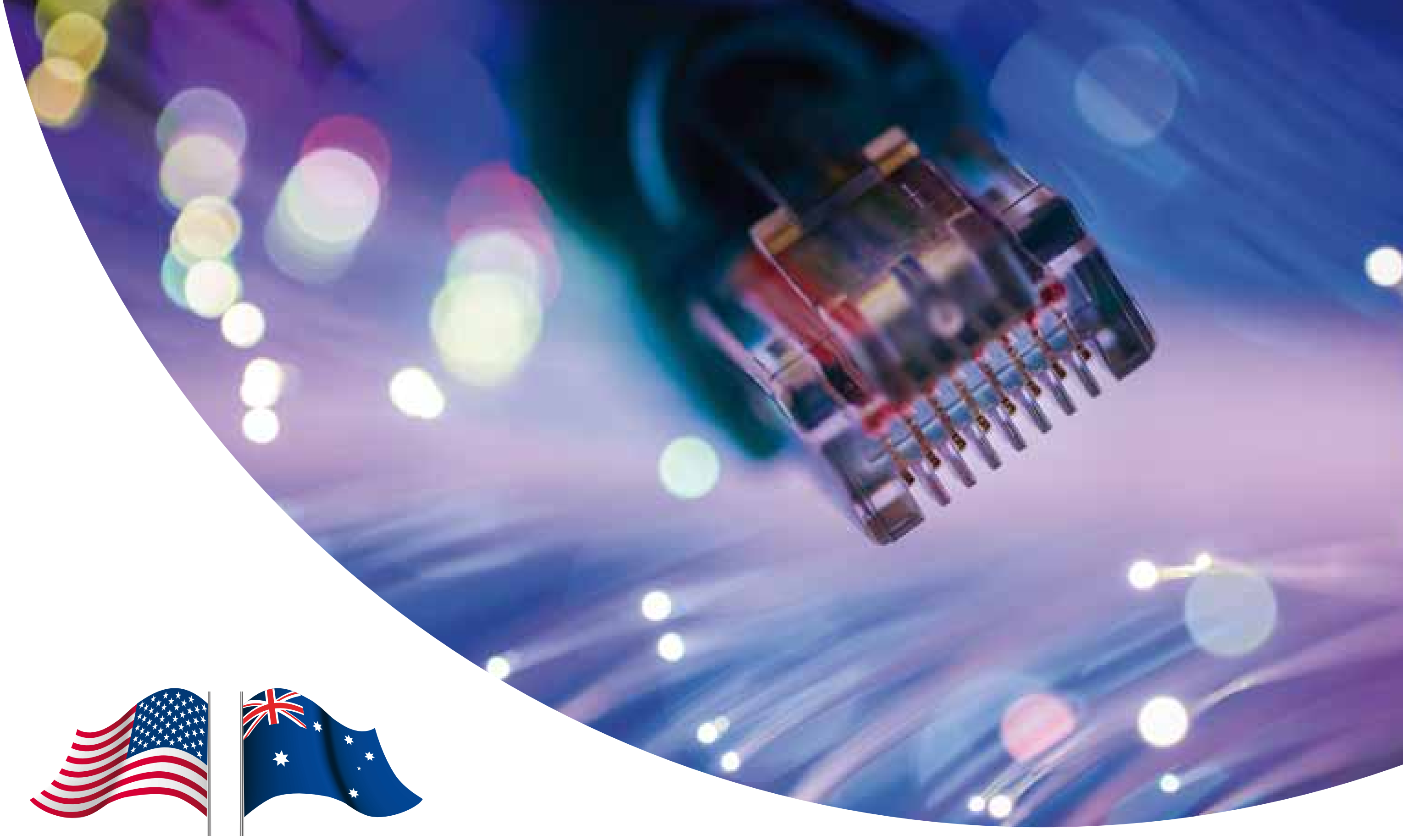


Enabling Technologies Technical Exchange Meeting

23–24 May 2016

ABSTRACT BOOK

University of New South Wales

Sydney, Australia

Air Force Office of Scientific Research (AFOSR)

ANFF
Australian National Fabrication Facility

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

Australian Academy of Science

Enabling Technologies Technical Exchange Meeting

Sydney, Australia – May 2016

Abstract Book

Welcome

Welcome to Sydney and the 2016 Enabling Technologies Technical Exchange Meeting, which is held under the auspices of the United States – Australia Joint Commission Meeting on Science and Technology.

