Biosensors and Biosensing

Academic Research Activity in the UK

Knowledge Transfer Network

Electronics, Sensors Photonics

Issue 3

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Introduction

This guide provides information on UK academic groups active in biosensors and biosensing research. Its purpose is to help organisations looking for academic groups with particular expertise in the biosensor/biosensing field more easily identify such groups and thereby help facilitate activities such as finding partners for collaborative R&D projects and identifying exploitable technologies. The guide has been produced by means of web-based research and direct contributions from academic groups. Whilst the guide only provides summary information on research activities, where possible, web links have been provided for those wishing to get more detailed information about areas of expertise, capabilities, current projects and key contacts.

In this guide a biosensor is defined as a compact analytical device incorporating a biological or biologically derived sensing element (the bio receptor) either integrated within or intimately associated with a physicochemical transducer. The usual aim of a biosensor is to produce either discrete or continuous digital electronic signals that are proportional to a single analyte or a related group of analytes. Biosensing is defined as the specific application of a biosensor or any other sensor to monitor living systems.

Typical bio receptors are enzymes, microorganisms, antibodies, tissue, organelles and chemoreceptors. Typical transducer types are amperometric, potentiometric, semiconductors, thermometric, photometric and piezoelectric.

Biosensor/biosensing research involves many disciplines and therefore relevant activity tends to be distributed across various academic departments (e.g. physics, chemistry engineering, biochemistry, medical…) and across research groups both within and between universities. Because of this the guide is structured by academic group rather than by research activity or application area. A table at the end of the guide provides a basic route to identifying some of the specific research interests and areas of expertise found across the listed research groups.

Groups that are not currently listed but are involved in biosensor/biosensing research are encouraged to submit an entry for the guide by contacting Robert.Angus@espktn.org with details.

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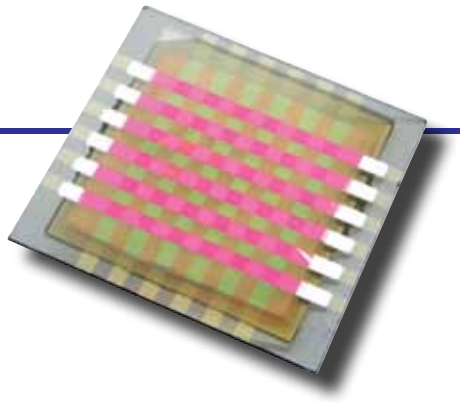
Content



Academic Groups

2.1 Aston University

2.1.1 Aston Institute of Photonic Technologies

Head of Group: Prof. Sergei Turitsyn

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Keywords highlighting areas of interest and expertise of group: Aptamers, DNA, fibre optic sensors, bragg grating, immunoassays, microfluidics, photonic biosensors, surface plasmon based sensors,

Biosensor/Biosensing Research Capabilities

The Aston Institute of Photonic Technologies has a well-established track record of innovation in grating devices for applications in telecommunications, signal processing and optical sensing. The main areas of research relevant to biosensors and biosensing are fibre gratings fabrication and design and fibre grating devices and their application in biomedical and biochemical sensors.

Biosensor/Biosensing Related Research Projects

Exploitation of Advanced Photonic Biosensors

A new tool for fast and ultrasensitive detection of biochemical and biomolecular interactions. We are currently exploring a new class of photonic biosensors for fast, sensitive and real-time detection of very small biochemical samples and the dynamic analysis of protein/protein, protein/DNA and cellular interactions. The photonic biosensors are developed using UV and femtosecond inscribed fibre gratings and microstructures in speciality fibres, including D-shape, multimode and multicore fibres. To realise bio sensitivity/selectivity, bioactive coating materials, such as DNA, are being exploited. The work is carried out collaboratively with the Molecular Bioscience Research Group at Aston University. It is envisaged that the highly bio-sensitive/selective optical sensors will have potential applications in genomics, proteomics and drug discovery research and development, as well as in environmental monitoring.

Photonic Microfluidic Devices by UV and Femtosecond Laser Inscription.

The fabrication of photonic microfluidic devices, exploiting femtosecond and UV laser inscription and chemical etching, has recently been demonstrated. The integration of Bragg grating structures with the microfluidic channels makes it possible to optically detect small quantity of biochemicals and biomolecules. Applied as bio-chemical sensors, these photonic microfluidic devices benefit from miniature size, robust structure, high sensitivity and their applications could cover a wide range of measurements including cell manipulation and sensing, flow cytometry, immunoassays and DNA analysis.

Sol-gel based biocoating materials for optical biosensors.

A collaboration with the Department of Prosthetic Dentistry and Biomaterials Science, University of Turku, Finland. The aim of this project is to develop sol-gel derivated bioactive coatings for fibre grating based biosensor applications. The devel-

oped sol-gel biocoating materials will be highly absorbing by fibre gratings and active only to the selective biochemical and biomolecule samples. A range of sol-gel based biocoating materials will be developed and applied to the fibre grating structures. This could be a potentially low-cost technique to realise optical biosensors.

Polymer fibre grating sensors.

This work is focused on the development of the technology of fibre gratings in polymeric fibre (POF), which is in many ways inherently more biocompatible that silica fibre. We are interested in the potential to modify the polymers forming the fibre to provide sensitivity to specific chemical and biochemical species.

Funding was until recently provided by the EU via the FP7 project PHOSFOS. One aim of the latter project is to develop polymer fibre based sensing surfaces that may find application in the long term monitoring of respiration, for enhanced rehabilitation following accidental trauma or surgical interventions as well as for the detection of pressure points under bed-ridden patients.

Surface plasmon based sensors.

Fibre sensors are being developed with very high index sensitivity by using fibre gratings to couple light to surface plasmons excited on a metal-coated fibre. Applications being pursued include biosensing using aptamers and cellular imaging. Funding provided by EPSRC.

2.1.2 Biomaterials Research Unit

Head of Group: Prof. Brian Tighe

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Keywords highlighting areas of interest and expertise of group: Fibre optic sensors, membranes, biofouling

Biosensor/Biosensing Research Capabilities

Aston Biomaterials Research Unit has extensive experience of the design of permselective and reactive membranes and of biological interface conversion processes, which are frequently initiated by the irreversible deposition of proteins at polymer surfaces. We have extended the experience gained in the biomaterials field where the principle of biomimesis (using natural surfaces as design models) is increasingly employed to the area of sensor membranes for use in biological environments.

In this way we are able to fabricate membranes with controlled permeability coupled with the necessary resistance to non-specific deposition and fouling processes. Past projects have included the design of membranes for potentiometric, FET-based and fibre-optic sensors. Our current wok is focussed on fibre-optic sensing where we work with both academic and commercial partners.

Biosensor/Biosensing Related Research Projects

The principal objective is to extend the clinical applications of fibre-optic sensors. One particular group of opportunities are those related to the eye. Because of vascular leakage, the tear film contains a range of analytes that can be used to monitor more generic aspects of bodily health, and the potential of this is now being recognised. There are many target

analytes including those that are generically related to tear chemistry – such as tear electrolytes - and those that are specific to the success of contact lens wear – especially proteins and immunoresponsive markers such as the kinins and immunoglobulins.

A second and related area is chronic wound healing. The financial impact of chronic wound care is enormous and increasing, a feature of an aging population. It is widely recognised that the burden of cost to healthcare providers could be significantly reduced and the well being of patients improved through the development of more effective treatment regimes and better understanding of the effect of specific wound dressing materials on detailed biochemical aspects of the healing process.

Our research target is the development of an in situ analytical methodology, exploiting advances in fibre-optic sensor technology embedded within the dressing, to enable enhancement of understanding of the dynamics of the interface between the wound and dressing, which is critical to the understanding of the healing process and the understanding of aspects of patient-to-patient variation and patient specificity. In addition to total protein, pH, osmolarity, and the concentration of key electrolytes, many immunoresponsive markers analogous to those associated with the anterior eye are important in the progress of wound healing.

The aim of these and related projects is to develop responsive membranes with a high degree of biocompatibility with the target environment and adapt these to different healthcare problems as a basis for improved understanding and for product evaluation and development.

2.2 Bangor University, School of Chemistry

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Keywords highlighting areas of interest and expertise of group: Electrochemistry, monolayers, conducting polymers, electrocatalysis

Biosensor/Biosensing Related Research Projects

Active research in the field of Electrochemistry and sensors is currently being carried out in the following areas:

- Optical and electrical properties of novel conducting polymers. We are currently investigating the use of CPs in type III supercapacitors and sensors for volatile organics.
- The design of sensors and recovery systems for precious and heavy metal ions.
- This work is being carried out in collaboration with C-Tech, Capenhurst (UK).
- Self-Assembled Monolayers (SAMs). This project is concerned with the fundamental aspects of charge transfer and restructuring of SAMs. Furthermore, the modification of SAMs for use in sensor technology is also investigated.

Electrocatalysis

The oxidation and reduction of small organic molecules at electrode surfaces is investigated using in situ IR techniques (SNIFTIRS and EMIRS). Emphasis is placed on the reactions of CO and CO2 at a variety of metals.

Design of sensors for explosives

We are currently developing a variety of sensors for the detection of low levels of explosives.

Design of sensors for TB

This work is carried out in collaboration with Prof Baird's group.

Cancer therapy

This work is being carried out in collaboration with Dr Thomas Caspari

Other research

In addition to the above, we are actively collaborating with EU and UK partners in the study of nano-structured metal oxides. The following techniques are currently used in addition to conventional electrochemical methods.

- Scanning Tunnelling Microscopy
- Electrochamically Modulated Infrared Spectroscopy (EMIRS)
- Subtractively normalised Interfacial FTIR Spectroscopy (SNIFTIRS) (Bruker IFS 133v.)

2.3 University of Bath, Bath Biosensor Network

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Keywords highlighting areas of interest and expertise of group: Amperometry, bacterial biosensors, bioavailable metals, bio-chips, bio-films, DNA, electrochemistry, enzymes, FRET sensors, glucose biosensors, immunoassays, membranes, micro-arrays, microfluidics, nanoparticles, nano-structured materials, neural network, organic semiconductors, photonic bio-sensors, potentiometry, single molecule transducers, surface plasmon based sensors, tissue fluorescence, holographic biosensor

Biosensor/Biosensing Research Capabilities

The University of Bath conducts internationally leading research on different aspects of biosensor development and applications: from sensor and instrumentation development to signal processing; from integration of biology with devices to study of biomolecular interactions. Application areas are as diverse as bio-medical, pharmaceutical, industrial, environmental, food, defence, and sports.

The Bath Biosensor Network is a collaborative University-wide multidisciplinary support network that capitalises on the diversity of the excellent biosensor-related research in Bath. It promotes interdisciplinary collaborations as well as the sharing of ideas and facilities across departments. The Network combines expertise from researchers from diverse disciplines, including many of those in the University's Interdisciplinary Research Clusters of Sensors and Sensing and Technologies for Healthy Living and Wellbeing.

A wide and diverse range of facilities is available at the University of Bath including: small-angle X-Ray scattering, NMR, Mass spectrometry, Brewster-angle microscopy, plate-reading fluorescence spectrometer, flow cytometer, epi-fluorescence microscope; Surface Plasmon Resonance, Surface Plasmon Field Enhanced Fluorescence, FRET; class 100 clean room for semiconductor-based sensor fabrication, micro and nano processing; optoelectronics characterisation laboratory; IC design software, state-of-the-art device test facilities, poling and piezoelectric device manufacture, surface profilometry, microstructural characterisation; Atomic Force Microscopy, Scanning Tunnelling Microscopy, Transmission Electron Microscopy.

Biosensor/Biosensing Related Research Projects

Development of label-free electrical techniques for biosensing applications

Contact Person: Dr Pedro Estrela, Department of Electronic & Electrical Engineering

Development of label-free electrical techniques for the detection of DNA and proteins, suitable for implementation with portable instrumentation. Development of arrays of field-effect transistors and electrochemical biosensors such as electrochemical impedance spectroscopy-based sensors. Some current projects include:

- Development of CMOS and TFT arrays of field-effect transistors for label-free electrical protein microarrays.
- Use of nanomaterials for the development of ultra-sensitive biosensors for the detection of DNA and protein interactions.

CMOS biocompatible multiple electrode array

Contact Person: Prof John Taylor, Department of Electronic & Electrical Engineering

A low-cost electrode design has been devised for drug discovery pharmacology, neural interface systems, cell-based biosensors and electrophysiology research, based on high-volume CMOS (complementary metal oxide semiconductor) integrated circuit technology. The electrode is formed by the anodisation of CMOS metallisation to form nanoporous alumina. The process was developed to address the concern of aluminium neurotoxicity, improve corrosion resistance under physiological conditions and to present a preferential morphology for cell–substrate adhesion.

Mapping proteins within cells using magnetic force microscopy

Contact Person: Dr Sergey Gordeev, Department of Physics

Labelling of specific proteins in cells using magnetic nanoparticles and mapping their distribution using magnetic force microscopy (MFM).

Novel biomaterials: towards a cost-effective biosensor for the multiplex detection of sexually transmitted infections

Contact Person: Dr Chris Frost, Department of Chemistry

The aim of this interdisciplinary project is to integrate expert knowledge in the area of materials synthesis, molecular biology and electrochemistry to prepare a panel of distinct electronic labels for the rapid multiplex detection of the common sexually transmitted infections Chlamydia and Gonorrhoea for application in an inexpensive, disposable commercial biosensor.

The site-selective chemical modification of peptides and proteins

Contact Person: Dr Chris Frost, Department of Chemistry

The development of enabling chemical technology for the site-selective labeling of peptides and proteins with redox-active molecular tags. By changing the molecular structure we can tailor the oxidation potential of the label to allow for multiplexing. Our initial interest in these systems is for the development of rapid immunoassay methodologies. However we are also interested in a rapid screening technique for compounds that inhibit particular kinds of protein-DNA binding. Protein-DNA interactions are essential for fundamental cellular processes such as transcription, DNA damage repair and apoptosis. Identifying chemical structures that disrupt protein-DNA binding is an important step for the development of new drugs.

Fish noses and their application to biosensors

Contact Person: Dr Jonathan Cox, Department of Chemistry

The notion that fish have noses comes as a surprise to many people. In fact, the olfactory apparatus of fishes exhibits great variety in form, and the sense of smell in some species is particularly acute, exceeding that of dogs. Indeed, fish noses could be regarded as a natural example of a highly refined lab-on-a-chip.

This work considers how the architecture and organisation of fish noses might be exploited to make ultrasensitive sensors for aquatic environments. Sharks, sturgeon, garpike, pufferfish and hagfish may all have a part to play in this unfolding story.

Study of the mechanisms involved in the use of cell-penetrating peptides as drug delivery agents

Contact Person: Dr Ian Eggleston, Department of Pharmacy & Pharmacology

The analysis of peptide-carbohydrate recognition is an area of increasing importance in drug discovery and biotechnology. We are interested in cell-penetrating peptides (CPP) as drug delivery agents. There has been a huge amount of study and speculation as to the mechanisms by which these highly charged peptides are able to efficiently translocate across cell-membranes and hence transport attached molecular cargo into cells. One model involves an initial interaction between these peptides and anionic carbohydrate cell surface components. We are using electrochemical biosensors to help model this interaction.

Sensing by-products of hollow fibre bioreactors for tissue engineering constructs to aid the regeneration of damaged tissue

Contact Person: Dr Marianne Ellis, Department of Chemical Engineering

Label-free electrical and electrochemical biosensors for monitoring of media components and metabolites in tissue engineering bioreactors, which are used for stem cell expansion and the development of tissue engineering constructs to aid the regeneration of diseased or damaged tissue. In the first instance we will use hollow fibre bioreactors and bone-like MG63 cells.

Non-invasive monitoring across the skin

Contact Person: Prof Richard Guy, Department of Pharmacy & Pharmacology

The long-term objective is the development and optimization of a novel, noninvasive, iontophoretic approach for clinical monitoring via the skin. The low-level current density drives both charged and highly polar (yet neutral) compounds across the skin at rates much greater than passive diffusion. As the skin offers a uniquely accessible body surface across which

information can be extracted, we hypothesize that truly noninvasive and highly sensitive devices, which exploit uniquely paired flows of at least two substances, can be developed for iontophoretic monitoring applications. The research strategy aims to optimize iontophoretic and sensing technology to satisfy three key criteria for success: (a) fundamental understanding of electrotransport across the skin; (b) reproducible enhancement of transdermal permeability to identify clinical monitoring opportunities via the skin; and (c) characterization and validation of simple, user-friendly devices for sample collection coupled with sensitive and specific analytical tools. Current applications include the monitoring of glucose, lactate and various therapeutic drugs.

Calibration Free Continuous Invasive Sensor Targeted at Glycaemic Control

Contact Person: Dr Tony James, Department of Chemistry

Development of contact lenses that use "Sensor Hologram" technology to help diabetics ensure their blood sugar level is not dangerously high or low. The new system involves special contact lenses which sense the glucose levels in the tear fluid of the wearer's eye, which may be linked to the concentration of glucose in the blood. Changes in the glucose level in the tear fluid alter the wavelength of light reflected by the "Sensor Hologram" in the contact lens, and this can be detected by a small device held up to the eye to give an accurate reading of the wearer's glucose level. This painless system will allow diabetics to monitor their glucose levels more often, leading to better blood sugar control and fewer health problems.

Catalysis and sensing for our environment

Contact Person: Dr Tony James, Department of Chemistry

Most industrially important chemicals are produced using catalysts, which speed up chemical reactions and make them more environmentally-friendly. This is done by cutting the amount of waste produced and reducing the energy needed to drive the reaction. Chemical and biological sensors can be used to monitor environmental conditions such as air and water quality. A key area of research at Bath in this area is in sensing chemicals such as fluoride in water. At low concentrations, fluoride gives health benefits, but higher concentrations can be detrimental to health. Fluoride sensing can also be used to detect chemical weapons used for terrorism.

Fundamental studies of lipid vesicle adsorption on micro-patterned monolayers

Contact Person: Dr Toby Jenkins, Department of Chemistry

Phospholipids are the basic building blocks of cellular membranes found in Nature. The mechanism of self-assembly of such lipids, by fusion of lipid vesicles on solid surfaces is of much current interest since this provides a way of preparing bio mimetic lipid membranes on surfaces, with characteristics similar to that of cellular membranes.

New glucose biosensors

Contact Person: Dr Toby Jenkins, Department of Chemistry

Boronic acid – ferrocene molecules are being tethered to gold surfaces with the aim of developing new generation non-enzymatic glucose biosensors. This work is being extended, using the surface plasmon enhanced fluorescence technique to detect a range of analytes, including fluoride anions.

Functional protein incorporation

Contact Person: Dr Toby Jenkins, Department of Chemistry

It is intended to incorporate a number of membrane proteins into the lipid membranes created in other research projects.

This is of interest for two reasons; firstly it will facilitate the study of the fundamental structure-function relationship of biochemically important membrane proteins, for example ATPase and bacteriorhodopsin. Secondly, in principal, it provides a method for making a biosensor that utilises Nature's own biosensing mechanisms. Such an approach could also have applications in screening potentially pharmaceutically active agents.

Identifying appropriate locations for biosensor placement in the human body

Contact Person: Dr Keith Stokes, School for Health

Work is being carried out in the School for Health to identify appropriate sampling techniques for repeated / quasi-continuous measurement of endocrine and inflammatory markers (currently focussing on saliva and capillary blood sampling) and this is moving towards the measurement of markers in interstitial fluid to better understand whether concentrations in blood and saliva provide useful information about the situation in and around working muscle. In all of this work, inter-individual variation has always been evident and we are looking towards studying tailored training plans based on specific genetic polymorphisms and / or the response of specific hormones to a training bout.

2.4 Bolton University, Institute for Renewable Energy and Environment Technology

Key Contact:

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Keywords highlighting areas of interest and expertise of group: Surface acoustic wave, microfluidics, carbon nanotubes, point of care, piezoelectric sensor, lab-on-a-chip, microarray

Biosensor/Biosensing Related Research Projects

Film Bulk Acoustic Resonator-based Ultra-Sensitive Biosensor

This was an EPSRC funded large project with partners from Cambridge and Manchester Universities, and Zhejiang University, China. The project aimed to develop a highly sensitive film bulk acoustic resonator (FBAR) biosensor array for point-of-care and diagnostic applications, and also aimed to integrate the biosensor array with an on-chip surface acoustic wave (SAW) based microfluidics for liquid transportation and mixing to reduce the reaction time and minimize non-specific bonding for accurate detection. We have successfully developed technologies to deposit high quality ZnO piezoelectric thin films with extremely low stress and defects by using highly target utilization sputtering system, and fabricated high performance FBARs with quality factor (Q) larger than 1000. We have also pioneered a technology of fabricating FBARs using carbon nanotubes (CNTs) layer as the top electrode, and achieved FBARs with Q-value over 2000, the best record reported. We have demonstrated that the FBARs are good physical sensors for sensing temperature, pressure, humidity, UV-light with high sensitivities; and FBARs can be used as for accurate detection of biomolecules, especially in gas phase, and showed it is feasible to develop FBAR array based sensing chip which can perform multi-sensing in parallel with self-temperature reference. The biosensors are fast, label-free, and suitable for real time detection; and they are extremely small with dimensions of a few tens of micrometers and have an extremely small mass detection limitation below 10^{-13}g. This low cost, highly sensitive, label-free, fast and parallel array technology offers the real possibility of practical, real time diagnosis.

SAW-based Lab-on-a-Chip for Diagnosis

This project is funded by the Leverhulme Trust to develop a synthesis method to deposit nanorod ZnO films and to use the

material to fabricate lab-on-a-chip with integrated biosensors and microfluidics all based-on a single actuation mechanism of surface acoustic wave (SAW). We have developed a novel technology of synthesizing ZnO thin films in solution and have filed a patent application for the technology. The smooth flat films consist of densely packed ZnO nanorods only, thus possessing high piezoelectric constant, excellent electrical and optical properties owning to nanostructures and quantum confinement, suitable for fabrication for acoustic wave devices, micropower generators and electronic and optical devices. We have successfully developed a technology of SAW-based microfluidics and biosensors, demonstrated that SAW devices can be very good micropumps and micromixers to transport and to mix liquids and reagents; and good sensors to detect low concentrations of biomolecules. SAW-micropump can transport continuous flow as well as digital droplets, and is an active mixer particularly useful in mixing liquids in small volumes which can improve the mixing efficiency and minimize non-specific biobonding. SAW-based lab-on-a-chip is simple in structure and fabrication, low cost and very reliable as there are no moving-parts involved; and SAW-based lab-on-a-chip can be integrated with Si-electronics for control and signal processing etc. We are also developing a number of novel SAW-based devices such as cell lyses and PCR.

