has been altered from its natural one to that for a quite different, non-biological analyte.

The use of proteins as detectors often involves their expression , purification and manipulation in a new , exposed environment. This is not only an expensive process but renders the protein liable to damage and destruction, thereby compromising its functionality and viability. Instead, a protective, robust environment is required where the protein can be replaced if necessary such as is provided by a biological cell. In this case, we chose yeast because it is robust and resilient. By engineering, it can be endowed with the the ability not only to harbour the detector system but also a reporting mechanism.

This contribution will describe the development of a sensor system using these two ingredients which possesses the properties of high sensitivity and selectivity, rapid , reversible and reproducible response, stability and inexpensive production.

THE PERSONAL ENVIRONMENT,
CLIMATE CONTROL FOR A HEALTHY ENVIRONMENT

N. Barsan, U. Weimar,
Institute of Physical Chemistry, University of Tuebingen

ABSTRACT

It is already well-known that in Europe we spent 90% of our time in buildings and vehicles1, which means that indoor environment has become our natural environment. This is a major change for a species that used to live outdoors some tens of thousands of years ago in the temperate regions of the world. The buildings we are living in need to provide us with the best possible conditions at reasonable costs; the latter include also the impact on the environment.

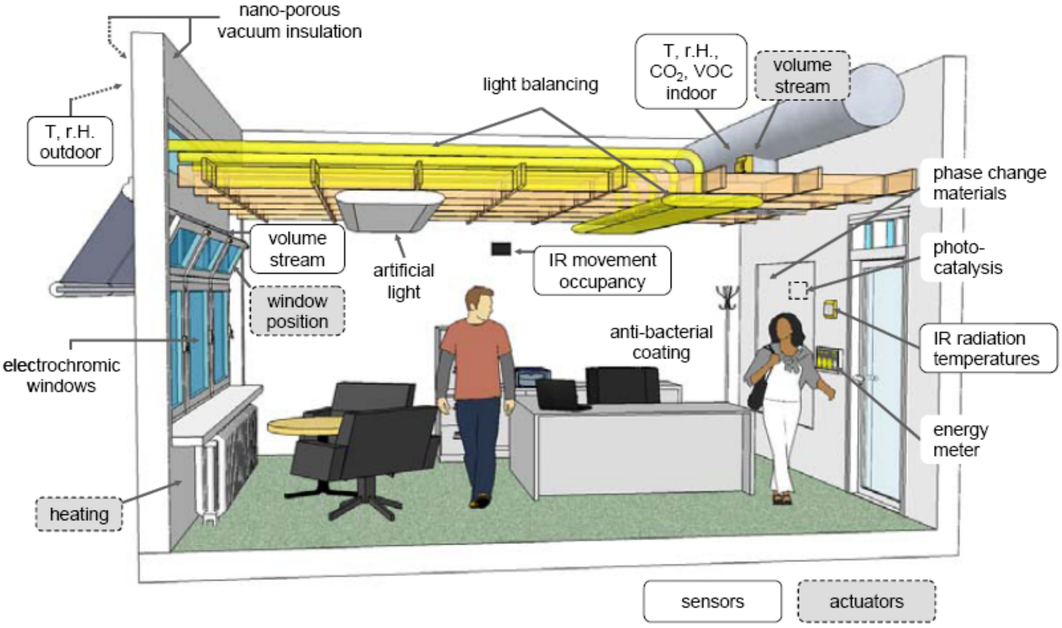

Figure 1. Example of a possible Clear-up system installation in a commercial building

Such challenges are addressed by a new European IP, Clear-up, which aims to develop sustainable approaches for providing an optimized, in terms of **energy** and **usability,** indoor environment. The main idea is to use sensors and intelligent control to provide an **energy-optimised** indoor environment where active and passive systems for lighting, ventilation and temperature are combined in one building. The example provided in *Figure 1* deals with the case of an office building and presents some of the elements that will help monitor and control the temperature and air composition.
Clear-up will develop new components and subsystems for control of temperature, light and air. The project will integrate a range of different technologies into subsystems. For example, phase change materials, natural ventilation, passive and active cooling and window shades and electrochromic windows may all contribute to moderating temperature. The presentation will bring examples of the approaches and of the performances of the available systems.