The program is presented in three streams: materials science, physics and biomedical sciences, with a view to helping you establish and strengthen research collaborations with trans-Pacific colleagues.

We hope you find the technical exchange rewarding and enjoyable.

Co-Chairs:

Mrs Rosie Hicks, CEO *Australian National Fabrication Facility*
Dr Sofi Bin-Salamon, International Program Manager *Air Force Office of Scientific Research*

"This outstanding effort is the result of the exceptional resourcefulness and teamwork by everyone involved to build enduring scientific partnerships between the U.S. and Australia. As the relationships seed and grow, the importance of working together shines as the foundation to success."

Dr Bin-Salamon commenting on the 2015 Enabling Technologies Technical Exchange Meeting

With thanks to our host the University of New South Wales.
Organising committee: Ms Julie Ward & Ms Vanessa Dawson.

Delegates at the 2015 Enabling Technologies Meeting, Arlington VA.

Contents

Photoswitchable Bioprobes

Professor Andrew D. Abell
andrew.abell@adelaide.edu.au
Adelaide node leader ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP),
The University of Adelaide, Australia
Department of Chemistry, The University of Adelaide

The development of biosensors to detect biological markers associated with key biological processes and disease requires a detailed understanding of their molecular interaction with a receptor or reporter molecule. It also requires the development of new sensing platforms and architectures that can exploit these effects. This seminar will consider some of the fundamental chemical and biochemical ideas behind such endeavour and our efforts to exploit them in solution and on surfaces. Particular attention will be given to our recent work on developing switchable sensing platforms, the activity of which can be turned on and off photochemically and with other external stimuli.

1. *Photoswitchable Membranes Based on Peptide-Modified Nanoporous Anodic Alumina: Toward Smart Membranes for On-Demand Molecular Transport. Tushar Kumeria, Jingxian Yu, Mohammed Alsawat, Mahaveer D. Kurkuri, Abel Santos, Andrew D. Abell, Dusan Losic.* Advanced Materials ***2015***, 27, *3019.*

2. *Photoregulation of α-Chymotrypsin Activity by Spiropyran-Based Inhibitors in Solution and Attached to an Optical Fiber. Xiaozhou Zhang, Sabrina Heng, Andrew. D. Abell.* Chemistry A European Journal ***2015***, 21, *10703.*

3. *A Dual Sensor for pH and Hydrogen Peroxide Using Polymer-Coated Optical Fibre Tips. Malcolm S. Purdey, Jeremy G. Thompson, Tanya M. Monro, Andrew D. Abell, Erik P. Schartner.* Sensors ***2015***, 15, *31904.*

4. *Boronate Probes for the Detection of Hydrogen Peroxide Release from Human Spermatozoa. Malcolm S. Purdey, Haley S. Connaughton, Sara Whiting, Erik P. Schartner, Tanya M. Monro, Jeremy G. Thompson, Robert J. Aitken, Andrew D. Abell.* Free Radical Biology & Medicine ***2015***, 81, *69.*

5. *Unravelling the Interplay of Backbone Rigidity and Electron Rich Side-Chains on Electron Transfer in Peptides: The Realization of Tunable Molecular Wires. John R. Horsley, Jingxian Yu, Katherine E. Moore, Joe G. Shapter, Andrew D. Abell.* J. Am. Chem. Soc. ***2014***, 136, *12479.*

6. *Dual Sensor for Cd(II) and Ca(II): Selective Nanoliter-Scale Sensing of Metal Ions. Sabrina Heng, Adrian M. Mak, Daniel B. Stubing, Tanya M. Monro, Andrew D. Abell,* Analytical Chemistry ***2014***, 86, *3268.*

7. *Microstructured Optical Fibers and Live Cells: A Water-Soluble, Photochromic Zinc Sensor. Sabrina Heng, Christopher A. McDevitt, Daniel B. Stubing, Jonathan J. Whittall, Jeremy G. Thompson, Timothy K. Engler, Andrew D. Abell, Tanya M. Monro.* Biomacromolecules ***2013***, 14, *3376.*

8. *Optimising in situ click chemistry: the screening and identification of biotin protein ligase inhibitors. William Tieu, Tatiana P. Soares da Costa, Min Y. Yap, Kelly L. Keeling, Matthew C. J. Wilce, John C. Wallace, Grant W. Booker, Steven W. Polyak, Andrew D. Abell,* Chemical Science ***2013***, 4, *3533.*