2.5 University of Bristol, Department of Electrical and Electronic Engineering, Photonics Research Group

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Keywords highlighting areas of interest and expertise of group: Microarrays, nanostructured materials, photonic biosensors, nanoantennas, semiconductor lasers, lab-on-a-chip, bio-chip

Biosensor/Biosensing Research Capabilities

The Photonics research group at Bristol has world class modelling, measurement and fabrication facilities, including access to the University of Bristol's 3000+ node supercomputer for electromagnetic modelling, a Focused Ion Beam nanofabrication facility and a class 1000 cleanroom with Electron-beam processing facilities.

Biosensor/Biosensing Related Research Projects

Integrated Tunable Flat Lenses (TuneFul)

This 3 year EPSRC grant (EP/J01303X/1) in collaboration with the University of Exeter and BAE, Bristol will take the next major step forward in the emerging field of optical nanoantennas by creating tunable nanoantenna arrays configured as flat lenses which will be integrated with a range of semiconductor lasers to create electronically tunable laser facets for focusing, steering and spectral control. This will revolutionise the field of semiconductor lasers by producing high spectral purity beams which can be controlled without the need for bulky, expensive external optics with applications from optical communications to sensors and biophotonics[1,2].

[1] J.Stokes, P.Bassindale, J.W.Munns, Y.Yu, G.S.Hilton, J.R.Pugh, A.Yang,Z.H.Yuan,A.Collins, P.J.Heard, R.Oulton, A. Sarua, M.Kuball, A.J.Orr-Ewing and M.J. Cryan, "Direct Measurement of the Radiation Pattern of a Nanoantenna Dipole Array", European Conference on Integrated Optics, ECIO 2012, Barcelona, Spain April 2012 (PostDeadline Paper)

[2] G. R. Nash, J. L. Stokes, J. R. Pugh, and S. J. B. Przeslak, P. J. Heard, J. G. Rarity and M. J. Cryan "Single Lateral Mode Mid-Infrared Laser Diode using Sub-Wavelength Modulation of the Facet Reflectivity", Appl. Phys. Lett. 100, 011103 (Jan 2012)

Integrated Laser Induced Fluorescence System Using Photonic Crystal Cavities (CrystaLIFe)

This project (now completed) was a 3 year EPSRC grant (EP/G011664/1) which developed photonic crystal cavities for enhancing the emission from fluorescently tagged molecules which can dramatically enhance the sensitivity and reduce the analyte volume in lab-on-a-chip biosensors[1-3]

[1] N.A. Hueting, E. Engin, A.Md Zain, A. Sarua, P.J. Heard, M.Kuball, T. Wang and M.J. Cryan, "A Gallium Nitride Distributed Bragg Reflector Cavity for Integrated Photonics Applications", CLEO US, San Jose, USA, May 2012

[2] Y. Zhang, L. McKnight, E. Engin, Ian M Watson, M.J.Cryan, E.Gu, M.Thompson, S.Calvez, J.L. O'Brien, and M. D. Dawson, "GaN directional couplers for integrated quantum photonics", Applied Physics Letters, Appl. Phys. Lett. 99, 161119 Oct 2011

[3] E. Engin, J.L. O'Brien and M.J.Cryan, "Design and Analysis of a Gallium Nitride-on-Sapphire Tunable Photonic Crystal Directional Coupler", J. Optical Society of America B, Vol. 29, No. 5 May 2012

2.6 Brunel University

2.6.1 Centre for Electronic Systems Research (CESR)

Director: Professor Wamadeva Balachandran (Bala)

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Keywords highlighting areas of interest and expertise of group: Bio-chip, DNA, microfluidics, neural network, lab-on-a-chip, point-of-care, lateral flow

Biosensor/Biosensing Research Capabilities

The scientific objective of the Centre for Electronic Systems Research (CESR) is to investigate underpinning scientific fundamentals necessary to develop algorithms and measurement techniques to implement intelligent sensors and electronic systems capable of efficient control and operations of industrial processes and health care systems.

Research interests focus on the interface with the real world and involve areas such as bio-naotechnology (Lab-on-a-Chip for point-of-care-diagnostics), GNSS and wireless technologies based LBS systems for blind navigation, biometrics, use of ultrasonic and electromagnetic acoustic guided wave for NDT, fundamentals of charge particle dynamics, measurement systems for pharmaceutical drug aerosol characterisation, medical electronics, pattern recognition, image processing, theory and application of neural networks, evolutionary hardware, and human factors in product and system design . We investigate processes and mechanisms found in nature to inspire alternative approaches to the design and implementation of intelligent electronic systems.

Biosensor/Biosensing Related Research Projects

- The ongoing research in bio-nanotechnology is focused on the development of a fully integrated micromachined microfluidic device for point-of-care diagnostics (collaboration with St. George's Medical School and LGC)

- Development of a POCT device for HBA1c using multiple biomarkers
- Development of lateral flow devices for POCT using paper microfluics and printed electronics
- Development of a POT device for haemochromatosis (collaboration with Kings College)
- Artificial intelligent techniques are employed in modelling of DNA mismatch repair expression and microsatellite instability in transitional cell carcinoma of the bladder and to improve the accuracy of the bladder cancer prediction
- Nanotechnology based fingerprint sensor with liveness detection based on sweat pore activity is being developed to improve authentication to achieve desired FAR and FRR
- Development of an optical measurement system for bipolar charge measurement of pharmaceutical aerosols (close collaboration with Pfizer)

2.6.2 Brunel Institute for Bioengineering (BIB)

Director: Prof. Peter Brett

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Keywords highlighting areas of interest and expertise of group: Robotics, smart surgical tools, soft tissues, flexible tissues, implantable biosensors, amperometry, electrochemistry, glucose biosensors nano-structured materials membranes lab-on-chip, enzymes

Prof Peter Brett, Dr Xinli Du

Biosensor/Biosensing Research Capabilities

Peter Brett and Xinli Du have leading research experience in robotics for surgery and cellular processing, and smart sensing in biomedical applications. The work on robotic surgery commenced in 1989, and has focused on the real time control of tools in tissues to control interaction, behaviour and state. The novel techniques have been demonstrated successfully in the operating room and work in real time, sensing tool progress relative to flexible, deforming and soft tissues. The techniques are an efficient means for sensing and requiring few sensing elements in contrast to the number of outputs. Controlling the interaction between tools and tissues enable cutting relative to tissue position in real time to achieve unprecedented accuracy in flexible tissues. The approach also is adaptable to disturbances induced by the user such that the micro-robotic tools demonstrated in the operating room can be deployed by hand while maintaining precise results. The new distributive approach to sensing has also been demonstrated successfully in a range of applications from discriminating human motion and behaviour through tactile sense to discriminating contacting conditions on steerable endoscopes and catheters, to discriminating cells and in other defence related applications.

The research has been funded by the European Union, EPSRC, BHF, industry and by the MoD.

Biosensor/Biosensing Related Research Projects

- Smart Robotic Surgical Tools
- Micro-drilling robots in Surgery
- Steerable Digits with Touch-Sense
- Smart Monitoring Sensing Surfaces in Medicine for discriminating patient motion and response.

Dr Krishna Burugapalli

Biosensor/Biosensing Research Capabilities

Current focus for Krishna's biosensor research is on making implantable biosensors function reliably in the body for a long time through miniaturization of sensors; use of electrospun biocompatibility and mass-transport limiting coatings; reproducible manufacture of miniature enzymatic biosensors; and development of Lab-on-Chip device for multiple biomarkers for rapid diagnosis and monitoring, especially for diabetes. Pre-clinical functional efficacy and biocompatibility testing of implantable biosensors and other biomedical devices in small animal models, is another key aspect of Krishna's research.

Biosensor/Biosensing Related Research Projects

- Understanding and favourably modifying biosensor - tissue Interactions
- Electrospun nano-fibrous tissue engineering and mass-transport limiting membranes for implantable biosensors
- Miniaturization of biosensors, through use of nanomaterials including CNT fibres, and metal nanoparticles
- Reproducible manufacture of miniature enzymatic biosensors
- Label-free sensing using SPR and SERS for multiplex Lab-on-Chip device

2.6.3 Wolfson Centre for Materials Processing

Director: Prof Jack Silver

Key Contacts:

Dr Wenhui Song	(T) 01895 266123	Email: wenhui.song@brunel.ac.uk
Prof Asim Ray	(T) 01895 267794	Email: asim.ray@brunel.ac.uk
Dr George Fern	(T) 01895 265628	Email: george.fern@brunel.ac.uk

Keywords highlighting areas of interest and expertise of group: nanomaterials, nanoparticles, functional polymers, molecular imprinted polymers, membranes, carbon nanotubes, surface plasmon based sensors, microarrays

Biosensor/Biosensing Research Capabilities

The Wolfson Centre for Materials Processing has extensive expertise in the synthesis and processing of a wide range of materials from polymers, polymer composites, organics, inorganics, phosphors, and ceramics to a range of soft solids for biomedical (diagnostics, imaging and pharmaceutical), personal care products, packaging, environmental, energy, display and lighting industries. The centre has access to the wide range of physical testing, micro structural and chemical characterization facilities necessary for this project, including optical/electron microscopes (FESEM and TEM), AFM, XRD, EDX, XPS, SIMS, Raman, FTIR, UV-Vis-NIR, DSC, DMA,TGA, nano indentation, a range of spectrometers and photometers for

the measurement of light emission.

Dr Wenhui Song

Dr. Song's research interests include both fundamentals and applications of nanomaterials, functional polymers and their composites. She has developed a strong interest in self-organising materials including carbon nanotubes, liquid crystalline polymers, conjugated polymers and biopolymers. Her group's research activities have extended in development of carbon nanomaterial electrodes for biosensing and bio-energy storage, processing nanostructured polymer membranes for biosensor coating and tissue scaffold, and processing biopolymer micro/nano-particles for drug delivery and diagnostics.

Biosensors/Biosensing Related Research Projects:

- Carbon nanotubes and their micro-fibre based biosensors and bio-fuel cells.
- Electrospun biopolymer nanofibre membrane for coatings of orthopaedic implants, implantable sensors and devices.
- Controlled process of biopolymeric micro-/nano particles and capsules for drug delivery, diagnostics.
- Coatings of nanostructured conjugated polymers and carbon nanotube composites thin films by electrochemical deposition, electrophoresis and layer-by-layer self-assembling for biosensors and bio-fuel cells.
- Block-copolymers and their blends for pressure sensitive adhesives for medical and personal care products

Selected publications:

- Z. Zhu, W. Song, K. Burugapalli, F. Moussy, Y. Li and Xiao-Hua Zhong, Carbon Nanotube Fibre Based Enzymatic Glucose Biosensor, Nanotechnology, 2010, 21 165501.
- W. Song, I. Kinloch and A.H. Windle, Liquid Crystallinity of Multiwall Carbon nanotubes, Science, 2003, 302, 1363.
- W. Song, X. Fan, A. H. Windle, S. Chen and R. Qian, Elastic-Constant Anisotropy and Disclination Interaction in the Nematic Polymers, I. Apparent Variation in Anisotropy, Liquid Crystals, 2003, 30(7),765.
- W. Song, H. Tu, G. Goldbeck-Wood and A. H. Windle, Elastic-Constant Anisotropy and Disclination Interaction in the Nematic Polymers, II. Effect of Disclination Interaction, Liquid Crystals, 2003, 30(7), pp.775-784
- W. Song, A.H. Windle, Isotropic-Nematic Phase Transition of Dispersions of Multiwall Carbon Nanotubes, Macromolecules, 2005, 38, 6181.
- W. Song, H. Tu, G. Goldbeck-Wood and A. H. Windle, Effect of Elastic Anisotropy on Disclination Interaction of Nematic Polymers, the Journal of Physical Chemistry, 2005, 109(41), 19234.
- X. Zhang, J. Zhang, W. Song, Zhongfan Liu, Controllable Synthesis of Conducting Polypyrrole Nanostructures, the Journal of Physical Chemistry, 2006, 110(3), 1158.
- X. Zhang, W. Song, P. Harris, G. Mitchell, T. Bui, and A. Drake, Chiral Polymer Carbon Nanotube Composite Nanofibres, Advanced Materials, 2007, 19, 1079.
- X. Zhang and W. Song, P. Harris, G. Mitchell, Electrodeposition of Chiral Polymer Carbon nanotube Composite Films, ChemPhysChem, 2007, 8, 1766.
- W. Song and A.H Windle, Size-Effect and Elasticity of Liquid Crystalline Microstructure of Multiwall Carbon Nanotubes, Advanced Materials, 2008, 20, 3149.

Prof Asim Ray / Dr George Fern

Deposition techniques include; spin-coating, polyelectrolyte self-assembly (PESA), a variety of printing techniques and sol-gel processing which are used in our laboratories for thin film deposition of physically interesting organic and inorganic materials/molecules. The technology of composite films as membranes for chemical and bio-sensors has been developed over the last few years and the design of optoelectronics for chemical and biosensors and sensor arrays has become one of the main directions of our research.

The group has also worked on both ATR and interferometer techniques for environmental and bio-sensing. A motion free, wavelength selective imaging surface plasmon resonance system has been developed. This is designed to visualise the broader metabolically driven and cytoskeletal charges of surface captured cells in response to stimuli creating a broadly applicable screening tool for optimisation of a wide range of bioprocesses. Cell surface contact charges can be monitored simultaneously for a (heterogeneous) population of surface adherent cells. When a response to a pre-selected external stimulus (e.g. enzyme substrate) is registered by a specific cell sub-group at the surface, then that cell group provides a preselected panel for further optimisation for a particular receptor or enzyme cascade. The system has application in the discovery of environments conducive to a diverse range of bioprocessing and the robustness will lend itself to integration with the bioprocesses for feedback control and bio-optimisation.

Biosensor systems have been developed that detect biological materials and organic compounds in drinking water. Minimal maintenance requirements are maintained for commercially viable replacement of current environmental sensor practices. The desired limit of detection has also been improved by three orders of magnitude over most existing technologies for our applications. Specifically the miniaturised device consists of a stacked planar waveguide, the top surface of which is coated with spun host polymeric membranes containing Molecular Imprinted Polymers (MIPs). The integration of two diverse technologies, stacked silicon dioxide/silicon nitride waveguide and bio-organic thin film yields an enhanced sensitivity, reliable and robust product. The science developed during our research projects has been used for detection of pesticides, biological agents and insecticides at ppb levels in water and has potential for adaptation to probe bio warfare and infectious agents.

Biosensor/Biosensing Related Research Projects

- A grant from the European Office of Aerospace Research and Development, USA on wearable electronics (2008-2011).

Recent Publications

- Pal, C. Cammidge A.N., Cook M. J, Sosa-Sanchez, J. L., Sharma A. K, . and Ray, A.K. 2012 In situ chemichromic studies of interactions between a lutetium bis-octaalkyl substituted phthalocyanine and selected biological cofactors. Journal of the Royal Society Interface 9(66) 183-189. DOI: 10.1098/rsif.2010.0726
- Paul, S., Paul, D., Fern, G. R. and Ray, A.K. 2011 Surface plasmon resonance imaging detection of silver nanoparticles tagged immunoglobin. Journal of the Royal Society Interface 8(61) 1204-1211 Doi:10.1098/rsif.2010.0747.
- Paul, S., Vadgama P. and A.K. Ray 2009 Surface Plasmon Resonance Imaging for Biosensing. IET Nanobiotechnology 3(3),71–80 doi:10.1049/iet-nbt.2008.0012.
- Paul, S., Paul, D., Basova T and A.K. Ray 2010 Characterization of protein adsorbtion on different liquid crystal phthalocyanine thin films IET Nanobiotechnology 4(1) 1–9 doi:10.1049/iet-nbt.2009.0011
- Pradhan B., Sharma A. K. and Ray A.K., 2009 Nanoscale films of organic dyes for broadband environmental sensing J. Materials Sci. Materials in Electronics (DOI: 1007/s10854-008-9718-x) 20(3), 267-271.

- Basova, T., Paul, S., Paul D., Vadgama P., Gürek, A.G., Ahsen V and A.K. Ray, 2008 Liquid crystalline phthalocyanine thin films as nanoscale substrates for protein adsorption Journal of Bionanoscience 2, 114–118.
- Basova, T., Jushina, I., Gürek, A.G., Ahsen V. and Ray, A.K. 2008 Use of the electrochromic behaviour of lanthanide phthalocyanine films for nicotinamide adenine dinucleotide detection. *Journal of the Royal Society Interface* 5(24), 801-806 (DOI:10.1098/rsif.2007.1241)
- Chaure S; Paul, D; Vadagma, P. and Ray, AK 2010 Spectroscopic investigation of sulfonate phthalocyanine to probe enzyme reactions for heavy metals detection Journal of Hazardous Materials, 173(1-3) 253-257

2.7 University of Cambridge

2.7.1 Institute of Biotechnology

Director: Professor C.R.Lowe

Key Contacts:

Prof. C.R. Lowe	Email: crl1@biotech.cam.ac.uk
Prof. E.A.H. Hall	Email: lisa.hall@biotech.cam.ac.uk

Keywords highlighting areas of interest and expertise of group: holographic biosensors, nanoacoustic sensor, amperometry, antibodies, bacterial biosensors, DNA, electrochemistry, enzymes, FRET sensors, glucose biosensors, immunoassays, ion channel based sensors, membranes, microarrays, microbial biosensors, micro/nano spheres, nanoparticles, potentiometry, surface plasmon based sensors, whole cell biosensors

Biosensor/Biosensing Research Capabilities

Professor C.R. Lowe

Prof. Lowe's current research interests include: Enzyme and microbial technology; affinity chromatography; biopharmaceuticals; optical, acoustic and microengineered sensors; sensors for chemical agents and pathogenic organisms; diagnostics and therapeutics for neuropsychiatric disorders. The research group has been heavily committed to promoting the imaginative combination of biological science with chemistry, electronics and materials science for the development of novel biosensors and diagnostics for over 3 decades.

Much of the groups' more recent activities have been directed towards the development of new technologies applicable to sensors that may be applied in an "alternate site" format such as the ward, outpatients, surgery, home, field, battlefield and workplace. Thus, the group has pioneered a number of developments in biosensor technology, including a variety of new transducer concepts based on electrical, optical, acoustic and microengineered systems and a library of underpinning technologies designed to immobilise, spatially arrange and orientate biological molecules on transducer surfaces. This combination of new transducer and underpinning technologies, with financial support from the BBSRC, EPSRC and many other organisations, has led to tangible deliverables, including the formation of five new companies, Affinity Sensors Ltd, Cambridge Sensors Ltd, Smart Holograms Ltd, Paramata Ltd and Rebha Ltd.

Biosensor/Biosensing Related Research Projects

Current work is devoted to assessing various acoustic, plasmon resonance, holographic and microengineered sensors for monitoring low molecular weight analytes, proteins, DNA and whole cells. Key projects include:

- Development of holographic (bio)sensors for chemical agents and spore forming pathogenic organisms for detecting bioterrorism agents
- Fundamental studies on spore germination and its application to detection and decontamination
- Real-time holographic glucose biosensors for monitoring tear fluid
- “Virtual” instruments
- Holographic optical elements and their applications
- Other grating systems
- Magnetic acoustic resonator sensor
- Intrinsic sensing materials
- Nanoacoustic sensors
- Micro-NMR
- Micro-SPR

These programmes are being directed at both the development of sensor technology per se and for the introduction of diagnostics for diabetes, neuropsychiatric disorders, particularly schizophrenia and bipolar disorder, and pathogen-related infections, with a keen eye to clinical translation.

Professor E.A.H. Hall

Prof. Hall leads Cambridge Analytical Biotechnology (CAB). Research in the CAB Group links transduction technologies (electrochemistry, optics, ultrasound) with synthetic biology and nanomaterials to achieve sensors & diagnostic systems.

“Understanding of how biology can be interfaced with electronic, mechanical and optical systems and the development of new instrumentation or techniques to answer fundamental and applied questions concerning new biological measurement regimes” is a priority for research to provide new biofunctional materials and conquer challenges concerned with analysis, diagnosis, bioelectronics and smart drug or reagent delivery.

Prof Hall is recipient of the 2006 Gold Medal from the Royal Society of Chemistry for innovation and leadership in Analytical Science. She is a key driver in Analytical Biotechnology in Cambridge and in facilitation of new interdisciplinary science. As Director of the CAM^{bridge}SENS initiative she is active in investigating opportunities for extending the pillars that connect sensor activities in Cambridge to environmental monitoring and clinical management of disease.

Prof. Hall’s current research programmes:

- Biosensor protein engineering and synthetic biology: novel protein manipulation for analysis. From particulate proteins to redox protein mutants to binding proteins.
- ANSors (analytical nanosphere sensors): spatial and temporal resolution aimed at intracellular measurements and 2-D and 3-D structure assemblies.
- Bioactive ANSors: immunoassay to DNA
- Surface plasmon resonance: wavelength and angle scanning formats for bioassay. Design tools for instrumentation and material design.

- Electrochemically active polymers
- Ion Selective electrodes and optodes
- Synzyme-like ligands for biosensors

Biosensor/Biosensing Related Research Projects

The group has a world-class reputation for its lead in fundamental innovative research. It is also pro-active in responding to and advising industry of existing capability and future direction. Industrially sponsored research is organised in a truly collaborative format, with active input from all partners and 2-way exchange of expertise, intellectual and commercial invention and development. Applications are highlighted by almost every initiative for health, environment, energy, security and quality of life in all parts of the developing and developed world. Analytical Biotechnology is key to future innovation in this field.

2.7.2 Department of Engineering, Engineering for the Life Sciences

Head: Professor Keith Glover

Key Contact:

Dr Ashwin Seshia (T) 01223 332755 Email: aas41@eng.cam.ac.uk

Keywords highlighting areas of interest and expertise of group: micro cantilevers

Biosensor/Biosensing research capabilities

Development of micromechanical cantilever biosensor technology and its applications in the Life Sciences. This work is being carried out in conjunction with the Biochemistry and Chemistry departments, as well as the IRC for Nanotechnology

2.7.3 Polysilicon TFT Group

Key Contact;

Prof Piero Migliorato (T) 01223 748302 Email: pm128@cam.ac.uk

Keywords highlighting areas of interest and expertise of group: Polysilicon, thin film transistors, micro arrays, enzymes, ion sensitive FETs, monolayers, electrochemistry, DNA, protein, label-free detection

Biosensor/Biosensing research capabilities

The work of the Polysilicon TFT Group has concentrated in the past on the physics and modelling of polycrystalline silicon thin film transistors for various applications, including displays and memories. More recently the Group's activities have expanded to include a new approach to biosensor micro-arrays, exploiting the advantages of thin film transistors and other aspects of biosensing technologies. The Group is involved in UK and European collaboration programmes on biosensors.