1 K. Koistinen et al. INDEX project “Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU”, 2005 EUR 21590 EN

FEEDBACK AND CONTROL IN THE WATER INDUSTRY

Chris Rockey
South West Water

ABSTRACT

Water is essential to health and a glass of tap water is the most economical and environmentally friendly way to keep hydrated. The World Health Organisation clearly identifies that access to a safe supply of drinking water and a hygienic sanitation system are essential elements in an effective policy for public health protection. In the UK, water and sewerage undertakers should be proud of their excellent track record in providing these services but must remain vigilant to ensure the inherent trust built during over a considerable period of time is never lost.

In the operation of their business water companies have to manage a large number of diverse assets to meet strict water quality, environmental and economic regulations. They have utilised on-line water quality monitoring and control systems to this end for a number of years. Until relatively recently their application has been largely limited to controlling processes at treatment works, but a more holistic approach is now being adopted by companies and encouraged by the various Regulators.

With the development of Water Safety Plans companies are focusing on all aspects of water supply to mitigate risks from catchments through to customer's taps. This coupled with the emergence of new threats and the desire for more real time information means that the need for reliable and cost effective monitoring systems is ever increasing. Due to the scale of the task traditional instruments, measuring specific parameters, at numerous locations is unlikely to be viable. The development of miniaturised sensors measuring a small number of simple parameters coupled with a sophisticated approach to data interpretation may hold the key.

This brief presentation will race you from cholera in the 1830's to the near future outlining the challenges currently faced and expected by one of the UK's water and sewerage undertakers. The basics of process control as currently applied, the key parameters of interest from source to tap and some thoughts on how the need to transform large and complex data into information based on simple measurements may be achieved will be discussed.

MONITORING VOLATILE ORGANIC COMPOUNDS IN HUMAN BREATH

Christopher Walton, David Pitts, Paul Knight, Mitesh Patel
Volatiles Research Group, Cranfield University, MK43 0AL, UK

ABSTRACT

Breath analysis is potentially a very attractive diagnostic tool, being non-invasive, quick to perform, requiring little training of either operator or patient and carrying little risk. Interest in breath analysis has been fostered in recent years by the discovery that a number of disease states are associated with elevated concentrations of various classes of endogenous volatile organic compounds. Examples are ketones with diabetes; sulphides with liver disease; amines with kidney disease. Other markers of systemic origin (e.g. isoprene) may be present in a number of diseases and appear to be relatively non-specific.

Despite these advantages, however, breath analysis has not become part of routine clinical practice nor is there any immediate sign of it doing so. This is probably related to the technical difficulties inherent in breath as a sampling matrix:

- Low analyte concentrations; but having a wide dynamic range.
- High water content .
- Poor sample stability.

This suggests that breath analysis might be more easily employed in disease monitoring, where potential exists for the nature of the sample and the target analytes to be relatively well defined, than in diagnosis *per se*. However, use in monitoring would require widespread deployment of the technique, preferably to point-of-care. This in turn predicates the use of direct sampling of breath volatiles rather than indirect methods involving the use of some for of container or pre-concentration step.

One possible approach to development of a widely-deployable breath analysis method is in the development or adaptation of the gas sensor systems used in electronic noses (E-nose). E-noses use an array of non-specific sensors in conjunction with pattern recognition techniques to create a classification model which allows different samples to be categorised. They have been used successfully in breath analysis to identify various diseases, but they are nonetheless still laboratory-based instruments and have generally used indirect sampling methods. We report here the design, construction and initial testing of an instrument employing a single low-cost mixed metal oxide sensor originally designed for general-purpose air quality monitoring. The Single Metal-Oxide Sensor – Gas Analyser; (SMOS-GA a.k.a. the “Breathotron”) allows direct sampling of breath across the sensor without using an intermediate container or pre-concentration step.

We have examined the ability of the Breathotron to detect representative compounds at concentrations typically found in breath , specifically acetone, ammonia and ispopropanol from 0.1 to10 ppm. We also investigated how well mixtures of these compounds could be distinguished. Data from breath samples obtained from healthy volunteers undergoing and oral glucose tolerance test will also be presented. Our results suggest that a single sensor system, used with appropriate data reduction and analysis methods, is a promising avenue for development of point-of-care breath monitoring.

