Sensors 2017

Smart Chemical and Biological Sensing Technologies

Conference with Posters and Exhibition

Programme

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

A one day meeting on
Friday, 16th June 2017

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

Email: conference@aamg-rsc.org
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Smart Chemical and Biological Sensing Technologies

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Friday 16th June 2017

at The Royal Society of Chemistry, Burlington House,
Piccadilly, London W1J 0BQ

09:30 - 10:00 Registration and coffee

Session 1 Healthcare / Security Applications

Chair: To be Confirmed

10:00 CMOS gas sensors for healthcare
Julian Gardner
University of Warwick, UK

10:30 Optical molecular imaging - the real-time in situ detection of bacteria in man
Mark Bradley
University of Edinburgh, UK

11:00 - 11:20 Tea and Coffee

11:20 Electrochemical SERS for the discrimination of DNA from biothreats
Phil Bartlett
University of Southampton, UK

11:50 Detecting the threat
Licia Dossi
University of Cranfield, UK

12:20 Integrated Electrolyte Gated OFET and microfluidics for developing a biosensor platform
Glenn Sunley Saez
University of Manchester, UK

12:45 - 14:00 Lunch - Exhibition & Poster Session

Session 2 Materials / Environmental Applications

Chair: To be Confirmed

14:00 Making smarter biological interfaces for sensing
Paula Mendes
University of Birmingham, UK

14:30 Smart Sensors for Environmental Monitoring
Nathan Lawrence
ANB Sensors, UK

15:00 Controlled sp^2 addition to Boron-Doped Diamond: Development of an oxygen insensitive voltammetric pH sensor
Zoë Ayres
University of Warwick, UK

15:25 - 15:45 Tea / Coffee

15:45 Carbon dioxide measurements using long period grating optical fibre sensor coated with metal organic framework HKUST-1
Jiri Hromodka
University of Nottingham, UK

16:10 Gas sensing based on Langmuir-Schaeffer assembled commercial graphene platelets
Sebastian Nufer
M-Solv Ltd, UK

16:35 Concluding Remarks and End of Conference

ABSTRACTS

CMOS gas sensors for healthcare

Julian Gardner
University of Warwick

ABSTRACT

Recent years have seen a rapid increase in the demand for low cost, point-of-care sensors for the monitoring of health. This demand is being driven by emerging technological platforms for the Internet of Things, such as electronic devices for smart homes (e.g. Hive), wearable devices (e.g. Fitbit), and smart phones (e.g. iPhone). These smart sensors must be manufactured in very high volumes with low unit cost; for example 1 billion smart phones were sold year with Samsung alone selling over 100 million units. In this paper, we explore the development of CMOS sensors using silicon-on-insulator (SOI) technology for the detection of airborne chemical compounds that are related to heathcare and well-being. The SOI CMOS technology is employed to make high-temperature, low-power micro-hotplates for semiconductor based gas sensors (e.g. metal oxide), and thermally modulated infrared (IR) sources for non-dispersive IR gas sensors with plasmonic structures for enhanced selectivity/sensitivity. We discuss the SOI CMOS technology and its application to indoor air quality (CO_2 and certain VOCs), and breath analysis for lifestyle and energy expenditure (ethanol/CO, CO_2/O_2). Finally, we consider the more demanding detection of breath biomarkers for illness (e.g. acetone, isoprene, and limonene) using CMOS gas sensors.

Optical Molecular Imaging - The Real-time in situ Detection of Bacteria in Man

Mark Bradley

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University of Edinburgh.

ABSTRACT

A formidable challenge in modern respiratory healthcare is the accurate and timely diagnosis of lung infection and inflammation. The EPSRC Interdisciplinary Research Collaboration (IRC) 'Proteus' seeks to address this challenge by developing an optical fibre based healthcare technology platform that combines physiological sensing with multiplexed optical molecular imaging. This technology will enable *in situ* measurements in the distal lung to assess tissue function in health as well as generate and characterise unique signatures of pulmonary disease.

In my talk I will describe the chemistry behind the teams optical imaging reagents and illustrate the first in vivo application of these materials that allow the detection of bacterial infection deep in the human lung.

Electrochemical SERS for the Discrimination of DNA from Biothreats

P. N Bartlett

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ABSTRACT

The development of sensors for the detection of pathogen-specific DNA, including relevant species/strain level discrimination, is critical in molecular diagnostics with major impacts in areas such as bioterrorism and food safety. In this lecture I will describe the use electrochemically driven denaturation assays (*E*-melting) monitored by SERS to detect and discriminate DNA. The method relies on the high surface enhancement at nanostructured gold electrode surfaces to give very sensitive detection of immobilised dsDNA and to follow the denaturation of the dsDNA as the electrode is swept to negative potentials [1-4].