Biosensor/Biosensing related research projects

1 - Ion Sensitive Field Effect Transistors (ISFETs)

- pH sensors
- Enzyme-based sensors

2 - Field Effect Devices for Label-Free Detection of Biomolecular Interactions

- DNA hybridization
- Protein interactions

3 – Electroactive Self Assembled Monolayers

4 - Modelling and Simulation of Electrochemical Biosensors

2.8 Cardiff University

School of Physics and Astronomy - Head of School: Prof Walter K Gear

School of Biosciences - Head of School: Prof Ole Petersen

Key Contacts:

Prof. Wolfgang Langbein	(T) 029 208 70172	Email: LangbeinWW@cardiff.ac.uk
Prof. Paola Borri	(T) 029 208 79356	Email: BorriP@cardiff.ac.uk

Keywords highlighting areas of interest and expertise of group: microsphere sensors, photonic biosensors, FRET sensors, plasmonic biosensors, nanoparticles, whispering gallery mode sensor, immunosensors

Biosensor/Biosensing Research Capabilities

The research group Biophotonics & Quantum Optoelectronics was established in September 2004. It is headed by Prof. Wolfgang Langbein (School of Physics and Astronomy) and Prof. Paola Borri (School of Biosciences). The group's main expertise is in ultrafast non-linear spectroscopy. Areas of research relevant to biosensors and biosensing are microsphere sensors, fluorescence resonant energy transfer, and plasmonic biosensors.

Biosensor/Biosensing Related Research Projects

Optical Biosensor based on Whispering Gallery Mode Technology. A highly sensitive prototype sensor was developed, where a polystyrene microsphere is used as an optical probe of the surrounding refractive index. The technique exploits the very sharp optical resonances exhibited by the microsphere, so-called whispering gallery resonances. Its sensitivity competes with that of state-of-the-art Surface Plasmon Resonance techniques. The detection can be made bio-selective by suitable surface treatment.

http://www.astro.cardiff.ac.uk/research/pm/researchareas/?page=whisper

Time-resolved fluorescence resonance energy transfer (TR-FRET) as a probe of biomolecular interactions. A method to measure binding affinities of biomolecules has been developed and patented (European patent WO2007057644 (A2)) by Prof. Trevor Dale (School of Biosciences) in collaboration with Prof. Adrian Harwood and Prof. Paola Borri. In the technique two biomolecules are anchored near each other using variable length tethers to create a nano-scale reaction chamber. Nano to micromolar concentrations can be generated using attomoles of biomolecules. The proportions of bound and free biomolecules are measured using TR-FRET over a range of concentrations / tether lengths, allowing binding affinities to be determined. The technique is compatible with a high throughput format and requires lower quantities of biomolecules for

more rapid assays at lower cost.

Optical detection of single metallic nanoparticles and sensitivity to surface Plasmon resonant shifts. A novel method to detect single small (<40nm) metallic nanoparticle has been developed which is background-free even in highly scattering environments and operates at power corresponding to negligible average photo thermal heating, hence is compatible with cell imaging and sensing applications.

Research funding bodies include DSTL, BBSRC, MRC, DTI, EPSRC.

2.9 Cranfield University, School of Health

Key Contacts:

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Dr Jeff Newman	(T) 01234 758341	Email: j.d.newman@cranfield.ac.uk
Prof. Dave Cullen	(T) 01234 758340	Email: d.cullen@cranfield.ac.uk
Prof. Leon Terry	(T) 07500 766490	Email: l.a.terry@cranfield.ac.uk

Keywords highlighting areas of interest and expertise of group: amperometry, antibodies, DNA, electrochemistry, enzymes, glucose biosensors, membranes, microfluidics, molecular imprinted polymers, nanomaterials, piezoelectric sensors, potentiometry, quartz crystal microbalances,

Biosensor/Biosensing Research Capabilities

Cranfield Health has capabilities and expertise in biosensors for medical (diagnostics and pharmaceutical), food, environmental, defence, process industry and space applications. Technologies include: Electrochemistry (amperometry, coulometry, impedimetric methods, potentiometry); Fabrication (including thick-film processes, thin film technologies, micro and nano-deposition of fluids, micro-laser fabrication, sonochemical ablation); Optical techniques (various evanescent field methods including surface plasmon resonance); Piezoelectric methods; Natural and synthetic receptors (enzymes, antibodies, DNA, molecular imprinted polymers (MIP) and many others); Microarrays; Bioinformatics; Instrument design and prototyping; Microfluidics (active and passive systems); Flow-injection analysis; Membranes; Scanning probe microscopy.

Biosensor/Biosensing Related Research Projects

Dr Ibtisam E. Tothill

Research in sensors and diagnostics covers developments of a range of medical, food and environmental sensors using different types of transducers and sensing materials. This includes micro/nanoarray sensors and the use of nanomaterials for signal enhancing and lab on a bead technology. Examples of recent research:

- SPR & QCM based sensors for protein and DNA based biomarkers, for disease detection (cancer, cardiovascular

disease markers, Microbial infections), contaminants and biotoxins.

- Electrochemical Biosensors for medical, food and environmental applications.
- Microarray sensors for mycotoxins analysis.
- Developments of synthetic/artificial receptors for diagnostics and sensors applications.
- Nanomaterials and nanosensor arrays.
- Chemical sensors for heavy metal ions analysis.

Prof. Seamus Higson

- Design and fabrication of micro-electrode arrays for applications ranging from DNA analysis, (including genomic and proteomic applications), through to enzymatic biosensors and electro- analytical chemical sensors. Fabrication routes involve, for example, electrochemical polymerisation techniques, screen printing technology and sonochemical ablation approaches. Sonochemistry finds further application for the study and exploitation for mass transport phenomena and the enhancement of both inorganic and enzymatic catalysis.
- Production, harvesting and exploitation of recombinant enzymes and their exploitation for bio-analytical systems.
- Exploitation of ultra-thin polymer film coating technologies – and ultra-thin film composite membranes.
- Production of electrochemical antibody based biosensors for a wide range of analytes ranging from biomedical markers through to environmental pollutants.
- Study of transduction interrogation regimes and the development of simplified chromatographic based enzyme assays.

Dr Jeff Newman

- Microfluidic biosensor systems using laminar flow liquid membranes
- Biosensor stabilisation
- Rapid methods for assessing toxicity
- Sensor / instrument integration strategies

Prof. David Cullen

- Biosensors and bio-analytical systems for life detection and characterisation in extreme and remote environments
- Example: developing the Life Marker Chip experiment / instrument for the European Space Agency's ExoMars mission
- Example: developing in situ Life detection instrumentation for subglacial environments including as part of the consortium planning to explore Antarctic Subglacial Lake Ellsworth
- Developing technology transfer applications of Life detection technology into medical, environmental and security and defence applications.

Dr Leon Terry

Research on developing sensors and diagnostics for fresh produce. Examples of recent research:

- Development of first biosensor for onion pungency under Defra HortLink HL0164
- Development of multi-analyte biosensor(s) for improved quality control of fruit (HDC CP_43)

2.10 University of Edinburgh

The University has significant capabilities and research expertise in biosensors and biosensing, which are listed by school below, detailing the relevant facilities, research studies and principal investigators. In addition, there is a strong track record of collaboration within Edinburgh to address multidisciplinary biosensing research programmes, typically involving researchers from several schools.

Key Multidisciplinary Contact:

Dr Andrew Mount (T) 0131 6504747 Email: A.Mount@ed.ac.uk

2.10.1 School of Biological Sciences

Head of School: Prof David Leach

Key Contact:

Prof Judi Allen (T) 131 650 7014 Email: SBS.ResearchDirector@ed.ac.uk

Keywords highlighting areas of interest and expertise of group: whole cell biosensors, synthetic biology, DNA, arsenic biosensor, genetically modified bacteria.

Biosensor/Biosensing Research Capabilities

Synthetic Biology Research – the Synthetic Biology group has capabilities of rapid genetic modification and DNA assembly suited to the development and testing of genetically-modified whole-cell biosensors. Through our collaborations with other research groups in the School of Biological Sciences and School of Engineering, we have access to advanced analytical and imaging equipment which can be used to interrogate such devices. Our collaborations via SynthSys (Centre for Synthetic and Systems Biology, Edinburgh) with researchers in the School of Informatics also allow us to develop mathematical models useful in the design and simulation of such systems.

Biosensor/Biosensing Related Research Projects

Whole cell biosensors for detection of heavy metals in the environment (Dr Chris French, Dr David Radford) – This project involves the development of whole-cell biosensors (bioreporters) for the detection of heavy metals and other pollutants in the environment, including:

- Development of a novel biosensor for the detection of arsenic compounds in groundwater. This is a major public health issue in Bangladesh, West Bengal, Nepal and other regions, with tens of millions believed to be at risk. Our system consists of genetically modified bacteria which can be stored and distributed in dry form. On exposure to water containing arsenate or arsenite, a pH change is generated, which can easily be detected visually, or quantified using cheap and simple equipment;
- Development of a visual monitoring system based on a web-cam and open source software, which can perform a

large number of assays simultaneously. Collaborators at Harvard University and Rhode Island School of Design are seeking funding to move this device toward the market;

- Development of a second-generation arsenic biosensor for field use. This project also involves development of a disposable plastic device to incorporate the genetically modified cells, as well as investigation of the legal issues associated with use of genetically modified cells for biosensing in the field. We have also developed devices for detection of copper, zinc, and other heavy metals, and are interested in applications of whole cell biosensors for monitoring biomarkers of human health.

2.10.2 School of Biomedical Sciences

Head of School: Prof Gareth Leng

Key Contact: Dr Till Bachmann (T) 0131 242 9438 Email: till.bachmann@ed.ac.uk

Keywords highlighting areas of interest and expertise of group: point of care, microarrays, DNA, immunoassays, electrochemical, biochip, multiparametric detection technologies

Biosensor/Biosensing Research Capabilities

The Division of Pathway Medicine (DPM) – The DPM has fully equipped Containment Level 2 (opt. access to Level 3) laboratories for molecular research involving cell culture, viral and bacterial pathogens, and parasites. Instrumental capabilities range from a microarray facility including a variety of spotters, laser scanners, robotic capabilities for genomics, transcriptomics and proteomics and a series of potentiostats for electrochemical research and biosensor development. DPM has strong informatics capabilities including SPRINT (Simple Parallel R INTerface), a framework that provides an easy access to high performance computing for the analysis of high throughput post genomic data using the statistical programming language R. We have access to SynthSys' Kinetic Parameter Facility and Systems Biology Software Infrastructure, and strong clinical links and collaboration with NHS partners (e.g. NHS Lothian). Dr Bachmann is a member of the steering group of the ESP KTN's Biosensing Group.

Biosensor/Biosensing Related Research Projects

Division of Pathway Medicine Research (Prof Peter Ghazal, Dr Till Bachmann) – DPM research falls into two main areas: Biochip Medicine and Host-Pathogen Biology. The Division explores how biochips can best be used for clinical research and profiling of viral and microbial pathogens and host response to infection as well as Global Health. DPM targets next generation in vitro diagnostics for point of care, global health and personalised medicine through the development of companion diagnostics. Our research fields include biochip research, rapid molecular diagnostics of infectious diseases with multiparametric detection technologies, immuno and DNA sensors and the development of label-free electrochemical diagnostic tests. We have considerable experience and expertise in the development and clinical evaluation of microarrays for rapid identification of bacterial species, genotyping of antibiotic resistance and in the analysis of systemic host response to infection by examination of whole blood transcriptional profiles. In several major projects DPM has collaborated with other UoE centres (Schools of Chemistry, Physics and Engineering) to develop biosensor platform technology and chronic wound care biosensing systems, innovative, nanoswitch label-free detection technology and Fluorescence Lifetime based Assays for Sensors and Healthcare (FLASH). The DPM has a strong translational focus which includes its biosensor programmes including industrial collaborations with Axis Shield Diagnostics, Zisys, Renishaw Diagnostics, Mologic, Smiths Detection Diagnostics (feasibility study for rapid antibiotic resistance detection in the Technology Strategy

Board's Detection and Identification of Infectious Agents (DIIA) Innovation Platform) as well as DPM spin out companies (Lab901 (now Agilent)).Global Health (Prof Sue Welburn, Dr Kim Picozzi) – DPM is involved in the monitoring and evaluation of a number of international disease control programmes - using high throughput molecular analysis for the detection of livestock and zoonotic pathogens.

2.10.3 School of Chemistry

Head of School: Prof Eleanor Campbell

Key Contact: Dr Andrew Mount (T) 0131 6504747 Email: A.Mount@ed.ac.uk

Keywords highlighting areas of interest and expertise of group: electrochemistry, microarrays, DNA, cellular imaging, molecular switches, optical biosensors

Biosensor/Biosensing Research Capabilities

School of Chemistry Laboratories – The Electrochemistry Group laboratories have a wide variety of electrochemical testing and characterisation equipment, advanced electrode R&D and fabrication facilities, finite element modelling, theoretical analysis of electrochemical response, particularly impedance, bioelectrochemical cells, dry box and Schlenk lines, fluorescence, X-ray photoelectron spectroscopies. The Cellular Biosensing laboratories have facilities for in-house sensor design and fabrication. SERS sensors can be interrogated using the School of Chemistry's Raman microscopy facility. There are also facilities for tissue culture with controllable oxygen concentrations down to 0.1% in order to mimic hypoxic environments. Finally, the Biomedical and Cellular Imaging laboratories can provide access to flow cytometry, high-content, high resolution microscopy based screening, and microarray tools.

The Scottish Instrumentation and Resource Centre for Advanced Mass Spectrometry (SIRCAMS) is one of Europe's best equipped multi-user facilities for high field Fourier transform ion cyclotron resonance mass spectrometry. FT-ICR MS is the technique of choice for many biological problems due to its ultra-high resolution, mass measurement accuracy and high sensitivity, which in favourable cases can enable experiments to be carried out on samples containing as little as 100 molecules. The centre has three Bruker Daltonics FT-ICR MS instruments, equipped with a wide range of ionization sources. One of our main interests is structural determination of proteins, RNA, DNA, and protein complexes using top-down fragmentation techniques. With FT-ICR MS, specific ions can be isolated and trapped, permitting further experimentation such as fragmentation studies using IR lasers or electron capture dissociation (ECD).

Biosensor/Biosensing Related Research Projects

Electrochemical Biosensing (Dr Andrew Mount) – The Electrochemistry Group is interested in the production and characterization of selective redox-active or other high added value layers on metal electrode surfaces. These films have been designed for the interconversion of electronic and biological signals, enabling integration of semiconductor and microarray technology with biology. As part of substantial multidisciplinary projects, we have developing the use of DNA molecules as molecular switches, controlled by electronic and biochemical signals, for applications in genomic science and technology, and novel biosensing platforms for multiparameter disease diagnosis and therapeutic monitoring. Also of interest is development of fluorescence sensing, on its own and combined with electrochemical sensing.

Optical Biosensors (Dr Colin Campbell) – the School of Chemistry has world-leading expertise in sensor design. We have developed a range of sensors to detect multiplexed targets ranging from whole cells to specific nucleic acid targets and have carried out research on both optical and electrochemical transduction methods. We are actively researching nano-sensors for making intracellular measurements using Surface Enhanced Raman Spectroscopy (SERS). These sensors are ideally suited for studying processes related to oxidative stress and redox regulation of cellular physiology.

Biomedical and Cellular Imaging (Prof Mark Bradley) – Working extensively with clinicians in Edinburgh (Professor Chris Haslett and Dr Kev Dhaliwal at the Centre for Inflammation Research) we have developed "smart" optical imaging probes that have been designed to detect and report on debilitating or life threatening medical conditions, such as respiratory disease and cancer. Our first fluorescent reagents have progressed from the bench into human trials, validating our translational pathway and offering for the first time the ability to carry out real-time optical molecular imaging for clinical diagnosis at point of care. Regenerative medicine requires the ability to detect and then track implanted cells. We have developed a range of highly efficient, yet benign cellular labelling tools, that allow the highest levels of labelling possible, yet show no toxicity and been have demonstrated in the real-time tracking of cells. These reagents are being used in vivo for cell therapy applications allowing clinicians to image cells which have been applied and monitor the efficacy of application.

Radical Solutions for Researching the Proteome (Dr Pat Langridge-Smith, Dr David Dryden) – Along with the Universities of Glasgow, Dundee and Strathclyde, the University of Edinburgh has been heavily involved with the RC-UK funded Interdisciplinary Research Collaboration (IRColl) in Proteomic technologies (RASOR). This is a unique research programme to advance proteomics and its application in life sciences and biomedical research. The RASOR research programme is underpinned by the Doctoral Training Centre in Proteomic and Cell Technologies which trains an average of 10 students per year on a 4 year MRes/PhD programme in scientific areas interleaving with RASOR objectives, in the fields of proteomics, imaging and microfluidics, with a particular focus on a wide range of technologies in cell and molecular biology, microarrays, sensors, instrumentation and spectroscopy.

2.10.4 School of Engineering

Head of School: Prof Alan Murray

Key Contact: Prof Anthony Walton (T) 0131 6505620 Email: anthony.walton@ed.ac.uk

Keywords highlighting areas of interest and expertise of group: dielectrophoresis, microelectrode arrays, quantum dots, microfluidics

Biosensor/Biosensing Research Capabilities

Biomedical Imaging at the Centre for Biomedical Engineering at Edinburgh (CBEE) – A key capability at the CBEE is that of label-free imaging and spectroscopy techniques, which are non-destructive and non-invasive to biological samples. Techniques include Atomic Force Microscopy (AFM), Raman spectroscopy, and CARS microscopy. Our Raman spectrometer has a live cell chamber, and has been extensively applied to (bio)chemical characterization, offering label-free biomarkers. Our CARS microscope was the first in the UK applied to living cells, and we have applied AFM to quantitative measurements on living cells and small biomolecules. The system allows for combined AFM and CARS.

Scottish Microelectronics Centre (SMC) – The SMC is a world class centre for R&D in the semiconductor sector and provides a dynamic environment linking academia and hi-tech companies. The centre has a comprehensive microfabrication toolset giving it the capability to process samples from millimetre scale chips up to 200mm diameter wafers and has suc-

cessfully integrated microfluidics, biomedical and electrochemical sensors and engineered surfaces for bio-attachment, biocompatibility and hydrophobicity. The centre regularly supplies sensor devices for collaborative projects within the Schools of Engineering, Physics, Biological Sciences and Medicine at the University of Edinburgh, as well as a multitude of external research efforts both nationally and internationally.

Edinburgh Microfluidics Prototyping (EMP) – The EMP provides microfluidic systems for academic research. The EMP provides both advice and practical solutions to take a project all the way from the original device design through fabrication and on to final assembly of the device including packaging and external fluidic connections. Patterned microfluidic channels can be produced in PDMS and dry-film laminates, and the centre can also provide silicon masters for repeated mould fabrication.

Biosensor/Biosensing Related Research Projects

Dielectrophoresis [DEP] (Prof Ron Pethig) – This work is directed towards establishing electrokinetic, biomarker-free techniques to discriminate between distinct cellular identities in heterogeneous populations, including haemotopoietic stem cells, differentiated derivatives in blood, and mesenchymal stem cells in adipose tissue. To explore its potential for cell-based biosensors or drug discovery tools, we've used DEP to monitor changes in cell states associated with activation and clonal expansion, apoptosis, necrosis and responses to chemical and physical agents. Artificial engineering of different sizes and shapes of cellular aggregates has been accomplished using DEP forces, suggesting applications in the production of scaffolds to guide tissue development and for controlled drug release. In collaboration with the School of Physics we are applying DEP to manipulate ribosomal RNA and quantum dots for biosensor applications.

SMART Microsystems (Prof Anthony Walton, Dr Jonathan Terry) – this IeMRC Flagship project is researching the integration of CMOS technologies with novel materials and innovative process technologies. Within this initiative, we are examining novel microfluidic sensing and actuation, in particular looking at so-called digital microfluidics or the electrical manipulation of droplets, using techniques such as electrowetting on dielectric (EWOD) and surface acoustic waves (SAW) to move, split, mix and sense biological samples.

Electrical cell impedance sensing [ECIS] (Dr Pierre Bagnaninchi, Dr Stewart Smith) – This project involved the development of microelectrode arrays for monitoring and manipulation of adherent cells on surfaces. The arrays have been mainly aimed at production of stem cells for regenerative medicine where there is a need to monitor and screen cell colonies.

Real-Time Fluorescence Lifetime Imaging (Dr Robert Henderson) – as part of the EU FP6 Megaframe programme, this project uses single photon avalanche diodes (SPADs) to perform fast fluorescence lifetime imaging microscopy (FLIM). This allows for high accuracy time resolution, high sensitivity, low cost, compactness, and high-throughput with parallelism by exploiting low dark count CMOS SPAD arrays to replace photomultiplier tubes (PMTs).

METOXIA (Prof Anthony Walton, Prof Alan Murray) – is a large-scale Collaborative Project of the EU FP7 within the theme HEALTH. The project investigates the mechanisms activated by lack of oxygen in cancer tumours, leading to treatment resistance of the cancer as well as to the malignant selection taking place in the patient ending up in the fatal process of metastasis. The project involves development of new drugs, radiation strategies, micro-environmental sensors and biomarkers for patient diagnosis and stratification.

2.10.5 School of Physics

Head of School: Prof Arthur Trew

Key Contact: Prof Jason Crain (T) 0131 6505265 Email: jason.crain@ed.ac.uk

Keywords highlighting areas of interest and expertise of group: DNA, microfluidics, dielectrophoresis, live cell imaging, antibodies, quantum dots,

Biosensor/Biosensing Research Capabilities

Institute for Condensed Matter and Complex Systems (ICMCS) – Research in this area spans many length and time scales: from aqueous solutions of small bioactive molecules through proteins and DNA to single cells, cell-cell interactions, and collections of organisms in ecosystems, studying phenomena occurring at picoseconds to decades. We use all three primary methodologies of physics: experiment, simulation and theory. Wet labs designed for routine work at biological hazard containment level 1, and upgradeable by containment level 2, are available. Among the powerful resources accessed by our computer simulators and theorists is a 5 teraflop IBM BlueGene-L supercomputer hosted by EPCC.

The Collaborative Optical Spectroscopy, Micromanipulation and Imaging Centre (COSMIC) – is a unique research facility based around advanced laser sources, microscopes and detection systems to create new infrastructure for research particularly at the interface between the physical and life sciences. Capabilities related specifically to biosensing applications include a wide array of spectral imaging modalities, fluorescence lifetime imaging including those enabled with total internal reflection geometries compatible with array, microfluidic and dielectrophoresis measurements, and combined multi-photon and CARS imaging for live cell imaging.

Institute for Astronomy – detailed surveys of the heavens present serious challenges both in the collection of massive data sets and their subsequent processing to provide vital information and high quality images. We have developed fast powerful algorithms to enable this on a practical timescale, and applied these algorithms to improve medical imaging, particularly MRI modalities. This work resulted in a spin out company, Blackford Analysis Ltd, whose recent work has demonstrated the ability of this technology to pin-point small secondary cancers that are not detectable by conventional imaging.