Andrew is Professor of Chemistry at the University of Adelaide and Adelaide node director of the ARC Centre of Excellence for Nanoscale Biophotonics. A past postdoctoral fellow at the University of Cambridge with Professor Sir Alan Battersby and Professor of Chemistry at the University of Canterbury; visiting scientist, consultant and senior Fulbright Fellow with SmithKline Beecham (now GSK) in Philadelphia. Co-founded an Adelaide-based company Calpain Therapeutics (winner of The 2011 University of Queensland Business School's Enterprise competition), past Head of School of Chemistry and Physics at the University of Adelaide and member of the Australian Research Council (ARC) College of experts. Andrew is a recipient of the Royal Australian Chemical Institute Adrien Albert Prize, The Alexander R. Matzuk Prize and Lecture in Drug Discovery (Baylor College of Medicine, Houston), Royal Society of Chemistry Easterfield Medal, and he is currently Australian Fulbright Ambassador. His research interests are concerned with understanding and exploiting the fundamental link between the chemical structure and shape of key biological molecules and their biological function in solution and on surfaces.

Nanostructured Solid State Hydrogen Storage Materials

Nicholas Loeve, Francois Aguey-Zinsou
n.loeve@student.unsw.edu.au
Materials Energy Research Laboratory *in nanoscale* (MERLin)
School of Chemical Engineering, UNSW Australia

Hydrogen is the ultimate clean energy carrier. It can be generated using renewable energy sources and consumption produces its own feedstock. Along-side cost reductions in the fuel-cell stack and efficiency improvements in hydrogen production, wide-spread adoption of hydrogen energy systems is dependent on solving the storage issue.

The current de facto storage system of compressed H_2 at 700 bar has a cost of \$US17/kWh[1], which is more than double the DoE's Hydrogen Storage System targets[2]. Expensive high-tensile strength materials are required, and compressed gas is approaching a cost effective limit of ~5.5 wt% H2[2]. A solid state approach is required for much greater gravimetric energy density, safety and efficiency, and candidate materials should be relatively cheap and abundant if costs are to be minimised.

MERLin is working on improving the performance of solid state hydrogen storage materials such as metal alloys and high-capacity complex hydrides. By exploiting material properties at the nano-scale we have reduced the high temperatures required for discharging those materials[3,4], and improved kinetics[5,6] and reversibility[4,3] during hydrogen cycling. The group is currently looking finer control of morphology during nano-particle synthesis, approaches to nano-confinement, and potentially cheaper and more abundant materials for use into the future.

1. O'Malley, K. et al. *Applied hydrogen storage research and development: A perspective from the U.S. Department of Energy.* J. Alloys Compd. ***645***, *S419–S422 (2015).*

2. *Ordaz, G., McWhorter, S. & Satyapal, S.* Onboard Type IV Compressed Hydrogen Storage Systems – Current Performance and Cost. *(2013).*

3. *Christian, M. L. & Aguey-Zinsou, K.-F. Core–strategy leading to high reversible hydrogen storage capacity for NaBH4.* ACS Nano ***6***, *7739–51 (2012).*

4. *Lai, Q., Christian, M. & Aguey-Zinsou, K.-F. Nanoconfinement of borohydrides in CuS hollow nanospheres: A new strategy compared to carbon nanotubes.* Int. J. Hydrogen Energy ***39***, *9339–9349 (2014).*

5. *Setijadi, E. J., Boyer, C. & Aguey-Zinsou, K.-F. Remarkable hydrogen storage properties for nanocrystalline MgH2 synthesised by the hydrogenolysis of Grignard reagents.* Phys. Chem. Chem. Phys. ***14***, *11386–97 (2012).*

6. *Liu, W. & Aguey-Zinsou, K.-F. Low temperature synthesis of LaNi5 nanoparticles for hydrogen storage.* Int. J. Hydrogen Energy ***41***, *1679–1687 (2016).*

Kondo-Francois Aguey-Zinsou received a Masters in Surface and Interface Sciences in 1997 and completed a PhD in heterogeneous catalysis at the University Pierre et Marie Curie (Paris) in 2000. He carried out postdoctoral research at The University of Queensland (Australia) in bio-electrochemistry. In 2003, he joined the research centre GKSS in Hamburg and worked on the development of advanced materials for hydrogen storage. In 2005, he moved to Queen Mary University London, and later to University College London, where he supervised projects on hydrogen storage, biofuel cells, and biomaterials. In 2009, he joined the School of Chemical Engineering at UNSW (Sydney). His current research focuses on the properties of light metals and their hydrides at the nanoscale.