Using this technique we can discriminate short tandem repeats (STRs) [5], single nucleotide polymorphisms (SNPs) that distinguish DNA amplicons generated from bacterial DNA [6], and discriminate strains within genetically highly similar bacteria DNA using amplicons containing Variable Number Tandem Repeats (VNTRs) [7].

References

1. S. Mahajan, J. Richardson, T. Brown, and P. N. Bartlett, "SERS-Melting: a new method for discriminating mutations in DNA sequences", *J. Am. Chem. Soc*., **130**, 2008, 15589-15601.

2. R. P. Johnson, R. Gao, T. Brown, P. N. Bartlett, "The effect of base-pair sequence on electrochemically driven denaturation", *Bioelectrochem*., **85**, 2012, 7-13.

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4. R. P. Johnson, N. Gale, J. A. Richardson, T. Brown and P. N. Bartlett, "Denaturation of dsDNA immobilised at a negatively charged gold electrode is not caused by electrostatic repulsion", *Chem. Sci*., **4**, 2013, 1625-1632.

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6. E. Papadopoulou, S. A. Goodchild, D. W. Cleary, S. A. Weller, N. Gale, M. R. Stubberfield, T. Brown P. N. Bartlett, "Using surface-enhanced Raman spectroscopy and electrochemically driven melting to discriminate *Yersinia pestis* from *Y. pseudotuberculosis* based on single nucleotide polymorphisms within unpurified polymerase chain reaction amplicons", *Anal. Chem*., **87***,* 2015*,* 1605−1612.

7. E. Papadopoulou, N. Gale, S. A. Goodchild, D. W. Cleary, S. A. Weller, T. Brown and P. N. Bartlett, "Strain discrimination of *Yersinia pestis* using a SERS-based electrochemical melting curve analysis of variable number tandem repeat sequences", *Chem. Sci*., **6**, 2015, 1846–1852.

Detecting the threat

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ABSTRACT

Law Enforcement Agencies (LEA's) are under constant pressure to increase their level of control over trafficking, smuggling and terrorism and other criminal activities. The detection of illegal materials is a very complex and costly task, since most explosives and drug precursors release very small amounts of vapours and in presence of numerous competitors which produce false answers. This is an important analytical problem which requires reliable, selective and sensitive detection methods that provide the highest level of confidence in the result.

The European Union is funding various projects aimed at supporting Police and Custom Officers in their prevention activities against terrorist and illegal drug related threats. The FP7-CRIM-TRACK project has developed an outstanding miniaturized, "Sniffer" system based on a new colorimetric sensor technology which gives nearly real-time information about potential illegal substances such as illicit drugs and their precursors, explosives and their precursors through detection of their vapour. This sensing technology has been developed by several partners from academic, SME and governmental EU institutions.

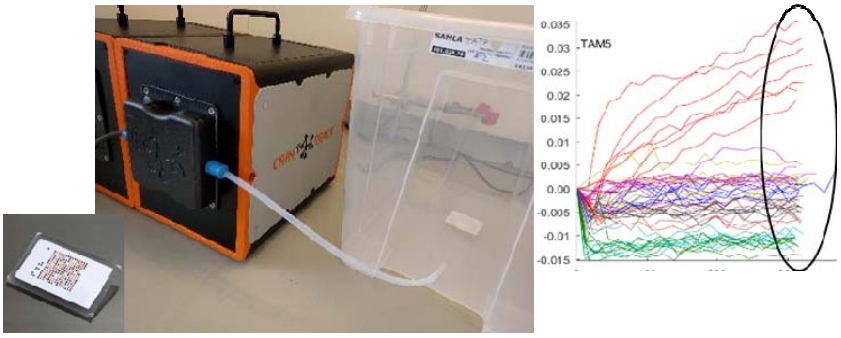

Figure CRIM-TRACK sniffer prototype-White Horse

At present a fully-integrated portable prototype for air sampling with disposable sensing chips and automated data acquisition has been developed. The prototype allows for fast, user-friendly sampling which has made it possible to produce large datasets of colorimetric data for different target analytes in laboratory and simulated real-world air-samples. The result of the analysis of potential threat compounds can be presented as a simple yes/no detection or in full detail. The technology under development in CRIM-TRACK has the potential to be an effective tool to control trafficking of illegal drugs, explosive detection, or in other law enforcement applications.