Biosensor/Biosensing Related Research Projects

Molecular recognition in Cancer Biomarkers – in collaboration with Mologic (Alere Medical) we have developed a single assay platform for the detection of cancer biomarkers. In particular, the work has led to identification of the molecular origin of antibody selectivity between two protein fragments from human chorionic gonadotropin (one of the world's most frequently assayed hormones) and leutenizing hormone, which differ only by a single point mutation. Mologic are considering development of the single, high-fidelity epitope identified as a universal single-site hCG assay for e.g. cancer screening; this was recently featured in Drug Discovery World, the leading pharma development title.

Biomolecular Origin of Disease – Edinburgh and Oxford Universities are the only UK partners in a major EU funded UK/German National Laboratory collaboration, aimed at accelerated innovation to improve quality of life, and pan-European strategic measurement capability development for ESFRI Roadmaps and EC 2020 programs. Comprehensive low and high-resolution measurement science infrastructures will be built to relate molecular structure to biological function with applications in diagnostics, sensing and therapy. The scientific and technological methodologies developed by the consortium will be used to establish generic rules to enable sequence-to-function prediction of peptides in native molecular and cellular environments.

Quantum Dot Biosensing – we were the first to demonstrate that dye molecular fluorescence lifetime was a sensitive reporter of local microenvironment, generally independent of fluorophore concentration. This is a potentially powerful multiplexed biosensing detection modality with extremely low light level operation, long data acquisition periods and on-chip processing capability for typical biological analyte concentrations; we have shown in collaboration with Electrical Engineering that by using a CMOS-SPAD imager in conjunction with DNA microarrays and TIRF excitation geometry we can resolve dye-labelled HCV and quantum-dot-labelled HCMV nucleic acid targets at below 10 nM concentration in < 26 seconds. In related work solution state hybridization detection using time-resolved fluorescence anisotropy of quantum dot-DNA bioconjugates has also been demonstrated through changes in the rotational correlation time of QD–DNA constructs, opening a new modality for hybridization detection using quantum dots.

Biomolecular simulation – Molecular dynamics (MD) simulations offer powerful support to experimental programmes, providing complementary data to measurement methods for the rational design of new compounds and of surface binding interactions for improved diagnostics. This NPL/IBM funded simulation using Edinburgh high performance computing now permits direct exploration of energy landscapes, conformational bias and environmental influences e.g. solvent composition, proximity to membrane surfaces. In principle, such MD simulations can provide molecular process detail at full atomic resolution and can often give better insight into system properties than experiment, provided forces are accurately described and the sampling of configurations is sufficiently extensive. A good example is our research on HIV viral structure and its interactions with other proteins and membrane surfaces, which has attracted considerable media attention.

2.11 University of Exeter

Key Contact:

Charlotte Lane Email: c.lane@exeter.ac.uk

2.11.1 College of Life and Environmental Sciences

Head of College: Professor Mark Goodwin

Keywords highlighting areas of interest and expertise of group: lateral flow devices, fungal pathogens,

Biosensor/Biosensing Research Capabilities

Molecules and Cells

Principal areas of research in the Molecules and Cells research group are the mechanistic study of enzymes, proteins and protein complexes and developing novel insight into the development, organisation, and differentiation of eukaryotic cells. Activity within the research group includes the development of novel biosensing technology to rapidly screen biological materials. This screening technology includes approaches that will allow the concentrations of molecules in blood to be measured that may act as biomarkers of disease and extend the field of differential diagnosis.

Plant and Microbial Sciences Group

This research group is particularly interested in the mechanisms by which fungal pathogens can infect living host plants, invade their tissues, and cause disease. It founded the BBSRC Consortium for Genomics of Microbial Eukaryotes (COGEME) phytopathogen EST database and is collaborating in the e-fungi data warehouse project as part of the BBSRC

e-science initiative. Industry funded projects include the development of mAb-based lateral flow devices for the detection of plant pathogenic and beneficial fungi in biowaste compost. The tests are marketed through a spin-out company Eco Diagnostics Ltd.

2.11.2 College of Engineering, Mathematics and Physical Sciences

Dean of College: Professor Ken Evans

Keywords highlighting areas of interest and expertise of group: antibodies, bacterial biosensors, electrochemistry, enzymes, glucose biosensors, microarrays, photonic biosensors, surface plasmon based sensors, , biomedical imaging

Biosensor/Biosensing Research Capabilities

Biophysics Group

The Biophysics group focusses on understanding the behaviour of biological systems through a broad programme of interdisciplinary research. Research activities span studies of cell membrane through to cellular response to physical signals to integrative studies on touch perception. We have established expertise in magnetic resonance imaging, optical imaging and vibrational spectroscopy

Biosensor/Biosensing Related Research Projects

Prof. Peter Winlove is involved in the development of optical and electrochemical sensors for molecules of physiological or clinical interest. One current interest, in collaboration with Prof. Jenny Littlechild (School of Biosciences), is primarily in the application of the enzyme systems of thermophilic bacteria, which promise to be more resistant to denaturation that is a major problem in the construction of enzyme-based biosensors. They are also pursuing the possibility of engineering enzymes and support systems to obtain an optimum configuration in which the redox site is coupled to the electrode whilst the binding site remains accessible to the substrate. Research into developing fluorescence-lifetime and Raman techniques suitable for applications such as high throughput drug screening is also on-going.

Biomedical Electrochemistry

Electrochemistry has an established place in medical research and clinical monitoring through instruments such as the blood gas monitor and the “glucose pen” for diabetes monitoring. However, in vivo measurements using microelectrodes implanted into tissue have remained problematical. We have developed instrumentation and protocols for measuring tissue oxygenation and nutrient delivery in humans. These methods are now widely used in the UK and abroad and current projects include studies on the myocardium during coronary bypass surgery, on the degeneration of the intervertebral disc and cartilage and on wound healing. Ultra microelectrodes can also be used on cells and tissue cultures in vitro. They offer very high temporal resolution and, particularly in approaches such as scanning electrochemical microscopy, micron scale spatial resolution. We are currently working to exploit these advantages to study metabolism at the cellular level. We are also trying to develop new electrodes for short lived species such as free radicals and signal molecules that are important in many areas of pathophysiology. Finally, we are combining electrochemistry with SERS to investigate molecular mechanisms underlying the operation of the self-assembled monolayer/ enzyme electrode systems that are relatively well establishes in applications such as glucose sensing.

2D Attogram surface plasmon resonance imaging

A Basic Technology Project to provide high sensitivity, highly parallel bio-sensing capability (funded by RCUK). Key Con-

tacts - Dr Andrew Shaw, Professor Bill Barnes, Professor Roy Sambles

The pharmaceutical industry has identified a need to extend its HTS capacity three-fold to provide better quality target screening for drug discovery. This research aims to develop the technology required for a ten-fold increase in screening capacity and improve the quality of the data recovered from each investigation. But our new basic technology will do more than discover drugs, it will open a new way of doing research - data driven discovery - that will revolutionise fundamental biology, diagnosis and medical therapy using genomic and post-genomic bioinformatics.

Objectives

1. Develop the technology for a HTS 1024 x 1024 pixelated 2D-SPR imaged, bio-addressable array;
2. Develop the technology for a 2D CMOS imaging camera with 1GHz temporal resolution, with a 10 nW light level at each pixel;
3. Interrogate the fabricated array with evanescent wave cavity ring-down spectroscopy (e-CRDS), differential phase surface plasmon resonance (d-SPR) and fluorescence enhanced imaging (f-EI) in real time;
4. Fabricate gold surfaces with nanostructured architecture to produce localised plasmon enhancement sensitivity;
5. Apply the attogram ml^{-1} sensitivity to DNA array screening, for mutation detection and disease markers and pharmacokinetic data on protein - ligand binding;
6. Demonstrate a proof-of-principle combinatorial chemistry library screening.

Electromagnetic Materials Research Group: Plasmonics

Biosensor/Biosensing Research Capabilities

The research focus is on the interaction between light and matter, where the group has a particularly strong interest in the fundamental study of electromagnetic materials that incorporate structure from the nanometre to centimetre scale. The remarkable progress in plasmonics in the past few years, both in developing a new photonics, and in concentrating light into ever-smaller volumes, opens up even more opportunities for the future. In particular it opens the way to new approaches in controlling the optical properties of molecules, and in using optics to monitor molecules. At Exeter research in this field is focused on exploring the extent to which plasmonics can be used to control light, and in particular exploiting the unique attributes of plasmonics to develop new materials – and extending the concepts of plasmonics into other spectral regions, especially THz.

The Centre for Electromagnetic Materials Research (CEMR)

The CEMR at the University of Exeter is comprised of 9 academics and approximately 20 research fellows and postgraduate students working within the School of Physics and School of Engineering. We have a range of in-house-designed sensors that lock to, and thereby track, the position of an optical mode as it changes with time having sensitivity to a change in refractive index of 10^{-7} (or better). Different systems are available that are wavelength-tuneable, can be fibre-coupled, have a pixilated sensing head, can be compact, lightweight, cheap and / or employ electrochemically-controlled binding at the sensor head. These are leading to new biosensing techniques. A non-invasive detector for malaria is currently under development.

Advanced Technologies Research Institute

Building on earlier work at the Universities of Exeter and Coventry, Exeter academics have continued to develop the first new technique for diagnosing malaria able to challenge the rapid diagnostic tests (RDTs) currently used in the field. Early results, published in the Biophysical Journal, suggested that the technique could be as effective as RDTs but far faster and cheaper, making it a potentially viable alternative. The team has more recently been working on a non-invasive version of the device, which with the assistance of a team from the Royal Tropical Institute (KIT), Department of Biomedical Research in Amsterdam, it trialled in Kenya later in 2008. Since then the work has continued to be funded by the Bill & Melinda gates Foundation (2008 – 2010).

2.12 University of Glasgow, College of Science and Engineering

Head of College: Professor John Chapman

Key Contact: Lynne Brown (T) 0141 330 2731 Email: lynne.brown@glasgow.ac.uk

Keywords highlighting areas of interest and expertise of group: cell engineering, lab-on-a-chip, bionanotechnolgy, point of care, gene sequencing, diagnostic devices, sensor arrays, photonic chip, emergency medicine, biochemical markers, optoelectronic tweezers, nanowire biosensors, simulation tools, radiation imaging, medical imaging, imaging detectors, biomarkers

Biosensor/Biosensing Research Capabilities

The University of Glasgow has a long established strength in physical electronics based on world leading device fabrication facilities in the James Watt Nanofabrication Centre (JWNC). The activities within JWNC integrate theoretical and technological research which underpins many applications oriented projects in bioelectronics and biosensors.

Research into sensors and sensor systems is dynamic and calls for many different skills and areas of expertise to be brought to bear on user defined problems. At the University of Glasgow we have developed a 6 layer ‘stack’ model to describe the generic functional elements contained within sensor systems. It is comprehensive in its coverage of the technical challenges that we face in sensors research and knowledge transfer, whilst also showing clearly the interfaces between areas of expertise that are required. The stack seamlessly illustrates the flow from raw measurand data through to pre-processed information, to inform the end user decisions.

Biosensor/Biosensing Related Research Projects.

Advanced diagnostic systems - low cost, miniaturised sensor systems for biomedical applications.

Prof Jonathan Cooper - Jon.cooper@glasgow.ac.uk

The Advanced Medical Diagnostics research group was established over 20 years ago, and has a strong track record in many aspects of bioengineering, in particular; advanced biomedical diagnostics, biosensors, cell engineering, Lab-on-a-Chip and Bionanotechnology. The group is currently developing a series of low cost, miniaturised sensors. A key focus is the bottleneck of pre-processing prior to sensing. It can be complex and heterogeneous in nature, but also, the composition is highly variable as the mechanical properties and composition of e.g. blood, saliva, faeces change during the day, with age, with health/nutritional status and with activity/exercise. The research addresses developed world ‘point of care’ applications to reduce costs and provide convenient and easy to use tools for diagnostics and screening. It also addresses

developing world applications where it could dramatically impact on patient morbidity and mortality due to e.g. malaria, TB and pneumonia which account for 10s of millions of deaths per year.

Ion sensing

Prof David Cumming – david.cumming.2@glasgow.ac.uk

Genomic technology can be used not only for rapid screening of whole genomes of humans, but relative genomics and identifying the genome of bacteria and other infectious agents. Sequencing provides an exact picture of the building blocks which make up any individual, and the microorganisms that affect us; with this understanding treatment can be more targeted and effective. Utilising the ion sensitive field effect transistor we investigated single sensors, sensor system on chip with only a few sensors (but complex electronics) to demonstrate that standard microelectronics industry technology (CMOS) could be used to make reliable sensors and electronics on the same chip. We then progressed to sensor arrays. The work was identified as being a potential gene sequencing technology. The resulting Ion Torrent system is now sold by Life Technologies. Sequencing has the ability to provide new understanding that will impact upon agriculture, industrial processes, cancer research and public health, amongst others.

Polymer photonics multiparametric biochemical sensor for point of care diagnostics

Dr Nigel Johnson nigel.johnson@glasgow.ac.uk

Neurological conditions e.g. stroke are notoriously difficult to diagnose, relying on the interpretation of physical symptoms and subsequent brain imaging before positive identification of a condition is possible. Rapid Detection of biochemical markers present within a patient's blood as an aid to diagnosis is expected to significantly improve a patient's chance of survival. With partners we are developing a biochemical detection device for use in emergency medicine. At the core is a photonic chip employing bus-bar waveguides and several optical cavities. The photonic optical circuitry used to route light around on the chip, and interact it with the medium being sensed, is defined via arrays of features with size of the order 100 nm. These are formed in polymer by nano-imprint-lithography providing a low cost technology. Portable devices for use by paramedics will aid the early diagnosis and treatment of stroke.

Optoelectronic tweezers (OET) for medical diagnosis

Dr Steven Neale - steven.neale@glasgow.ac.uk

There is a demand for medical diagnostic tools that provide more data on a patient's condition that is currently possible, e.g. continuous information streams, and faster production of data, or at the point of care. Optoelectronic Tweezers (OET) can be used as a tool to help gather this data. OET optically patterns electrical fields that then place forces onto cells. These forces can be used for medical diagnostics, they can also be used to produce information on the health of single cells e.g. allowing us to distinguish healthy from unhealthy sperm cells for IVF. OET allows us to quickly and easily apply different electrical patterns to samples and measure their response. By engineering small inexpensive devices with high sensitivity and high specificity available at the point of care we can revolutionise what data is available to health care professionals and speed up their access to it.

Tools for simulating the statistical variability in nanowire biosensors

Prof Asen Asenov – asen.asenov@glasgow.ac.uk

Nanowire biosensors are currently being developed to enable low cost, portable point of care devices that can perform DNA sequencing and, amongst other applications, detect nucleic acid biomarkers associated with disease. Designers and manufacturers will face the problem of spatial and temporal variability that increases with the sensors miniaturisation in a

drive to increase the sensitivity. Prof Asenov is develops tools and methodologies that enable the simulation of the spatial and temporary variability in functionalised NW bio-sensors at the design stage. The tools will demonstrate the impact of the variability on the sensitivity, reliability and yield of these devices – enabling manufacturers to manufacture higher quality devices without the expensive "trial and error" process.

Radiation imaging systems

Prof Val O'Shea – val.o'shea@glasgow.ac.uk

Radiation imaging systems have a broad range of applications including specialised medical imaging techniques. Advanced energy sensitive imaging detectors offer a range of powerful tools for the detection of disease that are not possible with current detector performance. Energy sensitive detection of X-ray quanta in highly pixellated systems can be achieved through the use of custom designed low noise ASIC systems that can be integrated to a suitable detector material. The resulting system can be designed to measure the energy of each individual quantum as it is detected and the image processed with a set of weighted rules depending on the energies detected. Techniques based on imaging Au nano-particles coated with various biomarkers are just being developed for novel diagnostic techniques. Fluorescence suppression in high Z material improves its performance for imaging higher energy X-rays yielding better system performance. New diagnostic techniques with these capabilities will improve the quality of life of society over the coming decades.

2.13 University of Greenwich, School of Science

Key Contact:

Dr Bruce Alexander (T) 0208 331 8209 Email: b.alexander@greenwich.ac.uk

Keywords highlighting areas of interest and expertise of group: electrochemistry, microarrays, nanostructured materials, photonic biosensors, protein structure, monolayers

Biosensor/Biosensing Research Capabilities

The Functional Interfaces Group is a multidisciplinary group of academics with areas of expertise in spectroscopic analysis, electrochemistry, polymer and dendrimer chemistry, colloid and surface science, pharmaceutical analysis, formulation science and computational chemistry and cheminformatics. The principle interests of the group are in the modification of interfaces for chemical or biochemical sensing, novel pharmaceutical delivery or the design and development of functional nanomaterials, e.g. semiconductors or smart polymers.

The School of Science has a wide range of instrumental analysis available and an analytical chemistry laboratory accredited accredited to ISO 17025:2005. Research capabilities in the Functional Interfaces Group include:

- Circular Dichroism
- Electrochemical analysis
- Raman microscopy and surface-enhanced Raman spectroscopy
- Fluorescence
- ATR-FTIR spectroscopy

- Diffuse Reflectance UV-vis spectroscopy
- Supercritical CO_2 processing
- Electron microscopy
- Dynamic light scattering
- Calorimetry and Thermal Analysis.

Biosensor/Biosensing Related Research Projects

Novel Micro-Patterned SERS Substrates Surface-enhanced Raman spectroscopy (SERS) has been reported to rival fluorescence for sensitivity. SERS offers the advantage that more information is encoded in a SERS spectrum than in fluorescence which means SERS offers greater potential for multiplex analysis. However the sensitivity of SERS is crucially linked to the nature of the surface used. A novel technique for generating patterned surfaces has been developed which allows facile preparation of micro-arrays suitable for SERS-based detection systems. Use of self-assembled monolayers affords control of the chemistry of these surfaces and allows the analysis of biomolecular species of interest, such as DNA, proteins or glycoproteins. The method of preparation of these surfaces may also have use in holographic sensors.

Functional Stimuli-responsive materials Polymeric materials that can change their structure and properties in response to an external stimulus, such as pH or temperature, are being used as an architecture upon which reporting units can be added. Present projects are interested in the design of polymeric microgels functionalised with fluorescent labels which respond to the presence or absence of an analyte. Other projects are on-going in areas related to the detection and analysis of biochemically relevant molecules in a breadth of samples such as on-line analysis of pharmaceutically relevant polymorphs or glycoproteins.

Biopharmaceutical and Protein Structural Quality Control The structure of proteins or peptides is directly linked to their function or efficacy. Quality control of the structure of biopharmaceuticals based on proteins or peptides is therefore of importance, particularly as structural changes may occur between batches, upon storage or upon processing, e.g. as part of the formulation process. However, established methods to quantify structural change can be subjective, relying on the interpretation of an experienced analyst. Work is ongoing to develop a technique for quantitative structural analysis based on instrumental analysis, such as circular dichroism or fluorescence spectroscopy, that removes this level of interpretation and is entirely objective, leading to a potential automated test of quality control.

2.14 Heriot-Watt University

2.14.1 School of Engineering and Physical Sciences

Head of school: Professor Steve McLaughlin

Key Contact: Dr Grant Sellar (T) 0131 451 4469 Email: g.sellar@hw.ac.uk

Keywords highlighting areas of interest and expertise of group: aptamers, bacterial biosensors, DNA, immunoassays, microarrays, micro cantilevers, microfluidics, bioMEMS, Lab on a chip, synthetic biology, biomarkers, point of care, optical tweezers; nanoparticles, particle tracking; fluorescence; 3D imaging; cell imaging; computational techniques

The biosensor/biosensing related research activities of key researchers in the School of Engineering and Physical Sci-

ences are as follows:

Dr Will Shu w.shu@hw.ac.uk

Dr Shu's current research activities explore the new possibilities enabled by MEMS and Nanotechnology and the interfaces with life sciences. His research interests and on-going work include the following areas:

- Microcantilever sensor array: biosensors, chemical/gas/explosive sensors, tactile microsensors.
- Micro/nano-fluidics: integrated microfluidic systems for synthetic biology, cell culture and high-throughput drug screening; sensor integrated microfluidic devices.
- Microbiomechanics: cell mechanics, mechanotransduction.

Biosensor/Biosensing Related Research Projects:

- For rapid disease diagnosis (DNA, protein and bacteria detection) using aptamers
- Real-time live cell monitoring for drug screening;
- Fabrication of ultrasoft polymer microcantilever cantilever arrays
- Integrated micromechanical sensor and microfluidic systems
- Lab on a chip systems for synthetic biology:

As part of the £2.4 million Genome Segment Assembly (GSA) research program funded by Scottish Enterprise, the team led by Dr. Shu at Heriot-Watt delivered a novel microfluidic platform for assembly of DNA parts into biosynthetic pathways. The platform will afford high-throughput combinatorial assembly of large DNA segments in a fast and reliable way and will be licensed to commercial partners in Scotland and the U.S. allowing them to offer assembly services. (more details)

Professor Marc Desmulliez

Prof Desmulliez is Professor of Microsystems at Heriot-Watt University and Director of MISEC (www.misec.hw.ac.uk). He has wide ranging interests associated with microsystems, particularly biological and medical applications, and has published over 320 papers on optoelectronics and MEMS integration. He has extensive experience working in, and managing large research projects involving multiple partners, e.g. the 3D-Mintegration Project (www.3D-Mintegration.com).

Biosensor/Biosensing Related Research Projects:

- Design, test and biological validation of microfluidic systems for blood plasma separation
- Surface Acoustic Wave devices for the manipulation of fluids within microfluidic based systems
- Micro Total Analysis Systems (μTAS) for environmental based monitoring
- BioMEMS solutions for the point of care detection of cardiac biomarkers
- Novel RF Microfluidic Sensor for Particle-Cell Detection
- Non-invasive prenatal diagnosis
- Lab-on-chip solutions for the detection of pathogens such as viruses, bacteria and parasites in safe drinking water (start January 2013).

Dr Lynn Paterson l.paterson@hw.ac.uk

Dr Paterson's research interests centre on the use of light in biology and medicine, as a research tool or as a therapy, in addition to finding novel uses in single cell investigations for commercially available nanoparticles.

Biosensor/Biosensing Related Research Projects:

- Novel biophotonics devices. A continuous flow microfluidic cell separation platform aimed at separating human embryonic stem cells from differentiated cells has been demonstrated.
- Intracellular optical micromanipulation. Moving particles inside the crowed environment of a single live cell using optical tweezers.
- Silver nanoparticle interaction with bacterial cells. Novel optical tweezers are being developed to allow us to investigate the interaction between bacterial cells and silver nanoparticles.