POINT OF CARE MONITORING

Dr Gary Thorpe
Wolfson Research Laboratories, CEP Evaluation unit, the University of Birmingham, and Gary Thorpe Associates Limited UK

ABSTRACT

A wide range of point of care (POC) testing systems is commercially available world-wide. These cover applications in diverse areas in healthcare and are based on numerous established or emerging technologies. The systems differ widely in complexity and range from disposable, single use non-instrumental systems to integrated systems designed for rapid detection of biohazards by automated DNA detection. POC systems are used in a range of extra-laboratory situations, include qualitative, semi-quantitative and fully quantitative devices, and can produce a single result or a panel of multiple, simultaneous results. Results can be indicated by various means including the production of coloured responses of varying intensity, symbols or words, or by conventional digital readout.

Several factors are critical for the application of technologies in routine POC testing. Irrespective of the complexity of technologies, systems should be; simple to use, based on ‘self contained’ stable reagents, conveniently stored, and designed to minimise operator dependent steps such as timings, volume pipetting, sequential procedural steps, calibration, and subjective determination of results and their interpretation. POC systems incorporating emerging or established technologies should also enable production of appropriate cost and ‘clinically’ effective results for specific applications, with the system’s characteristics including identification of suitable samples, performance and limitations clearly identified in the product’s claims and instructions for use.

The POC healthcare market is currently dominated by systems for use in blood glucose monitoring and by single use immunoassay devices. However, an enormous number of POC applications including clinical chemistry and microbiological tests are currently becoming available. The introduction of ‘miniaturised and packaged’ systems, encouraged by a need for systems for bio-warfare/bio-terrorism detection of chemical and biological agents, offer exciting opportunities for rapid and sensitive assays and detection of infectious agents. The introduction of new technologies and assays offers extremely exciting prospects and challenges for POC diagnostics.

SENSORS IN THE FOOD INDUSTRY INCLUDING ARRAYS

Emeritus Professor Brian Birch
Luton Institute of Research in the Applied Natural Sciences (LIRANS), University of Bedfordshire , 250 Butterfield , Great Marlings, Luton, LU2 8DL UK
www.beds.ac.uk/research/lirans

ABSTRACT

The Food Industry deals with a huge number of materials and process. There are the macro components; fats, proteins, carbohydrates, water down to minor amounts of enzymes, vitamins, minerals, flavours, colours. These are processed by a variety of means to yield the final product for consumption. The industry and consumer have similar needs; that the product should be of defined quality, be safe and be produced and sold at target cost. All needs must be traceable for regulatory purposes. These requirements have led to the development of a wide range of analytical and monitoring techniques applicable to all parts of the manufacturing supply chain. These techniques can be characterised as: In line (within the process operation), At line (close to but not within the process operation), Off line (sample removed to a location remote from the process operation – perhaps a nearby laboratory).

Virtually all in line monitoring operations are physical in nature; temperature, flow, density, viscosity. The at line and off line analyses tend to rely on sophisticated instrumentation (chromatographs, spectrophotometers, mass spectrometers and their combinations) for both major and minor components. It is in these areas that the uses of biochemical and chemical sensor systems have been under development for some decades. As a generalization, the minor components of foods are most suited to measurement by biochemical and chemical sensors and of those, water soluble and volatile materials appear preferable.

Safety in food operations is paramount. The detection of foreign bodies (glass, metal, stone etc.) is mature, well practiced methodology. The use of simple systems to detect thermal abuse in storage is also well developed. Using the principles of DNA fingerprinting it may in the future be possible to detect foreign, unwelcome, organisms e.g. frogs in spinach, rattlesnakes in tomatoes. Above all, bacteriological safety is key. The entire supply chain including machinery and premises is subject to routine and frequent audit. Traditional plate techniques, supplemented by more rapid colony counting instrumentation are understandably still the procedures of choice. However real-time polymerase chain reaction (PCR) is increasingly used to good effect.

The development of artificial noses for the measurement of flavours and other volatile components attracted much attention some years ago. Generally arrays were constructed having elements composed of materials with differing responses to sought materials (and/or arrays with similar responsive elements). Data were processed using neural networks, principal component analysis etc. Some 10 years ago there were a number of companies offering these noses. That number is now much reduced and of those remaining, the use of fingerprint mass spectrum instruments rather than chemical arrays appears the technique of choice.

This brief survey of a very broad area has aimed to show that the aspirations of some years ago for the use of chemical and biochemical sensor arrays in foods have not kept pace with the optimism at that time. However there are still significant opportunities for these devices, albeit in niche applications.

Reference: Instrumentation and Sensors for the Food Industry . Editors; Erika Kress-Rogers and C.J.B. Brimelow. Woodhead Publishing Ltd. 2001