Keywords: Vapours detection, explosives, drugs, precursors, CRIM-TRACK sniffer

Integrated Electrolyte Gated OFET and microfluidics for developing a biosensor platform

Glenn Sunley Saez, Prof Michael Turner and Dr Michelle Webb

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ABSTRACT

The clinical application of simple and frequently performed assays promises to enable faster therapeutic decision-making, inform accurate prognosis and help deliver cost-effective treatment. Point of care (PoC) devices rely on user friendly sensor platforms capable of delivering robust and reliable real-time detection of target biomarkers without the need for labelling (i.e. label-free biosensing).

Organic field effect transistors (OFETs) have gained interest as promising biosensors as they benefit from intrinsic signal amplification and electrical output to produce high sensing performance which is easy to interpret combined with low cost fabrication, allowing the development of disposable electronic sensing systems ideal for PoC testing.

Electrolyte-gated organic field effect transistors (EGOFETs) benefit from a simple device architecture utilising an aqueous gating solution allowing a low operating potential (<1 V) and *in-situ* detection of the analyte in solution.

In order to address the aforementioned issues a microfluidic cell for use with EGOFET sensors was developed. Integration of microfluidics with biosensors improves device reproducibility and performance, whilst simplifying fabrication and operation.

A bespoke characterisation platform was also developed to allow a user friendly time efficient and controlled setup for performing the electrical characterisation, removing the need for a microprobe station. The resulting platform is therefore well placed for bio-functionalisation and further development as a biosensor.

Making smarter biological interfaces for sensing

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ABSTRACT

With nature as an inspiration, coupled with the increasing capability to understand and manipulate structures of matter at molecular and nanoscale level, new opportunities are opening up for developing more complex and dynamic biological interfaces for highly sensitive, selective and on-demand sensing. The lecture will highlight how the availability of sophisticated new experimental techniques and tools of nanotechnology can be used to create three-dimensional (3D) nanostructured surfaces to monitor dynamic complex biological processes in real time at the single cell level. The creation of stimuli-responsive interfaces as sensing platforms with the capability to detect binding events only when required will also be discussed. In addition, progress on molecularly engineered surfaces for specific glycan recognition and earlier and more accurate diagnoses of diseases, such as cancer, will be described.

Smart Sensors for Environmental Monitoring

Nathan Lawrence

ANB Sensors

ABSTRACT

The application of digital and data driven solutions has revolutionised business operations and processes across countless industries in recent years, and now the environmental sector is ready for these systems. There are numerous opportunities to save money by using smart technologies to improving understanding of environmental impact, asset management and process optimisation. Growth in this market is driven by three major factors: Enhancing efficiency, cost and regulation. As this digital revolution takes hold there is now more than ever a need to develop smart sensors for improved monitoring, automated control, environmental understanding and asset management.

This presentation will provide an overview of ANB Sensors approach to sensor development, how we perceive a sensor should operate and how we aim to deliver this. In-situ checks of the sensors performance and mitigation measures are key to enhancing the sensors lifetime and performance. The development of a novel solid state pH sensor will be provided as a case study as to how we are trying to achieve these goals.

Controlled sp^2 addition to Boron-Doped Diamond: Development of an oxygen insensitive voltammetric pH Sensor

Zoë J. Ayres
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ABSTRACT

pH measurements are extremely important and ubiquitous in chemistry, with many industries required to take pH measurements routinely. It is also becoming increasingly important to monitor the changes in pH in natural waters to determine the biological and ecological impact of climate change. The most common pH sensor to date is the glass pH sensor however the technology suffers from several limitations including fragility and being subject to 'alkali errors' where interfering ions such as Na^+ can affect the pH response.

In this presentation, the development of boron doped diamond (BDD) pH sensor capable of overcoming these disadvantages is described. As BDD itself is not pH sensitive, an innovative strategy to create pH sensitive and electrochemically active functional groups (quinones) on laser ablated regions of a diamond surface is explored. Importantly, the resulting pH sensor exhibits the advantageous bulk physical properties of BDD, including low background currents, robustness, insensitivity to oxygen reduction, whilst accurately sensing pH over a large pH range 1-13 in both buffered and unbuffered solutions. The sensor is deployed in a host of real-world samples, with accurate determination of the pH of seawater and river water, as well as more complex matrices such as blood. Accurate pH measurements are demonstrated over extended periods of with the sensor showing great promise for in-situ pH monitoring.