Dr Alan Greenaway A.H.Greenaway@hw.ac.uk

Dr Greenaway's research interests include adaptive optics, optical metrology; optical aperture synthesis; optical propagation; studying dynamic processes in 4-dimensions (space and time) in fluid flow and bio-medical applications; ultra-high dynamic range imaging and femtosecond lasers.

Biosensor/Biosensing Related Research Projects:

- Real-time 3D imaging for biological and medical research. A new approach to four-dimensional (4D = 3D plus time) bio-imaging has been developed using a specially designed diffraction grating to simultaneously record information from multiple object planes onto a single image plane. The system has been designed as a small module that can be adapted to fit onto many different manufacturers' microscopes.
- Particle Tracking for biological and medical applications. An algorithm has been developed which allows the extraction of accurate 3D position information from fluorescent particles contained within the focal volume imaged by a grating. This can be used to perform particle tracking of fluorescently tagged bio-particles in vivo or in vitro.

Dr Weiping Lu w.lu@hw.ac.uk

Dr Lu's research interests in the area of the Physics and Life Sciences Interface include working with biologists to develop advanced computational techniques for analysing fluorescence microscopy images. Currently developing new image processing algorithms capable of detection and tracking of transport particles within biological live cells under low SNR environments.

Biosensor/Biosensing Related Research Projects:

- Image de-noising. A new de-noising approach has been developed that combines feature extraction and non-local means filtering for the analysis of live cell fluorescence images
- Particle tracking. The quantitative analysis of particle trajectories provides important information about working mechanisms and structures in living cells. Nearest neighbour association and Bayesian state estimation are being combined for robust particle tracking in live cell imaging sequences.

2.14.2 School of Life Sciences

Head of School: Professor David Hopkins

Keywords highlighting areas of interest and expertise of group: nanomaterials, nanoparticles, bioavailability; environmental; biomarkers, environmental; pollution

The biosensor/biosensing related research activities of key researchers in the school of Life Sciences are as follows:

Professor Teresa Fernandes

Professor Fernandes' research is focused on addressing fundamental issues relating to the sustainable management of aquatic ecosystems. Recent activity includes the assessment and management of eutrophication, aquaculture impacts, nanomaterials in the environment and intertidal habitats as nursery for flatfish; the development of a sustainable sprat fishery within the Firth of Forth, approaches for the management of coastal systems and biomarkers as biosensors of pollution.

Biosensor/Biosensing Related Research Projects:

- Address the ecotoxicological impacts of nanomaterials on a variety of test species and endpoints
- Manufactured Nanomaterial Bioavailability and Environmental Exposure (NanoBee)

Dr Mark Hartl

The main focus of Dr Hartl's research group is the development and application of marine ecotoxicological biomarkers as biosensors of exposure to aqueous and sediment-associated contaminants in the marine and estuarine environment. Of particular interest are the impacts of oil industry discharges, oilfield chemicals and engineered nanomaterials on marine and estuarine organisms, ranging from bacteria to fish.

Biosensor/Biosensing Related Research Projects:

- Use of genetic biomarkers in mussels as biosensors of contaminants in highly diluted produced water in the oil and gas industry
- Silver nanoparticle interaction with bacterial cells. Novel optical tweezers are being developed to allow us to investigate the interaction between bacterial cells and silver nanoparticles (collaboration with Dr Lynn Paterson).

2.15 University of Hertfordshire

2.15.1 School of Life Sciences, Microbiology, Molecular Biology and Biotechnology Research Group

Head of Group: Dr David Naseby

Key contact: Dr David Naseby (T) 01707 284397 Email d.c.naseby@herts.ac.uk

Keywords highlighting areas of interest and expertise of group: Bacterial biosensor, microarrays, point of care, label-free detection

Summary of Biosensor/Biosensing Research Capabilities

The MMB research group has expertise in most areas of microbiology, molecular biology and biotechnology. It has specific expertise in the detection, identification and quantification of biological entities such as bacteria or small molecules in environmental or clinical samples. Further cutting edge research using molecular biological techniques to enable the use of bacteria or fungi as the sensing element in biosensor systems has resulted in the spin out of Biosense Technology Ltd from the university to develop a range of biosensors in conjunction with pharmaceutical partners.

Current Biosensor/Biosensing Research Projects

Microbial based biosensors for pharmaceutical development. A group of five biosensors have been developed which will revolutionise a critical point in the pharmaceutical development cycle cutting up to 6 months off the time to required to take a pharmaceutical product to market. The project in collaboration with two large multinational companies utilised molecular biological tools to enhance the signals produced by microorganisms upon sensing changes within their local environment. The biosensors produced are aimed to eventually replace specified pharmacopeial tests. This technology has resulted in a whole range of regional and national awards over the past two years.

Novel microarray technology for detection and identification of microorganisms in environmental and clinical samples. The MMB research group is developing a range of easily accessible, low cost, low-density microarray systems that can be utilised in the field, diagnostic laboratories and eventually at the point of care. The detection system is label free, which is a significant advantage over current technology reducing costs and producing robust signal that does not require advanced laboratory equipment for interpretation. The signal produced on consumable test strips can be read by a low cost, robust portable integration system that can be used in the field, at the point of care and in any standard laboratory. Applications of the technology include detection of specific pathogens in the environment (including human, plant and animal pathogens), delineation of antibiotic resistant bacteria (from non resistant bacteria) at the point of care and detection of specific genes in a biological sample.

A range of other projects is also underway including the detection and quantification of specific hormones in biological and environmental samples and the detection and quantification of specific chemical and biological elements in a range of samples.

2.15.2 School of Engineering and Technology Microfluidics & Microengineering Research Group

Key Contacts:

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Keywords highlighting areas of interest and expertise of group: Microfluidics, BioMEMs, Biodetection.

Biosensor/Biosensing Research Capabilities

The Microfluidics & Microengineering Research Group (MMRG) conducts both academic and commercial microfluidics R&D in the broad field of bespoke microfluidics-enabled systems, specialising in the design and creation of microfluidic devices, sub-systems and all the necessary fluidic, mechanical, electronic and software support systems to facilitate operation of microfluidic and microengineered devices.

Our multidisciplinary team, working in self-contained facilities, is highly geared to respond to the needs of both industry and governmental agencies. Our laboratory incorporates rapid prototyping facilities for plastic microfluidic systems including a dedicated class 1000 Microfabrication cleanroom for SU-8/PDMS processing and precision assembly areas.

The Group also has expertise in CAD/CAM plastics processing via, micro-milling, polishing, laser ablation and plastic-elastomer bonding. We also have CFD flow modelling capabilities.

Biosensor/Biosensing Related Research Projects

Current research interest in the Group includes magnetic bead processing and microwave heating for microfluidics, particulate modelling in microfluidics, micropumps, micromixers and various microengineered systems and devices for bio-based microfluidics. The Group also has interest in the application of microfluidic and microengineered systems in genomics and combinatorial chemistry.

Recently concluded commercial projects include,

- Portable Integrated Biological Battlespace Detection Technology (PIBBDT)
- Automated fluid handling and sample processing systems
- Cyclone-based air sampling systems
- Filtration-based air sampling systems
- Multichannel antibody patterning system
- Dean-flow sample preparation devices

Current funded commercial projects include,

- Electro wetting (EWOD) systems
- Automated sample processing system for biological essays

We have also developed turnkey instruments for companies such as QinetiQ, Smiths Detection and Merck Neuroscience, as well as producing various systems for the Ministry of Defence. Sponsors of previous projects/collaborators include University of Edinburgh, LMB, Cambridge, EPSRC, BBSRC, DTI, Wellcome Trust, British Heart Foundation, EU, Zeneca and Glaxo-Wellcome.

2.16 University of Hull, Department of Chemistry

Head of Department: Professor Gillian Greenway

Key Contacts:

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*Department of Biology

Keywords highlighting areas of interest and expertise of group: micro reactor, surface functionalization, micro TAS, Lab on a chip, microfluidics, DNA, Sepsis, STI, biochip array

Biosensor/Biosensing Research Capabilities

Key areas of expertise of the Hull group are micro reactor design and fabrication, surface functionalisation and analytical methodology and reaction optimisation and system and process integration (so called micro TAS or Lab on a chip). In the past few years the Hull team has focused on exploiting the biomimetic aspects of micro fluidic devices with a particular emphasis being placed on biomedical/clinical type applications.

Highlights from the Group's research include the development of a micro fluidic based Lab-on-a-chip system that can produce a DNA forensic profile in one hour (EPSRC EP/D040930 EP/007385) and the establishment of micro fluidic methodology that can maintain viable biological tissue, achieved through the careful design and control of nutrient delivery, removal of waste products and gaseous exchange (BBSRC BB/E002722/1).

This basic scientific research was recently extended to demonstrate the relevance of the technology in underpinning personalised medical prognosis with work involving the monitoring cell death, cell viability and histo-architectural changes on fresh primary head and neck squamous cell carcinomas (HNSCC) biopsies, or metastatic lymph nodes from patients exposed to the chemotherapy agents Cisplatin, 5-Fluorouracil and Docetaxel, alone and in combination. In addition the integration of systems and processes including the real world interface to Lab on a chip devices is being addressed through a number of projects including TSB funded work into rapid STI and sepsis detection.

Biosensor/Biosensing Related Research Projects

- Replacement of animal models for tumour biology with a multifunctional microfluidic-based approach; NC3Rs, Jan. 2012 - Dec. 2014
- Development of a rapid multiplex Lab on a Chip system for the detection of 10 STI pathogens using Biochip Array technology; TSB/EPSRC, Oct. 2010 – Sept. 2013
- Lab on a chip, micro Total Analytical Systems, micro fluidics, biomedical applications http://www2.hull.ac.uk/science/chemistry/research/process_miniaturisation_and_me/lab_on_a_chip.aspx

2.17 Imperial College London

2.17.1 Department of Chemistry

Key Contact:

Professor Tony Cass (T) 020 7594 5195 Email: t.cass@imperial.ac.uk

Keywords highlighting areas of interest and expertise of group: amperometry, antibodies, aptamers, bio-chips, DNA, electrochemistry, enzymes, glucose biosensors, immunoassays, microarrays, microfluidics, nanoparticles, nanostructured materials, potentiometry, voltammetry, point of care, arsenite sensing, minimally invasive biosensors, nanopores

Biosensor/Biosensing Research Capabilities

The Cass Group is focussed on research and development in providing innovative sensing solutions to challenges in healthcare (environmental, human and animal). The work encompasses materials science (nanomaterials for biomedicine, nanoparticles for labelling in diagnostics and bioanalysis), micro- and nanofluidics (hybrid microfluidic devices), instrumentation (optical and electrochemical) as well as cell and molecular biology (protein engineering, aptamer selections,

molecular biology).

Cass Group research facilities include:

- 'Wet Labs' for molecular biology, flow studies, materials charactersation, biomaterials processing, cell culture and testing, instrumentation
- Micro- and Nanofabrication and characterisation suite including laser micromachining, dip pen nanolithography, electrochemical SPR, biosurface imaging (Combined AFM/Raman microscopy, imaging ellipsometry, scanning electrochemical microscopy, IR microscopy, contact and non-contact profilometry) and microarraying

Biosensor/Biosensing Related Research Projects

Projects in this area (in collaboration with other faculties) include:

Molecular engineering of biomolecules (proteins, peptides and aptamers) as sensing elements

Using peptide and aptamer synthesis or molecular biological techniques to generate novel reagents for sensing clinically relevant target analytes.

Minimally Invasive Biosensors

Very small sensors are by definition much less painful when inserted into the body and also require much less sample for making a measurement. Platforms are being developed that integrate microsampling, microfluidics and ultra sensitive detection of key biomarkers for disease diagnosis, prognosis and monitoring.

Salivary Diagnostics

Microfluidics based salivary sampling with integrated electrochemical (amperometric) detection. The main focus here is on therapeutic drug monitoring.

Point of Care Diagnostics in Osteoarthritis

As part of a Wellcome Trust funded centre in engineering solutions for osteoarthritis (http://www3.imperial.ac.uk/osteoarthritis) we are developing point of care devices to provide rapid monitoring of osteoarthritis biomarkers and genotyping based on electrochemical sensors.

Biosensors in Fertility and Pregnancy

In collaboration with bioengineering and clinical colleagues we are developing point of care electrochemical biosensors for key biomarkers in fertility (luteinizing hormone) and induced cholestasis of pregnancy (bile acids).

Infectious Disease and Environmental Biosensors

BBSRC funded projects in arsenite sensing (with Dr J Santini, UCL) and animal influenza sensing (with Dr Munir Iqbal, IAH, Compton)

Nanopore Group (Key Contacts Dr Tim Albrecht & Dr Joshua Edel)

Biosensor/Biosensing Related Research Activities

- Nanoscale charge transport and charged interfaces

- Single-molecule biosensing with solid-state nanopores and nanopore/electrode structures
- DNA/DNA, DNA/protein, and protein/protein interactions at the single-molecule level
- Epigenetic modification of DNA (DNA/antibody) with nanopores
- Nanopore device design (chip fabrication) and electronics design

2.17.2 Department of Materials

Key Contact: Professor Molly Stevens

Keywords highlighting areas of interest and expertise of group: nanoparticles, enzymes, quantum dots, FRET sensors

Biosensor/Biosensing Related Research Activities

Colorimetric Gold Nanoparticle-based Biosensors

These liquid-phase assays produce a fast and distinct colour change upon detection of a target analyte, which allows for rapid testing with high sensitivity. We are developing novel nanostructured assemblies based on gold nanoparticles and peptides which react dynamically to the presence of targeted enzymes, allowing for sensing with high specificity.

Fluorescent Nanoparticle Biosensors

Nanoparticle biosensors which change their fluorescence characteristics in response to specific enzyme activity are being developed. These are based on quantum dot and FRET-acceptor molecule pairs bound by peptide linkers, with the change in fluorescence being measured using a fluorimeter or plate reader. Such a system allows for sensitive and quantitative detection of target enzymes.

2.17.3 Department of Medicine

Key Contact: David Low, Autonomic and Neurovascular Medicine Unit, St Marys Hospital, Division of Brain Sciences, Faculty of Medicine

Keywords highlighting areas of interest and expertise of group: body sensor networks, wireless sensor devices

Biosensor/Biosensing Related Research Activities

Sensor Technology and the Diagnosis of Autonomic Dysfunction

A prompt and accurate diagnosis of neurological disorders is critical in order to ensure the most appropriate treatment strategies are adopted and the assessment of such strategies is vital. Current clinical investigations of cardiovascular autonomic function include 24 hour intermittent monitoring and diary recording outside the clinical setting, which has a number of limitations. Recent development of miniaturized body sensor networks (BSN) facilitate continuous monitoring and analysis of various key physiological and physical parameters, providing invaluable clinical data. The overall aim of this research is to examine the diagnostic use of miniaturised wireless sensor devices in autonomic dysfunction patients.

2.17.4 Department of Bioengineering

Head of Department of Bioengineering: Professor Ross Ethier

Key Contacts:

Dr Martyn Boutelle, Reader in Biomedical Sensors Engineering (T) 020 7594 5138 Email: m.boutelle@imperial.ac.uk

Dr Danny O'Hare, Reader in Sensor Research (T) 020 7594 5173 Email: d.ohare@imperial.ac.uk

Keywords highlighting areas of interest and expertise of group: Electrochemistry, amperometry, potentiometry, microfluidics, microarrays, microelectrode sensors, u-TAS, DNA, glucose biosensors,

Summary of Biosensor/Biosensing Research Capabilities

The groups of Dr O'Hare and Dr Boutelle are developing highly sensitive electrochemical biosensors that are being applied to the detection of biologically and physiologically relevant small molecules, such as oxygen, cyanide, potassium, glucose, neurotransmitters and neurochemicals. The groups have expertise in the following areas:

- Development of integrated microelectrode based sensors
- Electropolymerisation to produce conductive and non-conductive electrode coatings.
- Amperometric and potentiometric approaches to ion measurement.
- Development of microfluidic platforms for biomedical sensors including microdialysis sampling
- Advanced signal processing of time resolved data.
- Development of low noise, low power and wireless instrumentation for sensors and biosensors.

Dr Boutelle is interested in the development of new sensor techniques for use in medicine, particularly for the analysis of brain function during and after surgery. His research group is interdisciplinary, covering biomedical sampling with microdialysis, amperometric and potentiometric sensors, microfluidic manifolds for analysis of 10-100 nanolitre droplets, signal processing techniques, clinically safe instrumentation , measurement of blood flow with laser speckle, measurement of human brain electrical activity, neuroscience relating to the understand the mechanisms of brain injury. Clinical measurements are through collaborations with King's College Hospital, St Mary's Hospital, University Hospital Cologne, Charite Hospital Berlin

Dr. O'Hare is interested in the design and application of novel sensors in physiology. His research includes work on molecular recognition, novel sensor architectures, microfabrication of sensor arrays and separation techniques (m-TAS) and the application of novel signal processing techniques to electrochemical sensor data. Physiological applications include the neurochemistry, angiogenesis and mass transport to tissue.

Biosensor/Biosensing Related Research Projects

Dr Boutelle

Low volume continuously reading potassium sensor

We monitor brain potassium, sodium and calcium levels in a 30 nanolitre flow cell. These are important neurochemical markers linking the timescales of spontaneous brain depolarisations measured electrically and other neurochemical changes.

Biosensors to study energy usage in tissue.

Microelectrode based biosensors for glucose, lactate, pyruvate and ATP to be used together with measurements of blood flow to establish energy budgets for enruotransmission.

Microfluidic biosensor systems for the continuous analysis of neurochemicals in clinical microdialysis streams.

The low volumes and precise geometries of microfabricated devices are ideal environments for microelectrode based biosensors allow devices to be placed much nearer to a tissue sampling probe. We are designing droplet based digital microfluidic devices for electrochemical sensors and biosensors. These greatly shorten the time between the occurrence of an event in tissue and its detection, can be self calibrating, and avoid flow induced dispersion of transient changes, and hence provide faster ' chemical feedback' for the clinical team.

Dr. O'Hare

Microfabricated tissue perfusion sensor, miniature implantable biofuel cell, whole column detection for microfabricated hplc, metal oxide pH sensors, non-linear time series analysis of electrochemical data, reactive oxygen and nitrogen species in biology, microfabricated sensor arrays, supramolecular ion sensors, electrochemical detection of DNA hybridisation.

2.17.5 Department of Chemical Engineering

www.imperial.ac.uk/vsci

Key Contact: Prof. Sergei G. Kazarian (T) 020 7594 5574 Email: s.kazarian@imperial.ac.uk

Keywords highlighting areas of interest and expertise of group: chemical imaging, microfluidics, Raman microscopy, cellular imaging

Biosensor/Biosensing Research Capabilities

- Advanced vibrational spectroscopic systems and specialised accessories
- FTIR spectroscopic imaging (4 different imaging systems)
- Macro and micro ATR-FTIR spectroscopic imaging
- Confocal Raman microscopy
- Tip-enhanced Raman spectroscopy (Raman combined with AFM)
- FT-Raman spectroscopy

Biosensor/Biosensing Related Research Projects

We are developing new approaches in chemical imaging by obtaining chemical maps of materials at the microscopic and nanoscale resolution level. For example, we can analyse processes inside tablets when they dissolve, which helps pharmaceutical companies to develop more effective formulations. We also analyse the chemistry of fingerprints, benefitting forensic science. We apply methods of chemical imaging to biomaterials and biomedical systems.

Our research in this area includes imaging of atherosclerosis, imaging of protein crystallisation, imaging of skin and transdermal drug delivery, chemical imaging of live cancer cells and other cells and tissues. We also use spectroscopic imaging to study the diffusion of model drug molecules into live tissue samples and developed the applicability of macro ATR FTIR imaging to study many samples simultaneous for high-throughput analysis; using this approach we analyse many different samples under identical conditions and apply chemical imaging processes in microfluidics. We apply tip-enhanced Raman microscopy to image materials at nanoscale spatial resolution. These research activities have been sup-

ported by the EPSRC and currently are supported by the ERC Advanced grant; our research was presented at the Royal Society's 350th Summer Science Exhibition in 2012. A summary of our research activities, publications in these areas and a presentation of our facilities is available at our research group web-site: www.imperial.ac.uk/vsci

2.18 University of Leeds

2.18.1 Faculty of Biological Sciences, Institute of Membranes & Systems Biology*

*School of Biomedical Sciences after 30/09/2012

Institute Director: Prof.Paul Millner

Key Contact: Prof. Paul Millner (T) 0113 343 3149 Email: p.a.millner@leeds.ac.uk

Keywords highlighting areas of interest and expertise of group: electrochemistry, enzymes, immunoassays, membranes, nanoparticles,

Biosensor/Biosensing Research Capabilities

- Protein chemistry especially of affinity:ligand interactions
- Application of affinity interactions to construct self-assembling biosensor and biocatalytic surfaces
- Development of labeless immunosensors plus other affinity sensors and novel electrochemical interogation routines.
- Application of nanostructured biosilicate particles for biosensors and biocatalysis.
- Development of photosensitizer loaded surfaces for light drive remediation of microbial and chemical water pollutants.
- Characterisation of biosensor and biocatalytic surfaces using biochemical, radiochemical, and biophysical techniques (fluorimetry, XPS, AFM, SEM and QCM) often in combination, e.g.electrochemical QCM

Biosensor/Biosensing Related Research Projects

- Development of a novel immunosensor platform for a wide range of analytes, including pesticides and antibiotics, heart attack, stroke and cancer markers (EC Project ELISHA - see www.immunosensors.com).
- Development of biosensors for emergency responders.
- Affinity activation of screen-printed carbon surfaces for enzyme based biosensors.
- Development of biosensors for post colorectal surgical resection;detection of ischaemia and anastomotic leaks.
- Fabrication of targeted fluorescent nanoparticles for intraoperative visualisation of colorectal cancer

2.18.2 School of Physics & Astronomy

Head of School: Prof Stephen Scott

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Keywords highlighting areas of interest and expertise of group: ion channel based sensors, membranes, nanoparticles, potentiometry, surface plasmon based sensors, quantum dots, and nanowires.

Biosensor/Biosensing Research Capabilities

Areas of expertise of this group include:

- Surface functionalisation and characterisation – new facilities include XPS, SEM, SAM, Spectroscopic Ellipsometry, SPR, AFM contact angle goniometry, Fluorescence, FTIR, Raman, QCM-D
- Synthesis of Molecules for Self-Assembled Monolayer formation (specifically for Bio-and Nanostructure attachment)
- Biological attachment and binding kinetics
- Solid Supported Bilayer Lipid Membrane formation and vesicle attachment to planar supports
- Impedance spectroscopy / cyclic voltammetry
- Electron and focussed Ion beam lithographies, conventional photolithography and electron microscopies
- CdTe quantum dotSynthesis and bio-functionalisation
- Cadmium free quantum dot synthesis
- Au/Co Core Shell nanoparticles
- Microbubble synthesis and functionalisation
- Functional liposomes
- Fabrication of Metal and semiconductor nanowires

Biosensor/Biosensing Related Research Projects

Development of lipid membrane platforms for:

- Ion channel based sensors
- Antibiotic screening
- Cytoskeletal interactions
- Membrane Arrays
- Imaging & Delivery based on combinations of qdots, liposomes, and microbubbles
- Multimodal Imaging – improving contrast
- Targeted Delivery – using liposomes

Development of metallic nanowires for label-free sensing biomarkers.

Development of Quantum dots for targeting specific cell receptors.

Generic Research

- Photo-patterned SAMs for bio-attachment

- Liposome fabrication

2.19 University of Manchester, Faculty of Engineering and Physical Sciences

School of Chemical Engineering and Analytical Science

Key Contacts:

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The School of Chemical Engineering and Analytical Science was formed on 1st October 2004 from a merger of the UMIST departments of 'Chemical Engineering' and 'Instrumentation and Analytical Science' and the Centre for Process Integration when UMIST was reborn as The University of Manchester.

Measurement Science and Instrumentation

Research on measurement science and novel instrumentation systems is carried out in the Centre for Instrumentation and Analytical Science (CIAS). The research is concerned with the measurement of phenomena ranging from nano-scale molecular processes in biological cells right through to macro-scale chemical processes. These measurements are of great importance to such areas as environmental monitoring, chemical reaction engineering, disease diagnosis, detection of drugs and explosives and imaging for health-care and the life-sciences. To meet these measurement demands, the research develops new analytical methodologies, sensing systems and instrumentation exploiting a wide range of advanced chemical, biochemical and physical sensors that utilise optical spectroscopies, complex mass spectrometries such ion mobility and secondary ion mass spectrometry, laser generated ultra-sound, laser trapping, polymer microfabrication, microfluidics, and optical fibre sensing.

Keywords highlighting areas of interest and expertise of group: Microfluidics, fibre optic sensing, polymer micro fabrication, DNA, optical waveguide sensing, bacterial biosensors

Summary of Biosensor/Biosensing Research activities

- Miniaturised systems based on polymer micro-fabrication are being researched to enable chemical and biochemical sensing into the nano-scale. This involves a combination of electroanalysis, electrokinetic separation systems and optical waveguide sensing. Systems to be monitored range in size from small drug molecules through proteins and DNA to cells and small liquid droplets. Such miniature sensors should also have important applications in high-throughput experimentation and bioassays.
- The design and development of robust optical chemical sensors and biosensors for the detection of gaseous, ionic and molecular analytes using molecular spectroscopic techniques is a long-term interest. These sensors aimed at industrial, environmental and biomedical applications are based on immobilised reagents that provide an optical signal. Signal processing and instrument design and construction are important components of the work.
- A rapid, non-invasive device to diagnose bacterial infections involving the University of Manchester and an international team of engineers and clinicians. The aim of the project, which was launched in 2006, is to design a hybrid gas-sensing array to discriminate the specific cocktail of volatile chemicals given off by bacteria as they grow. By using pattern recognition based on neural networks, it should be possible to create a system that will give real-time

diagnosis. The gas-sensing array will use both organic semiconductor and oxide forms of gas sensor to detect polar and non-polar chemicals. Although the techniques are both well established, no one has brought them together to make a hybrid array before. A prototype has been completed and is being validated clinically.

2.20 Newcastle University, Diagnostic and Therapeutic Technologies, Institute of Cellular Medicine

Key Contacts:

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Keywords highlighting areas of interest and expertise of group: bio-MEMS, bacterial biosensors, graphene biosensors, biochips, electrochemistry, intracellular nanosensors, immunoassay, lateral flow devices, ion-channel sensors, whole cell biosensors

Biosensor/Biosensing Research Capabilities

Research concentrates on the design and development of electrochemical and microelectromechanical (bio-MEMS) sensors and their application to investigations of the biochemical mechanisms underlying disease and cellular processes.

Biosensor/Biosensing Related Research Projects

- European Commission Framework 7 Integrating Project 'd-LIVER' (ICT-enabled, cellular artificial liver system incorporating personalized patient management and support). The essential aim of the d-LIVER project is to develop an ICT-based monitoring and ICT-enabled bio-artificial liver system, for remote and safe management of patients with chronic liver disease outside the hospital. d-LIVER applies scenario-driven development methodologies to address an unmet need for bio-artificial liver support via continuous detoxification as remote transient therapy at the Point-of-Need. The liver is a complex organ with various vital functions in synthesis, detoxification and regulation; its failure is life-threatening and the only curative treatment is transplantation. Whilst awaiting transplantation, or after liver resection, patients need to be supported with detoxification systems which, currently mainly based on filtration, do not support metabolic liver function. This can only be provided by living cells. Thus, development of ICT-enabled bio-artificial liver support systems with associated remote monitoring to assist in the treatment and management of liver patients in care settings extending from the hospital to the home is essential. d-LIVER targets sensor-based monitoring of patient health status at home, concentrating on continuous monitoring of physiological parameters and discrete measurement of a defined set of biochemical species. d-LIVER also targets remote monitoring and control of the bio-artificial liver and communication with patient sensor networks and hospital information systems. Systems will be capable of remote, secure communication of the status of both the patient and the bio-artificial liver to central clinical services such that they can schedule swift and beneficial treatment and remedial actions. In this way d-LIVER will provide fundamental advances in liver support by reducing hospitalisation costs while enhancing quality of care and, at the same time, reinforcing European leadership in Personal Health systems.
- European Commission Framework 7 Integrating Project 'CD-MEDICS' (Coeliac Disease – Management, Monitoring

and Diagnosis using Biosensors and an Integrated Chip System). The aim of this project is to create a low-cost, non-invasive intelligent sensor-based technology platform for assessment of predisposition to coeliac disease via HLA-typing, population screening, and monitoring of response to withdrawal of gluten from the diet for those who test positive for coeliac disease. Individual chips for HLA-typing and auto-antibody detection will be developed exploiting advances at the confluence of bio-, micro-and nanotechnologies.

- EPSRC Cross-Disciplinary Feasibility Account Utilising Graphene for Biosensing. A range of feasibility studies are engaging engineers with biomedical scientists to formulate highly novel and speculative projects focusing on graphene as the platform technology in chemical and biological detection.
- Development of Intracellular Nanosensors to Investigate Muscle Bioenergetic Abnormalities that are Potentially Associated with Myalgic Encephalomyelitis / Chronic Fatigue Syndrome (ME/CFS). When patients with ME/CFS undertake a standard level of peripheral muscle exercise they show marked abnormality in bio-energetic function. Over-utilisation of anaerobic metabolic pathways may limit their capacity to exercise and lead to the perception of fatigue. The Manning group is currently investigating the hypothesis that this energetic abnormality contributes significantly to the expression of fatigue in ME/CFS and that targeting this will result in the amelioration of fatigue-like symptoms. In vitro studies currently under development centre on the assessment of muscle mitochondrial function, intracellular pH (utilising a novel nanosensor approach) and the effects of alterations in the function of key enzymes involved in oxidative metabolism (e.g. pyruvate dehydrogenase). This study will ultimately benefit ME/CFS patients through an increased understanding of the mechanisms of peripheral fatigue and approaches to its treatment.
- Integration of Optical and Electrochemical Sensing Technologies for the Simultaneous Analysis of the Intra- and Extracellular Environment.The aim of this research is to integrate miniaturized electrochemical sensors and optical nanosensors resulting in a novel Sensing Live Cell Array format (SeLCA) for fast, high-content simultaneous studies of discrete cell colonies. This platform technology will address, for the first time, investigations of the functional, chemical, and time-dependent properties of free radical-mediated intra- and intercellular communication.

2.21 University of Nottingham, School of Biosciences

Head of School: Prof. K.A. Smart

Key Contact:

Dr Jon Hobman (T) 0115 951 6166 Email: jon.hobman@nottingham.ac.uk

Keywords highlighting areas of interest and expertise of group: bioavailable metals, gene-based biosensor, protein-based sensors

Biosensor/Biosensing Research Capabilities

Dr Hobman's primary interests are in biosensors for toxic metals. The key aim of the Group's work is to develop sensors for bioavailable metals. The group is interested in both protein- and gene-based biosensors for metals and has developed In vitro metal-binding protein biosensors, and in vivo gene expression constructs designed to gene promoters that are regulated by metal sensing transcription factors. The Group has worldwide IP protection on protein biosensors for metals with their collaborators from Belgium and Sweden.

Biosensor/Biosensing Related Research Projects

We are currently working on understanding the basic biology of novel metal responsive gene regulator proteins that would be candidates for biosensors for antimicrobial metals. We are working on overexpression and purification of the proteins and on studying the promoters on which they act.

2.22 University of Oxford, Department of Chemistry

Chairman: Professor S. G. Davies

Key contacts:

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Prof.. Mark Moloney	(T) 01865 275656	Email: mark.moloney@chem.ox.ac.uk
Dr Mark Wallace	(T) 01865 275467	Email: mark.wallace@chem.ox.ac.uk

Keywords highlighting areas of interest and expertise of group: biomimetic electrode surfaces, enzymes, DNA, ion channels, electrochemistry, protein pores, nanoreactor, stochastic sensing, nanoparticles, amperometry, microarrays, immunoassay, microfluidics, membranes

Biosensor / Biosensing Research Capabilities

The Fraser Armstrong group is working on Novel biomimetic electrode surfaces: Devising ways to attach enzyme molecules to carbon surfaces using strong covalent and non-covalent linkages and in such a way as to allow fast electron transfer to and from their active sites. These modifications are then applied to novel high surface area substrates for scale-up of the bio-fuel cell.

Hagan Bayley is the Professor of Chemical Biology at the University of Oxford. His laboratory has used protein pores as “nanoreactors” with which to examine both non-covalent and covalent chemistry at the single molecule level. Based on this work, Bayley developed “stochastic sensing”, a single-molecule detection technique, which has been demonstrated with a wide variety of analytes, including small cations and anions, organic molecules, proteins and nucleic acids. The laboratory is also developing approaches for ultrarapid DNA sequencing by using nanopore technology. In addition, droplet interface bilayers (DIB), which miniaturize single-channel recording in the bilayer format are being elaborated into arrays for the rapid screening of ion channels and pores. In 2005, Professor Bayley founded Oxford NanoLabs (now Oxford Nanopore Technologies) to exploit the potential of stochastic sensing and DNA sequencing technologies.

Paul Beer - The construction of novel redox- and photo-active molecular sensory reagents including macrocycles and interlocked host systems designed to bind selectively and sense via electrochemical and optical methods target guest species of biological and environmental importance. The fabrication of such sensor systems on to various electrode and nanoparticle surfaces is being undertaken with Dr Jason Davis.

Richard Compton - The work of the Compton group includes amperometric sensing using micro- and nano-electrodes and arrays of these, theoretical modelling of sensors and DNA sensors.

Ben Davis - The Davis group work on biosensors has explored the use of i) multifunctional nanoparticles for direct in vivo imaging of functional molecule presentation in models of brain disease (van Kasteren et al Proc Natl Acad Sci, USA 2009); ii) synthetic protein constructs for in vivo & functional mimicry and event detection, Nature 2007; iii) single molecule detection of carbohydrate-protein binding events for use in toxin & pathogen detection (MRC-funded with HB); iv) use of a broad range of biophysical techniques that encompass and interface with biosensors for the characterization of ligand, protein & enzyme function (SPR, MS, immunoassay, kinetics); v) carbohydrate arrays and conjugates for creating 'maps' of sugar interactions.

Jason Davis - The Davis group engineer the bielectrochemical interface, optimize electrode-molecule coupling and analyse electron transfer at molecular levels. Closely associated with this ability has been the recent establishment of ultrasensitive protein (cancer, diabetes and Parkinsons marker) detection protocols by electronic (impedance array) and optimal means. The group engineer a variety of optically functional (one colour, two colour, MRI active) nanoparticles for targeted high signal:noise stem cell tracking and in vivo target protein detection and interface a variety of switchable and sensory molecular machines with electrochemically or optically active interfaces (including nanoparticles). In recent years a number of these have been utilized in highly specific potentiometric or colorimetric anion sensing.

Mark Moloney has developed unique chemical methodology for the control of the surface properties of materials and have demonstrated the viability of this concept for the introduction of chromophoric, fluorescence, biocidal and biocompatible properties onto a wide range substrates, including organic, inorganic and polymeric materials. Current work aims to develop this concept for drug delivery, particularly in antibacterial therapeutics.

Mark Wallace - The Wallace lab at Oxford has developed new methods for the high-throughput screening of membrane receptors and ion channels, based on the microfluidic imaging of individual molecules in artificial lipid bilayers.

2.23 Queen Mary, University of London, IRC in Biomedical Materials

Director of IRC: Prof Pankaj Vadgama

Key Contacts:

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Keywords highlighting areas of interest and expertise of group: electrochemistry, microfluidics, tissue culture, optical biosensors, environmental toxins, membranes, biofilms, biofouling, enzymes, quartz crystal microbalance, fibre optic sensors, nanostructured materials

Biosensor/Biosensing Research Capabilities

The Interdisciplinary Research Centre (IRC) in Biomedical Materials at Queen Mary, University of London, with associated laboratories at Queen Mary's School of Medicine and Dentistry was founded in 1991 with core funding from the EPSRC. The IRC is a well-established and highly successful specialist centre that provides a valuable focus for research into biomaterials and related areas. Relevant research expertise includes electrochemical and optical biosensors for monitoring metabolites, environmental toxins and biomaterials properties. Capabilities include electrochemistry, waveguides, materials surface characterisation, tissue culture, microfluidics.

Professor Pankaj Vadgama

In the area of interfaces and sensors, research includes the use of screen-printed carbon electrodes as electrochemical surfaces for chlorophyll detection (an environmental biomaker). To facilitate selective biosensing, PVC membranes variously modified with surfactant and lipid have been tested. Low contamination biosensing has been achieved using parallel fluid microflows.

Biofouling remains a major obstacle to stable biosensor use, and work with microporous polymeric barriers has confirmed open pore occlusion by proteins is a major cause of electrode drift, with differences observed between proteins. Conductive poly (pyrrole) films with a range of topographies and loaded bioactive components have served as bioactive surfaces for keratinocyte growth and monitoring. Impedimetric measurements, cell growth, confluence and differentiation are being monitored. Protein biofilms formed at planar substrates are being investigated by nanoindentation, an alternative for cross comparison of protein structure of surfaces. Chronic lymphatic leukaemia cells are being studied at hydrogel surfaces, variously loaded with bioactive solutes as a model for cell-surface interactions. Porous polycarbonate membranes variously depleted of a hydrophilic surface layer and used as substrate for osteoblasts, has shown cell interaction effects.

Dr Steffi Krause

Disposable biosensors for the detection of enzyme activities based on the enzymatic degradation of thin polymer films have been developed. Film degradation in the presence of an enzyme is monitored using impedance measurements and Quartz Crystal Microbalance. Inflammation and bacterial infection are frequently accompanied by increased levels of host and bacterial proteases. Current efforts are therefore directed at the development of polymers that are degraded specifically by different proteases. Potential applications include the detection of periodontal disease activity and home monitoring of biomarkers in MS patients.

High resolution photocurrent imaging at insulator semiconductor structures can be used for the local measurement of electrochemical potentials (Light-Addressable Potentiometric Sensors (LAPS)) and impedance (Scanning Photo-induced Impedance Microscopy (SPIM)) with sub-micrometer resolution. Current efforts are directed at the development of this technique into a new tool for the interrogation of polymer based biosensor arrays and into an imaging tool for biomaterials and living cells.

Biosensor/Biosensing Related Research Projects

- Environmental toxicity monitoring (EPSRC funded) – In collaboration with Professor Clive Thompson (ALcontrol Laboratories)
- Implantable sensors and remote monitoring NEAT funded project on low power wireless transmission for invasive sensors
- Microfluidics for cell monitoring EPSRC funded project on microfluidic devices as microbioreactors with associated sensor based monitoring
- Optical fibre biosensors Koerber funded project on photonic crystal fibres for chemical sensing.
- Permeability determination for mass transport in tissue engineering (Industry China UK funded)
- Universal permeability testing in biological systems (BBSRC supported)
- Prototype sensor for periodontal disease monitoring (Funded by TSB, in collaboration with Michael Watkinson (QMUL), Ian Douglas and Andrew Rawlinson (Sheffield University), Oraldent, AND Technology Research and Industrial Design Consultancy)

- MMP-9 detector for inflammation monitoring in autoimmune diseases and solid organ graft rejection (Funded by the Barts and the London Charity, in collaboration with Gavin Giovannoni, David Baker, Michael Watkinson)

2.24 Sheffield Hallam University, Materials and Engineering Research Institute (MERI)

Director of MERI: Prof. Alan Smith

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Keywords highlighting areas of interest and expertise of group: total internal reflection ellipsometry, surface plasmon based sensors, planar waveguides, quartz crystal microbalance, enzymes, thin film deposition, planar polarization interferometry

BioSensor/Biosensing Research Capabilities

The Electronic Materials and Sensors Research group at MERI has significant experience and internationally recognised expertise in chemical and bio-sensing. Our line of research has evolved from studying physical and chemical properties of novel chemi- and bio- sensing materials deposited as thin films and has now reached the stage of development of novel bio-sensing experimental techniques and prototype sensor devices.

The group has facilities for thin film deposition, such as Langmuir-Blodgett, spin coating, electrostatic layer-by-layer deposition, sol-gel, vacuum evaporation and sputtering, as well as analytical equipment (UV-vis absorption and luminescence spectroscopy, spectroscopic ellipsometry, surface plasmon resonance, planar waveguide set-up, QCM impedance measurements, DC/AC electrical characterisation) suitable for both film characterisation and sensing. The facilities also include gas rig and several gases and vapour generators and sources. We have an unlimited access to technological (clean room, silicon planar technology) and analytical (TEM, SEM, AFM, XRD, Raman spectroscopy, etc.) facilities within MERI.

Biosensor/Biosensing Related Research Projects

Gas and organic vapour sensing array based on a combination of original (in-house-made) QCM sensors of volatile organic chemicals (VOCs) with commercial metal oxide gas sensors that provide the information on the presence of VOCs and toxic gases in the environment. This work has been carried out within EU projects, and several types of sensor arrays were designed to be used on a mobile robotic platform to assist Fire & Rescue Services, UK. These QCM sensors of VOCs appeared as a result of a long-term fundamental research in the adsorption of organic vapours in thin films of amphiphilic calixarenes.

The method of Total Internal Reflection Ellipsometry (TIRE) has been recently developed as a combination of highly sensitive spectroscopic ellipsometry such as J.A. Woollam M2000 with experimentally convenient Kretchmann SPR (surface plasmon resonance) geometry. Modelling and test experiments proved that the sensitivity of TIRE is an order of magnitude higher than that offered by conventional techniques of SPR and ellipsometry, therefore the method of TIRE is highly recommended for bio-sensing, particularly for immune analysis. Our recent research work showed that the method of TIRE was capable of detection of low molecular weight toxins of simazine, atrazine, T2-mycotoxin, nonylphenol, and microcystine in a wide range of concentrations down to a sub-ppb level. TIRE method was recently utilised for detection of bio-markers of Alzheimer's disease, and the study of protein-protein interaction.

A planar waveguide bio-sensing platform has been developed in the last 5-7 years and proved its advantages and versatility for a number of applications. The devices are based on silicon oxide - silicon nitride - silicon oxide sandwich structure

grown on the surface of silicon waver using conventional silicon microelectronics technology. The sensing window is etched in the top SiO_2 oxide layer and can be coated with application specific bio-sensitive layers. The devices can operate in three different regimes: (i) attenuated total reflection (ii) polarization interferometry and (iii) evanescent field excited luminescence (fluorescence). In all three regimes the response is enhanced by multiple reflections of the light during propagation through the waveguide.

The combination of planar waveguides operating in attenuated reflection mode with a composite coating containing organic chromophore molecules and enzymes allows the development of prototype enzyme sensor array devices. Such devices are capable of detection of different enzyme reactions as well as their inhibitions by different environmental pollutants, in particular, for detection of traces (down to sub-ppb concentrations) of heavy metal ions and pesticides in water. On-going research is currently focused on the exploration of planar polarization interferometry devices.

2.25 University of Southampton

2.25.1 Chemistry

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Keywords highlighting areas of interest and expertise of group: amperometry, electrochemistry, enzymes, DNA, nanostructured materials/electrodes

Biosensor/Biosensing Research Capabilities

Work in the research group in the field of biosensors covers a number of areas, all based around the application of electrochemistry to practical problems.

Current research includes high throughput studies to the modification of carbon electrode surfaces using amine oxidation and diazonium coupling reactions to build libraries of modified electrodes and studies of their applications including applications in enzyme electrodes, biofuel cells and NADH oxidation.

We are also active in the development of combined electrochemical and SERS methods for the detection of DNA and the discrimination of mutations. This work uses nanostructured metal surfaces as electrodes designed to give larges, stable and reproducible enhancements in Surface enhanced Raman Spectroscopy.

Finally the group remains interested in the modelling of electrochemical biosensor responses in order to understand the interplay of non-linear reaction kinetics and diffusion and as a tool for the design of optimised electrochemical biosensors for specific applications.

Biosensor/Biosensing Related Research Projects

- 3DNanobiodevice - Three-dimensional nanobiostructure-based self-contained devices for biomedical application, EU FP7-NMP-2009-SL-229255, EU funded project on bioelectrochemistry and biofuel cells using engineered enzymes, mediators and nanostructured electrodes to improve electrochemical communication between redox enzymes and electrodes.
- High throughput methods for development of modified electrodes for NADH, dopamine and ascorbate for biosensor applications.

2.25.2 Optoelectronics Research Centre

Head of School; Prof. David Payne

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Keywords highlighting areas of interest and expertise of group: DNA, fibre optic sensors, microfluidics, nanoparticles, nanostructured materials/electrodes, photonic biosensors, quantum dots, BioMEMS, optical waveguide sensors

Biosensor/Biosensing Research Capabilities

The Optoelectronics Research Centre has a well-established international reputation in the field of optical telecommunications and photonics. The ORC is a research-only school, with around 20 groups covering a wide range of areas, all to do with the study and manipulation of light (photonics), and photonic devices. Optical sensor technologies are being developed in a number of the research groups, including Optical Biosensors & Biophotonics Dr Tracy Melvin; Integrated Optics & Microstructures Professor J S Wilkinson; Planar Optical Materials Dr P G R Smith; Ultrafast Laser X-Ray Dr W S Brocklesby. The ORC has a long history of innovation and industrial collaborations. There are nine companies in the Southampton area with roots in the ORC, and many consultancy projects currently under way with a wide range of industrial partners. more…

Biosensor/Biosensing Related Research Projects

The majority of the research in the biosensing field in the ORC is being done in the research group of Tracy Melvin – Optical Biosensors & Biophotonics. The current programmes are in the following themes:

Highly sensitive, rapid detection biomolecules in low copy numbers (i.e. cytokines, genomiv DNA fragments in serum)

- Bionanomaterial approaches (quantum dots, plasmonics) for detection and for DNA analysis
- Optical sorting of cell populations (most notably stem cells)
- Optical patterning of surfaces with biomolecules in micron and submicron scales
- Integration of microfluidics with optical sensors
- In situ sensing (small scale bioreactors/arrays)
- Application and adaptation of technologies originally developed for optical telecommunications for optical biosensing.