Carbon dioxide measurements using long period grating optical fibre sensor coated with metal organic framework HKUST-1

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ABSTRACT

An optical fibre long period grating (LPG) based carbon dioxide (CO_2) sensor coated with HKUST-1, a material from the metal organic framework family, functional coating is presented. In-situ crystallization and layer by layer (LbL) techniques of HKUST-1 thin film synthesis are compared in terms of the feasibility of the deposition procedure (time and cost efficiency) and the sensitivity of the film to carbon dioxide. The sensing mechanism is based on the measurement of the change of the refractive index (RI) of the coating that is induced by the penetration of CO_2 molecules into the HKUST-1 pores. The HKUST-1 film was characterized by scanning electron microscopy (SEM). The thickness and refractive index (RI) of the 10, 20 and 40 layers thick films were determined using ellipsometry. The crystallinity of the films was examined by X-ray diffraction pattern (XRD). While no response to CO_2 was observed for the sensor coated using the in-situ crystallization technique, an LPG modified with 10, 20 and 40 layers of HKUST-1 films using LbL method upon exposure to CO_2 in the range of 500 ppm to 40,000 ppm showed good sensitivity. The film containing 40 layers exhibited the highest sensitivity to CO_2 with an obtained detection limit of 401 ppm.

Gas sensing based on Langmuir-Schaeffer assembled commercial graphene platelets

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ABSTRACT

Graphene has shown to be sensitive to various gas molecules among them Ammonia. Literature shows promising results concerning the detection limit of graphene towards these gases. These experiments are normally conducted under laboratory conditions as graphene is still quite a young material. Graphene starts to show up commercially on the market as small platelets with sizes in the range of 300 nanometres. The small size of the platelets prevents from using them individually for gas sensing applications. Here we investigate the gas sensing characteristic of assembled percolating graphene platelet networks using the Langmuir-Schaeffer deposition method. Rather than using the basal plane as detection mechanism we use the inter-sheet resistance of the assembled film to detect Ammonia. We deposit these films on industrial laser ablated interdigitated electrodes making a step towards industrialisation of graphene based gas sensors. Stable conductivity signals using this assembly method are shown.

POSTER ABSTRACTS

The feasibility of Pd electrochemical recovery and deposition from acetonitrile-water mixed solvents

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POSTER ABSTRACT

The aim to produce safe medicines, drives international, as well as governmental entities, such as the World health Organization WHO, and the European Medicines Agency to set stringent rules for the levels of metal residues (catalysts) in drug products.[1] Thus great attention has been directed towards the monitoring and reduction of toxic and heavy metals as well as hazardous substances.[2] Just as important is the development of effective recovery techniques for these metal residues. Despite the existence of several methods such as the use of scavengers, electrodeposition remains a relatively unexplored technique to tackle such a challenge.[2] In this work we investigate the electrodeposition of Pd, in the form Pd (II) acetate, from pure organic solvent (acetonitrile: MeCN) and mixed water : MeCN solutions, by means of cyclic voltammetry, ultraviolet-visible spectroscopy (UV-Vis), nuclear magnetic resonance (NMR), field-emission scanning electron microscopy (FE-SEM) and energy dispersive X-ray (EDX). In particular, we investigate the effect of changing water content on the metal recovery process. We show that in pure MeCN electrodeposition of metallic Pd on the electrode surface is not possible, the Pd(II) acetate undergoes reduction-oxidation to form Pd(0) but still remains complexed to the organic ligands. However by adding in small quantities of water electrodeposition is now possible. The mixed solvent system is thus a promising medium for electrodeposition of Pd from an organic solution where water content is a crucial factor that accounts for the feasibility of the process.

References:

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Laser micromachining as a route to spatial and density control of sp^2 carbon in boron doped diamond (BDD) electrodes: application to pH electrode sensing in unbuffered solutions.

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POSTER ABSTRACT

High power laser micromachining systems are used to cut diamond and have previously been used to manufacture all diamond electrochemical devices, including disk electrodes, band electrodes and ring disk electrodes. The machining process also leaves non-diamond (sp^2) carbon behind which has been found to have a significant effect on the electrochemistry observed. Recently, we have shown how we can use this approach to functionalise the BDD surface with sp^2 sites, which are more catalytically active than the surrounding sp^3 BDD surface. The nature of this sp^2 carbon is still not completely understood, but has been shown to contain quinone-like moieties (QLM's) which demonstrate a quantitative pH response and can be used as a measure of the surface sp^2 content.

QLM's produced on the surface of BDD by laser micromachining have a significant advantage over previous approaches. The QLM's are incredibly stable, being resistant to mechanical abrasion, extremely high temperatures and extreme environments. However, the challenge is to maintain the proton level constant at the surface during the electrochemical measurement. To this regard, we investigate ways in which we can either increase the flux of protons to the electrode surface or decrease the number of protons being turned over at the electrode surface. To mitigate this, two interdependent avenues are explored: (1) lowering the quinone surface coverage and (2) changing the mass transport to the electrode surface. This is achieved by manipulation of the laser micromachining parameters to create lower quinone surface coverages (Γ) and reduced pit sizes.