These programmes are highly collaborative – collaborators include Prof. T. Brown (Chemistry), Prof. C. Please (Mathematics), Prof. H. Perry and Dr J. Teeling (Biosciences), Dr M. Hill (Engineering Sciences) in the university, as well as teams in Manchester, Cambridge, Bath, Twente (NL), Chalmers (SE), UCSD (USA). Current funding includes BBSRC and EPSRC

2.26 University of Strathclyde

2.26.1 The Strathclyde Sensor Network

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Keywords highlighting areas of interest and expertise of group: antibodies, photonic biosensors, DNA, enzymes,, nanoparticles, glucose biosensors, microarrays, biomedical imaging, wireless sensors, point of care, minimally invasive biosensors

Biosensor/Biosensing Research Capabilities

Sensor and sensing activities at the University of Strathclyde are linked by a campus-wide research network incorporating all faculties and departments. The Strathclyde Sensor Network (SSN) acts as a readily available research pool for companies and academics interested in any of the wide ranging sensing activities underway at Strathclyde.

The network covers all aspects of sensor research from fundamental science, through the engineering of practical sensing technologies and devices, through to the computation and conversion of obtained data into crucial information. This offers a cross-disciplinary collaborative approach when developing solutions. Particular strengths include:

- Sensing for patient monitoring, biosensors, health and biomedical applications
- Biological and biomedical imaging for cutting edge health research
- Micro-array neural sensors and bio gels for neurological function/disease research
- Optoelectronic retinal prosthesis for sight restoration
- Sensors for optogenetic systems
- Sensor systems for use in energy generation, distribution, and conservation
- Sensors for harsh and inaccessible environments (extreme sensing)
- Gas and chemical sensing for energy, pollution monitoring/regulation, and process control
- Low cost, disposable and ‘self-powered’ wireless sensors
- Sensor networks, information retrieval and processing

2.26.2 Department of Pure and Applied Chemistry, Centre for Molecular Nanometrology

Director: Prof Duncan Graham

Key Contact:

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Biosensor/Biosensing Research Capabilities

The majority of the work conducted within the chemistry side of the Centre for Molecular Nanometrology focuses on the use of functionalised nanoparticles for the detection of a variety of different biomolecules. The biomolecular targets that are favoured include DNA, proteins, antibodies, antigens and small molecules of biological interest. This has been achieved by using functionalised nanoparticles that react with the specific biological target to yield a response that can be measured spectroscopically. The spectroscopic techniques include the Surface Enhanced Resonance Raman Scattering (SERRS), fluorescence and plasmon resonance. A number of different sensors have been developed and work is currently ongoing towards converting the in vitro work to in vivo. A consequence of this research has been the creation of a spin out

company, Renishaw Diagnostics Ltd which is currently commercialising the DNA sensing based aspects of the research.

Biosensor/Biosensing Related Research Projects

- DNA Detection by Surface Enhanced Resonance Raman Scattering (SERRS)
- New Labelling Chemistry for Biomolecules
- Enzyme Monitoring and Detection of Target Molecules (eg explosives and drugs) by SERRS
- Benzotriazole Chemistry
- Chemical Modification of DNA
- Proteomics analysis by SERRS
- Small biomarker analysis using SERRS and nanoparticles e.g. cytokines.
- Dip pen nanolithography using new chemical inks.

2.26.3 Institute of Photonics

Director of Research: Prof Martin Dawson

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Biosensor/Biosensing Research Capabilities

The Institute of Photonics is a commercially-oriented research unit within the University of Strathclyde. The Institute's key objective is to bridge the gap between academic research and industrial applications and development in the area of photonics. This is achieved through a portfolio of collaborative research and development projects which includes strategic long-term research, industrial contracts, academic-industrial collaborative research programmes, and consultancy.

The Institute conducts internationally leading research across a broad range of topics including: advanced solid-state lasers, diamond photonics, semiconductor materials and devices, hybrid and flexible photonics, advanced microfabrication, optogenetics and resulting applications.

Based on our expertise, we are developing underpinning photonic technologies for biosensors. The range of facilities available at the Institute of Photonics includes: semiconductor microfabrication and characterisation facilities, design, micro- and nano-patterning of soft- and hard materials, fully equipped optical labs.

Biosensor/Biosensing Related Research Projects

We are exploring the interface between Photonics, Nanotechnology and Chemistry to develop novel sensing solutions. In that context, we have been capitalising on our expertise in hybrid and flexible photonic devices for the following project.

An integrated and high-throughput diagnostic platform for biomolecule detection

Key contacts: Dr Nicolas Laurand, Dr Glenn Burley

The project is a collaboration between the Institute of Photonics and the Pure and Applied Chemistry department at the University of Strathclyde and a clinician at the University of Glasgow. The aim is to investigate the in vitro detection of biomolecules using 'nucleic acid resonator lasers'. The approach, based on an all-organic 'plastic' distributed feedback laser, benefits from the distinct advantages associated with optical biosensors but it is more amenable to miniaturisation than existing technologies, paving the way for full system integration of the sensor. Other advantages of our plastic laser biosensor include:

i. The sensing platform provides a direct (nano)interface with the biological world with no need to functionalise the sensor after fabrication (i.e. the device is inherently 'ready to sense').

ii. A plastic, conformable sensor is readily compatible for integration with disposable labware and is also seen as a path towards wearable photonic bio-instrumentation.

2.26.4 Medical Diagnostics, Bioengineering Unit

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Biosensor/Biosensing Research Capabilities

The Medical Diagnostics group, led by Professor Connolly, within the Bioengineering Unit at the University of Strathclyde is strongly focussed on Point of Care diagnostics and minimally invasive monitoring. As part of this focus we have a keen interest in a number of consumer health applications. One stream is concerned with monitoring levels of vitamins, ions, metabolites and other small molecular weight compounds (both in blood and skin) for applications within a pharmacy and home monitoring context. A second stream of research is concerned specifically with monitoring skin properties (such as permeability or structural changes) by rapid, cheap and non-invasive procedures.

We have developed sensors and instrumentation for in vivo human monitoring research. We have completed a number of in vivo studies, both in healthy volunteer and patient groups, which track changes in blood analyte concentrations, intact skin properties and wound management parameters.

- Sensors for monitoring skin properties, such as permeability and hydration
- Sensors for non-invasive blood analyte monitoring, such as glucose, lactate, vitamins and ions
- Sensors for monitoring a wound environment such as moisture, pH and bacteria

2.27 University of Surrey, Faculty of Engineering and Physical Sciences

Dean of Faculty: Professor Jonathan Seville

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Keywords highlighting areas of interest and expertise of group: antibodies, quartz crystal microbalance, piezoelectric sensors, microfluidics. nanoparticles, nanomaterials, amperometry, enzymes, membranes, electrochemistry, molecularly imprinted polymers, dual wave polarisation interferometry, dielectrophoresis, bio-assays

Biosensor/Biosensing Research Capabilities

At the University of Surrey, principal biosensor research is conducted in the Department of Chemistry and the Centre for Biomedical Engineering. We have expertise in developing biosensors for medicine, food and the environment as well as defence and security. Technologies include acoustic/piezoelectirc techniques (quartz crystal microbalance; QCM), electrochemical (amperometry, coulometry, impedance analysis);optical (dual wave polarisation interferometry); dielectrophoresis/microfluidics. nanoparticle modifications (silica, titania, carbon, conducting polymers; functionalised with proteins, enzymes and oligosaccharides); smart materials (molecularly imprinted polymers, permselective membranes); scanning probe microscopy.

Biosensor/Biosensing Related Research Projects

Dr Sub Reddy, Department of Chemistry, FEPS

- Smart Materials: Development of hydrogel-based molecularly imprinted polymers (HydroMIPs) for protein recognition. Development of synthetic receptor technologies to replace antibodies in bio-assays.
- Development of QCM biosensors for disease markers using HydroMIPs.
- Development of optical (dual wave polarisation interferometric) biosensors for disease markers (e.g. cancer and cardiac).
- Integration of pattern recognition and electrochemical techniques to develop diagnostic sensor arrays for biomedical and environmental monitoring.
- Study of molecular interactions in molecularly imprinted polymers using atomic force microscopy/spectroscopy
- Development of indicator dyes as smart patches in food packaging to measure food freshness.
- Development of surfactant-modified PVC membranes to improve biocompatibility and operability of biosensors.
- Application of HydroMIPs as novel nucleants for protein crystallisation

Dr Carol Crean, Department of Chemistry, FEPS

- Novel nanostructured biocompatible electrode materials
- Implantable electrode materials with improved electrical properties for biosensing
- Examining the influence of electrochemical pulsing on protein adsorption
- Attaching functional nanoparticles to proteins for biomarker sensing
- Nanomaterials development for diagnostics in healthcare

Prof Mike Hughes, Division of Mechanical Medical and Aerospace Engineering, FEPS

Prof Hughes acts as contact point for a group (including Drs Fatima Labeed, Kai Hoettges and Henry Fatoyinbo) studying the application of electric fields to concentrate, separate and analyse bioparticles including cells, viruses and bacteria. The majority of work involves the use of dielectrophoresis, a phenomenon of induced particle motion that can be used to analyse cell electrophysiology. This technology has recently been spun out to a company (DEPtech) that will bring a new product to market during the summer of 2012. Applications include:

- Stem cell differentiation
- Drug screening
- Apoptosis
- Oral cancer detection
- Cardiac electrophysiology

We have also developed an electrohydrodynamic technique for concentrating particles (from 10nm-10um diameter) from solution (to a depth of 3-500um) onto sensor surfaces, with applications for upstream preconcentration and sample preparation.

2.28 Swansea University

2.28.1 School of Medicine

Director of School: Prof. Gareth Morgan

Key Contact:

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Keywords highlighting areas of interest and expertise of group: DNA, FRET sensors, glucose sensors, surface plasmon based sensors, microarrays, bacterial biosensors

Biosensor/Biosensing Research Capabilities

Recombinant lectin for carbohydrate detection: expression, production and purification of protein-engineered lectin (rec Con A or rec Concanavalin A) for use in biosensors for sugars (glucose, mannose) and oligosaccharides (glycoproteins, glycopeptides, etc). The recombinant form of this protein is superior to the natural plant lectin in purity, stability and batch-to-batch variability, and should be advantageous for demanding biosensing applications (inc. nanotechnology areas).

Biosensor/Biosensing Related Research Projects

Con A is widely applicable as a recognition component in systems for measurement of glucose (diabetes glucose monitoring) and has been incorporated in diverse technology platforms including fluorescence-based (FRET) and surface plasmon resonance-based (optical nanosensors). However, greater affinity is shown for mannose-containing oligosaccharides, so that Con A binds to microbial structures (some bacterial lipopolysaccharides, mycobacterial polysaccharides and glycoproteins) as well as eukaryotic N-glycans of the oligomannose type (inc. glycoprotein gp120 of HIV). This lectin therefore has extensive applications in glycobiology and high-throughput glycomics for isolation and detection of glycoforms. It has been incorporated in lectin-arrays as well as being used as a labelled-probe with carbohydrate microarrays (carbochips).

See USA Patent No. US 7619072 (issued 17 Nov 09) and PCT Applicn. WO/2005/051987 for the advantages of engineered recombinant Con A over the native protein, particularly with regard to diabetic glucose sensing.

2.28.2 College of Engineering, Multidisciplinary Nanotechnology Centre (MNC) & Centre for NanoHealth (CNH)

Directors: Prof. Huw Summers (MNC, Engineering) / Prof Steve Wilks (CNH, Science) / Dr Steve Conlan (CNH, Medicine)

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Keywords highlighting areas of interest and expertise of group: antibodies, membranes, microfluidics, electrochemistry, DNA, enzymes, glucose biosensors, biofilms,microneedles, point of care, graphene,biosensors, nanowires,clinical trials facililities

Biosensor/Biosensing Research Capabilities

The Centre for NanoHealth (CNH), opened its new facility in Dec 2011. The £22m project, supported by the European Regional Development Fund through the Welsh Government, Swansea University (Colleges of Engineering, Medicine & Science), NHS and the Private Sector, is focussed on providing nanotechnology solutions to healthcare applications. A core theme of CNH is the development of novel biosensors for medical, industrial and environmental monitoring, building on our internationally recognised experience in:

- Biosensor technology based on semiconductor device platforms (graphene / SiC, silicon nanowires, ZnO nanowires)
- Semiconductor interfaces & devices
- Microneedles & microfluidics
- Point of Care (POC) device technology
- AFM studies of biological interfaces
- Rheological characterisation of complex fluids,
- Fermentation and membrane separation optimisation
- Printing & Coating aligned with biosensor, biomedical and biopolymer device fabrication
- Nanotoxicology
- Tissue engineering and smart scaffolds
- Intra-cellular nanosensors

The MNC/CNH has a comprehensive range of fabrication and imaging facilities:

- Nano / Micro fabrication facilities including: clean room (200 mm wafer capability) with electron beam lithography, photolithography, Nanoimprint Lithography (SCIL), PECVD deposition, ICP & DRIE etch & Rapid Thermal Furnaces;

and Printing & Coating facilities including Bioplotter and Aerosol Jet Printer.

- Imaging & characterisation: Cryo-SEM, EDX, XPS, AFM, EFM, STM, SNOM, Confocal fluorescence microsopy, Raman, FTIR, White light interferometery, Flow Cytometry.
- Rheometry and particle characterisation capabilities alongside NMR supported by polymer fabrication and analytical chemistry and bioprocess facilities.
- Tissue engineering, smart scaffold development, electrospinning.

Clinical trials facilities, collaboration with industry and the NHS are key reasons to engage with CNH.

Biosensor/Biosensing Related Research Projects

CNH has several interdisciplinary research initiatives focussed on the development of biosensors, including several prestigious EPSRC projects (Platform and Portfolio Partnership, Grand Challenge in Nanomedicine projects, graphene biosensors).

Current research projects with relevance to biosensors and biosensing include:

- EPSRC Grand Challenge: The study of blood clotting events using advanced rheometrical and NMR techniques; this is based on the quantification of parameters linked to the structure and mechanical stability of pre-clotting and clotting blood. The overall aim is to have a point of care facility that provides a wealth of information on the well-being of the individual. This work was recognised by the award of an EPSRC Grand Challenge grant for nanotechnology application to health care.
- EPSRC “Ultrasensitive Graphene Biosensors”: The development of biosensors based on epitaxial graphene (grown on silicon carbide) devices. Nanoscale graphene channels, functionalised with antibody bioreceptors have been used to detect cancer risk biomarkers at nanomolar concentrations.
- KTP (in collaboration with SPTS): Developing silicon and polymer microneedles, masters and microfluidics for integration into point of care diagnostic and drug delivery systems.
- NIHR (POC asthma sensor): Development of POC asthma sensors based on detection of nitric oxide – for improved diagnosis and effective management of asthma.
- The Welsh Centre for Printing and Coating (WCPC) group are building on their success in the large scale production of glucose sensors and breath sensors to study the printing of electronic circuitry in combination with biological materials such as DNA, collagen and a range of enzymes.
- A major research programme has been initiated for the development of an ultra-sensitive electronic nano-sensor that will be able to be implanted within the body and achieve real-time detection of biomarkers and transmission of information generated for remote external monitoring. This novel device will use bio-compatible ZnO nanowires as sensing elements and will be able to detect specific biomarkers by functionalising the nanowires using specific proteins. Prototype glucose sensors have already been developed at CNH.
- A core competence of the MNC is the direct measurement of the forces that act on single biological cells and proteins as they interact with surfaces in different environments, which is used to develop novel surfaces to control the biological interaction. Work on biocompatibility and biofilm formation is also being carried out to develop methods that quantify and control biological interactions at different surfaces including polymer membranes and electrodes used in biosensors.

- The MNC has extensive experience of synthetic membrane technology from fabrication and theoretical simulation to process application. This is now being applied to the development of smart membranes to aid the separation of chemical and biological species to improve biosensor application in complex environments. We are also developing biomimetic membranes to improve biocompatibility of implants and analytical devices.

2.29 University of Ulster, The Nanotechnology and Integrated BioEngineering Centre (NIBEC)

Director: Prof. James McLaughlin

2.29.1 Sensors Group

Key Contact:

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Keywords highlighting areas of interest and expertise of group: bio-chips, DNA, microarrays, electrochemistry, enzymes, glucose biosensors, potentiometry, microfluidics, point of care, graphene biosensors, vital signs sensing, micro total analysis systems (iTAS), nanotubes, wireless sensors

Biosensor/Biosensing Research Capabilities

The Sensors group has extensive experience and expertise in the design, fabrication and characterisation of a wide range of sensors and related devices (biosensing, vital signs, electrophysiological monitoring, pacing, defibrillation, iontophoresis). The group has major strengths in the areas of ac impedance/dielectric spectroscopy, cyclic voltammetry and potentiometry and in their use in the characterisation of materials, interfaces and devices and thus developing chemometric and physiologically derived algorithms for embedded onto integrated microprocessor solutions.. Work is carried out on modelling of the linear and non-linear electrical properties of electrode-electrolyte interfaces (platinum, iridium, Ag/AgCl, biological tissues, surface coatings, corrosion resistance) and materials (biological tissues, membranes, surface coatings). Recent work has developed new microfluidic based biosensors based on 1 micron gap impediometric inter-digitised electrodes. New projects are also underway in the areas of nanotubes/graphene electrochemical sensors, mid IR glucose detection, respiration patterns, SpO_2 sensing, pattern recognition and general wireless based vital signs monitoring as a connected health solution.

Biosensor/Biosensing Related Research Projects

Connected Health Innovation Centre (CHIC) is an Industry-led competence centre which is focused on collaborative research to support the connected health industry. Their members are drawn from a wide spectrum of business, clinical and academic interest including; health providers, medical device companies, systems integrators, health record specialists, clinical test experts and digital media developers. The centre is based in Northern Ireland and has strong links across local Government, Universities and public Health and Social care providers. The integration provides health and social care partners with collaborative projects which embrace a patient and citizen centric approach resulting in a faster time to market, resulting in economic and patient benefits.

Point of Care Sensing Systems. POC-Sensor Ireland is a Collaborative Project between the National Centre for Sensor Research at Dublin City University, the Nanotechnology and Integrated Bioengineering Centre at the University of Ulster and the Northern Ireland Health Trusts to establish a world-class virtual all-Island Centre in Point-of-Care Technology in Ireland. POC-Sensors work will lead to an enhanced understanding and control of the key processing stages involved in the design

and manufacture of sensor-and electrode-based micro-devices such as micro total analysis systems (ìTAS), bio-chips, bio-arrays and DNA sensors. It is anticipated that this fundamental work will lead to tangible technology transfer in the areas of blood analysis, cardiac enzyme detectors, liver and renal function, infectious diseases, gene disorders, etc. These will have major benefits to healthcare delivery and quality of environment on the island of Ireland, as well as substantial economic potential.

2.29.2 Carbon Based Nanomaterials Group

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Keywords highlighting areas of interest and expertise of group: DNA, graphene, carbon nanotubes, carbon based nanostructures,

Biosensor/Biosensing Research Capabilities

Our laboratory focuses in the research of carbon based nanostructures with specific application areas in alternative energy and biomedical sensor technologies. We focus on grapheme, carbon nanotubes, diamond nanorods and their hybrids for developing sensitive electrochemical biosensors for the direct quantification of nucleic acids, DNA drugs neurotransmitters and proteins. Microwave Plasma Enhanced Chemical Vapour Deposition and solution based strategies are developed for the controlled synthesis and functionalization of the novel carbon based materials.

Biosensor/Biosensing Related Research Projects

Electrochemical platform based on graphene nanosheets for biological Sensing.

The team has produced some pioneering results. Their primary contribution is the discovery of the electrocatalytic properties of graphene edges, employing a vertical array of self organised graphene sheets (http://www.nano.org.uk/news/oct2008/latest1647.htm).. This work has highlighted profound parallels between vertically aligned carbon nanotubes and graphene nanoflakes providing fundamental insights for the selective sensing of neurotransmitters and other analytes.

Graphene synthesised by solution approaches for detection of DNA and DNA drugs

We have demonstrated the potential of mildly reduced graphene oxide to become unique building elements in biosensors and electrocatalysis. The major thrusts of the research are the demonstration of graphene oxide disposable sensor for the enhanced detection of nucleic acids and the sensitive monitoring of the surface-confined interactions between the anticancer drug mitomycin C (MC) and DNA.

2.29.3 Biomolecular Diagnostics Group

Key Contact:

Group Leader: Prof James Davis (T) 028 90 366407 Email: james.davis@ulster.ac.uk

Keywords highlighting areas of interest and expertise of group: microfluidics, biofilms, smart bandage, smart catheter, functional materials, screen printing, stratified medicine, electroresponsive coatings

Biosensor/Biosensing Research Capabilities

Prod Davis' group specialises in the design and development of near patient test systems and have a particular interest in autonomous devices capable of providing a combined sensor-actuator function. The group has extensive facilities for the production of disposable sensors – based on photolithographic, screen printed or laser ablation patterning which can incorporate microfluidic reagent and sample delivery systems.

Biosensor/Biosensing Related Research Projects

Current projects involve: the design of smart bandages for wound monitoring and decentralised management, electroresponsive coatings for minimising microbial contamination within implantable medical devices and high throughput arrays for facilitating metabolomic analysis for the stratified application of medicines. The group has a long established expertise in the design of sensors for the detection of bacterial contamination and biofilm formation and this has been complemented by the recent development of composite films capable of generating reactive oxygen species. This has led to the production of smart catheter lines which are capable of detecting and actively responding to the presence of bacterial ingress and thereby counter the threat of biofilm formation

2.30 University College London/Imperial College, London Centre for Nanotechnology

Directors: Profs Gabriel Aeppli (UCL) and Milo Shaeffer (Imperial College)

Key Contact:

Dr Rachel McKendry (T) 0207 679 9995/0055 Email: R.A.McKendry@ucl.ac.uk

Keywords highlighting areas of interest and expertise of group: antibodies, bacterial biosensors, biochips,electrochemistry, immunoassays, enzymes, microarrays, microbial biosensors, microcantilevers, microfluidicsnanoparticles, nanostructured materials, photonic biosensors, surface plasmon resonance, whole cell biosensors. surface acoustic wave sensor, wireless sensors, point of care,

Biosensor/Biosensing Research Capabilities

The London Centre for Nanotechnology (LCN) is a UK-based multidisciplinary research centre, purpose-built to enable work at the forefront of science and technology. The LCN brings together two of the world's leading institutions, namely University College London and Imperial College London, with strong capabilities in the underlying disciplines - engineering, physical sciences and biomedicine - which are bridged by nanotechnology. The aim is to provide the nanoscience and nanotechnology needed to solve major problems in information processing, health care, and energy & the environment.

Biosensor/Biosensing Related Research Projects

i. **Cantilever Biosensor Microarrays**

- Miniaturised cantilever array technology to rapidly and selectively detect biomolecules.
- Optimised surface chemistry for femtomolar sensitivity.
- Surface characterisation – surface plasmon resonance, x-ray photoelectron spectroscopy, UV-VIS spectroscopy, electrochemistry, contact angle measurements.
- Theory & modelling.

- Novel holographic detection system for high-throughput screening applications.
- Portable, low cost silicon technology.

Key Applications: label-free biodetection of proteins, oligonucleotides, small molecule drugs (including antibiotics), bacteria (TB, MRSA) & viruses (HIV) and whole cells (CD4 T cells)

Investigators: Dr R. McKendry (LCN, UCL), Prof Robin Weiss FRS (Virology, UCL), Prof D. Pillay (Virology, UCL), Prof V. Emery (Virology, UCL & Royal Free Hospital), Dr J. Ndieyira (LCN, UCL), Prof G. Aeppli (LCN, UCL), Dr B. Hoogenboom (LCN, UCL), Dr D. Duffy (Physics, UCL), Dr T. Cass (Chemistry, Imperial), Prof M. Stevens (Materials, Imperial).

Collaborators: Prof C. Gerber (Basel).

Funding: £2M EPSRC Grand Challenge Award, BBSRC, COMPLEX (UCL).

Previous Industrial Collaborations: IBM Zurich, Veeco Instruments, Bio Nano Consulting

ii. Surface Acoustic Wave Sensors

- Next Generation Point of Care Diagnostics for HIV with wireless connectivity.
- Multimarker immunoassays.
- Nanoparticles.

Investigators: Dr R. McKendry (LCN, UCL), Prof R. Weiss FRS (Virology, UCL), Prof D. Pillay (Virology, UCL), Prof V. Emery (Virology, UCL & Royal Free Hospital),

Industry: OJ-Bio Ltd (Newcastle) and Japan Radio Company Ltd.

Funding: UCL Impact award, National Institute for Health Research.

iii. Point-of-Care Therapeutic Drug Monitoring Devices

Investigators: Dr R. McKendry (LCN, UCL), Dr D. Caruana

Industry: Sphere Medical Ltd.

Funding: Healthtech and Medicines KTN

iv. Micropatterning and Microfluidics

- Single cell microarrays fabricated via adhesive protein ‘patches’ (Dr R. McKendry, Prof B. Baum)
- Cell microfluidic assays (Dr G. Charras)
- Microfluidics and micropillar arrays to sort and preconcentrate markers – applications in whole blood for cell analysis (Dr D. Holmes, Prof T. Duke)
- Microfluidic devices with capacitive readout (Dr D. Holmes)
- Microfluidic devices with novel integrated photonic biosensors (Prof Aeppli, Dr P. Dalby)

Key Applications: single cell assays, protein assays, drug screening, testing new biocompatible materials.

Investigators: G. Charras (LCN, UCL) , J. de Mello (LCN & Chemistry IC), G. Aeppli (LCN, UCL), R. McKendry (LCN & Medicine, UCL), B. Baum (LMCB,UCL); P. Dalby (Dept. of Biochemical Engineering, UCL);

Industrial Collaborations: Centre for Integrated Photonics

Funding: MRC, BBSRC, BRIC, COMPLEX (UCL)

v. Advanced Nanoparticle Biosensors

- Nanoparticle bioconjugates for highly sensitive and specific detection of enzymatic biomarkers
- Advanced nanoparticle-peptide conjugate-based sensing mechanisms
- Colloidal gold colorimetric sensors for visually detectable signal transduction
- Fluorescent nanoparticle biosensors for highly sensitive and quantitative enzyme detection
- Inverse sensitivity sensors based on enzyme-directed crystal growth
- Optimised surface chemistry for biomolecule conjugation and colloidal stability
- Development of tools for advanced laboratory biomarker analysis as well as rapid testing
- Focus on translational technologies with high clinical potential

Key Applications: point-of-care testing, quantitative analysis of enzyme activity, diagnostic for a large range of disease (e.g. cancer, HIV, malaria, tuberculosis), versatile cross-platform technologies

Investigators: Prof Molly Stevens (Materials, Imperial)

Collaborators: Prof Luis M. Liz-Marzán (U. de Vigo, Spain) Dr Bruce Cohen (Lawrence Berkeley National Laboratory, USA)

Prof Francesco Stellacci (École Polytechnique Fédérale de Lausanne, Switzerland) Prof Michael Levin (Wellcome Centre for Clinical Tropical Medicine, UK) Dr Graham Cooke (Wellcome Centre for Clinical Tropical Medicine, UK)

Industry: Mologic (Alere), World Gold Council, National Physical Laboratory

Funding: EPSRC, ERC and The Wellcome Trust.

Additional information on biosensor activities at the Imperial College site of the LCN is listed under the main Imperial College entry. Key contact: Prof. Tony Cass.

2.31 University of Warwick, School of Engineering

Key Contact:

Julian Gardner Professor of Electronic Engineering (T) 02476 523695 Email: J.W.Gardner@warwick.ac.uk

Keywords highlighting areas of interest and expertise of group: microfluidics, neural networks, bacterial biosensors,, point of care, bioelectronics, olfaction, micro-electrodes,

Biosensor/Biosensing Research Capabilities

The Microsensors & Bioelectronics Laboratory (formerly Sensors Research Laboratory) was founded by Professor Gardner and has 10 research staff associated with it. Research is directed towards the field of microsensors and microsensor systems for the detection of chemical compounds in the gaseous and liquid phase. Microfabrication facilities exist that include designs suites, a small class 100 clean room, 4" wafer processing, metal and non-metal thin film deposition, microstereolithography for rapid prototyping of microfluidic packages, and microelectronics design software for smart sensors.

Biosensor/Biosensing Related Research Projects

- Research programmes include the fabrication of addressable micro-electrodes for biosensing, SOI CMOS sensors for headspace analysis, micro-noses for detection of pathogenic bacteria; smart surface acoustic wave based electronic tongues for the characterisation of various bioliquids.
- Recent programmes have been with small and large industries and hospitals and include the detection of bacterial infections in blood and urine samples in both clinical samples and more recently point-of-care samples.
- Considerable experience lies within the area of data processing from sensor array devices with novel parametric and non-parametric techniques developed.
- Latest work is in the area of the modelling and simulation insect communication as part of an EU funded project. For details see: www.warwick.ac.uk/go/ichem.
- A Centre for Cognitive and Neural Systems has been created at Warwick University with the Directors Prof Julian Gardner (Engineering) and Prof. Koen Lamberts (Psychology).

2.32 University of the West of England, Bristol, Institute of Bio-Sensing Technology

Institute Co-Directors: Prof. Richard Luxton and Prof. Janice Kiely

Key Contacts:

Prof. Richard Luxton	(T) 0117 3282472	Email: Richard.Luxton@uwe.ac.uk
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Keywords highlighting areas of interest and expertise of group: electrochemistry, microfluidics, bacterial biosensors, immunoassays,photonic biosensors, whole cell biosensors, impedance spectroscopy, fluorescence spectroscopy, printable electronics, screen printed biosensors, electroactive materials, bioluminescence, magnetic biosensors, conducting polymers, hyperspectral imaging

Biosensor/Biosensing Research Capabilities

The Institute of Bio-sensing Technology (IBST) seeks to integrate a broad range of expertise from a number of discipline areas to develop a focus for strategic development of new technology for bio-sensing. The Institute coordinates activities

to promote the development of bio-sensing technologies and acts as an interface between academia and industry, and a gateway for international knowledge exchange and collaboration. Academic partners at UWE working with the Institute include the Centre for Research in Biosciences, Centre for Health and Clinical Research, Centre for Complex Cooperative Systems, the Machine Vision Laboratory, and the Institute for Sustainability, Health and Environment to provide a multidisciplinary approach to scientific issues.

Research capabilities across Institues and Centres include:

- Disposable screen-printed electrochemical biosensors, immunosensors and their application in in vitro cell toxicity testing.
- Volatile organic carbon (VOCs) identification and detection in human and plant disease, off-taints on food.
- Paramagnetic particles as labels in biological affinity assays (immunoassay and DNA detection).
- Use of novel electroactive materials and printed electronics for biosensor applications
- Design and modelling of microfluidic devices
- Impedance spectroscopy for in vitro cell toxicity testing.
- 3D florescence spectroscopy for monitoring raw and wastewaters.
- Bioluminescence micro organisms as models systems and diagnostic indicators.
- Hyperspectral imaging for bioactive processes and biological systems
- Photometric Stereo for biomedical applications.
- Identification of novel biomarkers using genomics and proteomics.
- Design and development of novel prototype instrumentation.
- Signal processing and analysis of data from sensors.

Biosensor/Biosensing Related Research Projects

Development of electrochemical biosensors. Development of biosensors for the detection of a number of environmental and pharmacological important compounds using screen-printed electrodes and via HPLC with electrochemical detection; utilising GC/MS and spectroscopy on the degradation products of several important drugs and pesticides and the determination of trace levels of vitamins, coenzymes and drugs. One current example is a TSB funded project aimed at measuring low levels of metal ions in blood.

Magneto immunoassay. Development of reagent less, hand-held instrumentation and sensor technology based on paramagnetic particles as labels for the detection biological binding reactions is being developed. Projects based on magnetic detection include food quality and the development of diagnostic. One current project is NIHR i4i funded project working with North Staffordshire Health Trust focussing on non-invasive assessment of respiratory functions.

Acute Myeloblastic Leukaemia (AML) prognosis. Use of bacterial bioluminescence as an intracellular reporter; An example of a project in this area is a BBSRC funded project together with Nottingham University, developed a simple, rapid, test, using bioluminescent bacterial constructs, expressing lux genes, which are highly sensitive to cytosine arabinoside, to determine drug sensitivity of patient cells.

Volatile sensing projects Analysis of volatile organic compounds (VOCs) for biomarkers for disease diagnoses. Current work focuses on analysis of volatiles associated with humans, eg breathe, urine, stool analysis. An example of a current project is the Wellcome Trust funded OdoReader project in conjunction with the University of Bristol, and the University Hospitals Bristol NHS Foundation Trust. Aimed at rapidly diagnosing C. difficile, by analysing the gases from stool samples.

Novel materials and manufacturing process. Application of novel electroactive materials (nanostructured conducting polymers and electrocatalysts) to electrochemical sensors and biosensors, while also making these amenable to low cost mass production using technologies such as screen printing, inkjet printing and polymer MEMS fabrication. Integration of these sensors into functional diagnostic devices and systems eg point of care diagnostics using novel techniques such as breath monitoring and printed electronics technology. A current project is an EU collaborative project to develop paper thin sensors using printed electronics for testing cholesterol levels.

Cell based projects Development of whole cell biosensors using a range of technologies such as impedance, imaging, bioluminescence and in-situ biosensors. Example of an industrial funded project involves the development of a rapid toxicity testing system

Bioluminescence report systems Use of bioluminescent clinical strains of significant bacterial pathogens for evaluation of the pharmacodynamic effects of antibiotics; use of bacterial bioluminescence as an intracellular reporter; use of bioluminescent strains of food borne pathogens for evaluation of heat treatment of foods; the effect of low dose macrolide antibiotics on bacterial cell signalling. An example of an industry funded project in this area is the evaluation of the efficacy of disinfection regimes and sterilisation protocols using “glowing bacteria”.

Hyperspectral imaging is being used in a number of industry funded projects for applications in environmental analysis and biomedical research such as investingating anti-microbial effects.

Photometric stereo in dermatology. Adaptation of three-dimensional techniques for computer vision. Examples of projects are an EPSRC and MRC funding has been obtained to develop photometric stereo technology that is capable of capturing images of the skin, generating 3D views and analyzing the images to help experts differentiate between malignant melanoma and benign skin lesions

Marie Curie International Exchange Scheme and it currently at the stage of signing of Consortia Agreement. The project involves 9 partners, including USA, China and Ukraine. One aim of the project is to develop collaborative international links in the area of genetics and novel methodology for improving meat quality.

2.33 University of the West of Scotland, School of Engineering, Thin Film Centre

Key Contacts:

Dr Richard Fu (T) 0141 848 3563 Email: richard.fu@uws.ac.uk

Dr Stuart Reid (T) 0141 848 3610 Email: stuart.reid@uws.ac.uk

Keywords highlighting areas of interest and expertise of group: Mechanotransduction, human mesenchymal stem cells, hMSC, mouse lung endothelial cells, cell differentiation, bioengineering, regenerative medicine, surface acoustic wave, ultrasonic, piezoelectric, MEMS, lab-on-chip, microfluidics, cell manipulation, cell lysis, liquid mixing and pumping, nanostructured materials, cellular imaging

Summary of Biosensor/Biosensing Research Capabilities

Richard Fu, Reader in Physics (UWS)

Areas of interest: Lab-on-chip, surface acoustic wave, microfluidics, biosensing, smart materials and thin film, nanocomposites, shape memory, piezoelectric materials and devices.

Stuart Reid, SUPA Lecturer in Physics (UWS)

Areas of Interest: mechanotransduction in human mesenchymal stem cells (hMSC) and mouse lung endothelial cells, imaging related to cell morphology including KLF2 expression, calcium fluorescence, actin, vinculin, vimentin, Sox9, tubulin, osteocalcin, S100, STRO-1.

Biosensor/Biosensing Related Research Projects

Dr. Richard Fu:

Dr. Fu's main research work is focused on thin film based microfluidic bio-detection platform, based on surface acoustic wave, ZnO or AlN film and MEMS technologies. The biosensing lab-on-chip combines the functions of microfluidic transportation, mixing and bio-detection in a way that it can be used as a development tool for micro-diagnostic systems. Such thin film based lab-on-a-chip diagnostic systems will find use in both the consumer market for self-diagnosis and the professional healthcare market for real-time diagnosis in a hospital/clinic environment. Proof-of concept testing of the ZnO thin film based SAW devices have been done using biotin-strathavidin and prostate-specific antigen (PSA). Related work has been published in Appl. Phys. Lett., Sens. Actuat B, Biomicrofluidics, J. Appl. Phy. etc.

Dr. Stuart Reid:

Our preliminary work demonstrated, for the first time, that cells can respond to highly-coherent nanoscale mechanical displacements (paper submitted to Biophysical Journal). This work has stimulated a new research collaboration between CCE (Glasgow), the Thin Film Centre (UWS) and the Institute for Gravitational Research (Glasgow). The group is co-led by Dr. Matthew Dalby and Dr Stuart Reid. We are investigating this novel technique for influencing a key stem cell, the mesenchymal stem cell (MSC), for use in regenerative medicine. The principle aim is understanding mechanotransduction (how cells process mechanical signals) to allow us to develop simple stimulation protocols for cells in flasks (standard culture) to help provide high quality stem cells or targeted differentiation of specialised cells to clinic. This is presently a massive challenge (particularly when considering the aging population) and all other approaches being considered are highly complex and too costly for industry to take seriously. This pioneering work could provide a simple and cost effective route that could easily be incorporated to industrial cell growth. Significant efforts are being invested in imaging cell morphology and studying cell responses. Imaging includes: KLF2 expression, calcium fluorescence, actin, vinculin, vimentin, Sox9, tubulin, osteocalcin, S100, STRO-1.

Table showing area of interest and expertise versus University

	Amperometry	Antibodies	Aptamers	Bacterial biosensors	Bio-chips	Biofilms	Biofouling	Bioluminesence	BioMEMs	Carbon nanotubes	Cellular imaging	Clinical trials	Conducting polymers	Dielectrophoresis	DNA	Electrochemistry	Enzymes	Fibre optic sensors
Aston			▯				▯								▯			▯
Bangor													▯			▯		
Bath	▯			▯	▯	▯									▯	▯	▯	
Bolton										▯								
Bristol					▯													
Brunel	▯				▯					▯			▯		▯	▯	▯	
Cambridge	▯	▯		▯											▯	▯	▯	
Cardiff																		
Cranfield	▯	▯													▯	▯	▯	
Edinburgh		▯		▯	▯						▯			▯	▯	▯		
Exeter	▯			▯												▯	▯	
Glasgow					▯						▯							
Greenwich																▯		
Heriot Watt			▯	▯					▯		▯				▯			
Hertfordshire				▯					▯									
Hull					▯										▯			
Imperial College	▯	▯	▯		▯						▯				▯	▯	▯	
Leeds																▯	▯	
Manchester				▯									▯		▯			▯
Newcastle				▯	▯											▯		
Nottingham																		
Oxford	▯														▯	▯	▯	
Queen Mary						▯	▯									▯	▯	▯
Sheffield Hallam																	▯	
Southampton	▯								▯						▯	▯	▯	▯
Strathclyde		▯													▯		▯	
Surrey	▯	▯												▯		▯	▯	
Swansea		▯		▯		▯						▯			▯	▯	▯	
Ulster					▯	▯				▯					▯	▯	▯	
University College London/ Imperial College, London Centre for Nanotechnology		▯		▯	▯											▯	▯	
Warwick				▯														
West of England				▯				▯					▯			▯		
West of Sotland									▯		▯							

Table showing areas of interest & expertise versus University

	FRET sensors	Glucose biosensors	Graphene biosensors	Holographic biosensor	Immunoassays	Interferometry	Ion channel based sensors	Lab on a chip (LoC)	Lateral flow devices	Membranes	Microarrays	Microbial biosensors	Micro cantilevers	Microfluidics	Micro total analysis system (MicroTAS)	Minimally invasive Biosensor	Molecular imprinted polymers	Nanoparticles
Aston					▯					▯				▯				
Bangor																		
Bath	▯	▯		▯	▯					▯	▯			▯				▯
Bolton								▯			▯			▯				
Bristol								▯			▯							
Brunel		▯						▯	▯	▯	▯			▯			▯	▯
Cambridge	▯	▯		▯	▯		▯			▯	▯	▯	▯					▯
Cardiff	▯				▯													▯
Cranfield		▯								▯				▯			▯	
Edinburgh					▯						▯			▯				
Exeter		▯							▯		▯							
Glasgow								▯			▯							
Greenwich											▯							
Heriot Watt					▯			▯			▯		▯	▯				▯
Hertfordshire											▯			▯				
Hull								▯						▯	▯			
Imperial College	▯	▯			▯						▯			▯	▯	▯		▯
Leeds					▯		▯			▯								▯
Manchester														▯				
Newcastle			▯		▯		▯		▯									
Nottingham																		
Oxford					▯		▯			▯	▯			▯				▯
Queen Mary						▯				▯				▯				
Sheffield Hallam						▯												
Southampton														▯				▯
Strathclyde		▯									▯					▯		▯
Surrey						▯				▯				▯			▯	▯
Swansea	▯	▯	▯							▯	▯			▯				
Ulster		▯	▯								▯			▯	▯			
University College London/Imperial College, London Centre for Nanotechnology					▯						▯	▯	▯	▯				▯
Warwick														▯				
West of England					▯									▯				
West of Scotland								▯						▯				

Table showing areas of interest & expertise versus University

	Nanostructured materials/electrodes	Nanowire biosensors	Optical waveguide sensors	Photonic biosensors	Piezoelectric sensors	Point of care	Potentiometry	Protein biosensor	Quantum dots	Quartz crystal microbalance	Screen printing	Stochastic sensing	Surface acoustic wave (SAW)	Surface functionlisation	Surface plasmon based sensors	Synthetic biology	Whispering gallery mode sensors	Whole cell biosensors
Aston				▯											▯			
Bangor																		
Bath	▯			▯			▯								▯			
Bolton						▯							▯					
Bristol	▯			▯														
Brunel	▯					▯									▯			
Cambridge							▯								▯			▯
Cardiff				▯											▯		▯	
Cranfield	▯				▯		▯			▯								
Edinburgh						▯			▯							▯		▯
Exeter				▯											▯			
Glasgow		▯		▯		▯												
Greenwich	▯			▯														
Heriot Watt	▯					▯										▯		
Hertfordshire						▯												
Hull														▯				
Imperial College	▯					▯	▯		▯									
Leeds		▯					▯		▯						▯			
Manchester			▯															
Newcastle																		▯
Nottingham								▯										
Oxford												▯						
Queen Mary	▯									▯								
Sheffield Hallam			▯							▯					▯			
Southampton	▯		▯	▯					▯									
Strathclyde				▯		▯												
Surrey	▯				▯					▯								
Swansea		▯				▯									▯			
Ulster	▯					▯	▯				▯							
University College London/Imperial College, London Centre for Nanotechnology	▯			▯		▯							▯		▯			▯
Warwick						▯												
West of England				▯							▯							▯
West of Scotland	▯				▯								▯					

About ESP KTN

Electronics, Sensors, Photonics… plastic electronics, embedded systems, displays, lighting, instrumentation, control systems…it's all here at the Electronics, Sensors, Photonics Knowledge Transfer Network.

ESP KTN groups all these underpinning technologies together and more, to make a single entity focused on knowledge sharing for growth. We support our technology communities: and we reach out to bring together people that wouldn't usually meet, because sometimes the people you need to reach are not other technical people.

Our themes aim to address the Technology Strategy Board's "Challenge Led Agenda" for the key technology area of Electronics, Photonics and Electrical Systems.

Visit us at www.espktn.org or contact us at info@espktn.org

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SUSTAINABILITY

Electricity is our favourite form of energy: how can we generate it from renewable sources and how can we make our devices use less of it?

CONNECTED WORLD

The world is heading towards an 'internet of things': how can UK innovations make an impact, and how can UK PLC secure its place in this new paradigm?

TRANSPORT

Moving goods and people around is energy and time intensive: what can we do to improve this? Reducing the need for transport is one thing; another is to improve the efficiency of the transport that we have.

SECURITY

Defence and security especially civil resilience: but also more subtle aspects such as access to water, food and other resources.

QUALITY OF LIFE TECHNOLOGIES

Technology is enabling new capabilities in everything from medical diagnostics and treatment to new food processing techniques. Where are the key opportunities for UK companies, and what are the barriers to be overcome?

POWER

The journey from idea to product is a pipeline: we need to keep the creative end of the pipeline fruitful or it will run dry. Activities here include general support to universities and companies to take advantage of each other's knowledge