Nick Loeve is a PhD student with the MERLin group and is researching solid state ionic transport for electrochemical devices. He received a B.Eng (Chemical) with class 1 honours from UNSW in 2015.

Towards a 'proton battery' with an integrated carbon-based hydrogen-storage electrode

John Andrews* and Chun Wang**
john.andrews@rmit.edu.au
*Professor
**Professor, Director,
Sir Lawrence Wackett Aerospace Research Centre
School of Engineering, RMIT University, Melbourne

The innovative 'proton flow battery' concept (or 'proton battery' in short) was first proposed and experimentally tested by RMIT University in 2014 [1]. The proton battery employs a reversible PEM cell that in charge (or 'electrolyser') mode can produce protons (H+ ions) by water splitting on the positive electrode, and store these protons after passing through the nafion membrane directly in the opposite negative electrode made of a solid-state hydrogen storage material. In discharge (or 'fuel cell') mode, this process is reversed as protons return from the storage electrode through the membrane to the first electrode where they combine with electrons and oxygen to re-form water, thus producing an electric current in the external circuit. This technology combines the best features of hydrogen storage and batteries, and promises to be a critical enabling technology for efficient, long-duration electrical energy storage for use with renewable energy systems. Importantly the proton battery promises to have a much higher roundtrip energy efficiency than conventional hydrogen systems because critical conversions to and from protons and hydrogen gas are eliminated. In principle, its efficiency can equal lithium ion batteries, while storing more energy per unit volume and mass.

The early work at RMIT on the proton battery employed a composite metal hydride – nafion electrode for hydrogen storage. An AB5 metal alloy based mainly on La, Ce and Ni provided the sites for storing atomic hydrogen and conduction pathways for electrons, while the interspersed nafion medium allowed protons to reach the alloy particles [1]. However, the usual MH alloys employ heavy metallic elements, can catalyse the production of hydrogen gas, and contain expensive rare earth elements. Hence to minimise hydrogen gas evolution, lower the electrode cost and achieve a cost-competitive proton battery, we are now focusing on the use of carbon-based electrodes for proton storage. Previous work has shown a quite promising capacity of selected activated carbons with significant ultra-micro pores (less than 0.7 nm diameter) for reversible electrochemical hydrogen storage using an alkaline electrolyte [2,3]. We have recently measured experimentally similarly promising hydrogen storage capacities of a number of activated carbons with an acid-based electrolyte [4]. Novel graphene-based materials [5], and alternative proton conductors such as protic ionic liquids [6], also offer exciting possibilities in this application.

The Australian Defence Science and Technology Group, and the US Office of Naval Research Global, have both shown strong interest in providing seed funding for this research.

1. *Andrews, J. & Seif Mohammadi, S., 2014. Towards a 'proton flow battery': Investigation of a reversible PEM fuel cell with integrated metal-hydride hydrogen storage.* International Journal of Hydrogen Energy, *39, 1740-51.*

2. *Jurewicz, K. Frackowiak, E., & Beguin, F., 2002, Electrochemical storage of hydrogen in activated carbons,* Fuel Processing Technology, *77-78, 415-21.*

Professor John Andrews is the Leader of the RMIT Capability Technology Demonstrator Project, funded by the Australian Defence Science Technology Group, to develop and demonstrate a portable energy supply based on a reversible hydrogen fuel cell for defence applications. He has a BA(Nat Sci) (specialising in theoretical physics) and MA, from Cambridge University, UK, and a PhD from RMIT University. As leader of RMIT's renewable-energy hydrogen research group, he has published 16 scientific papers on topics related to the proposed ONRG project over the past five years, including the first proposal and experimental proof of the proton battery. He has successfully led a number of major energy research and development projects at RMIT over the past 20 years, including Project 6 in the CSIRO National Hydrogen Materials Alliance (2006-9) on renewable energy hydrogen systems. Earlier his book, *Living Better with Less* (Penguin 1981) was one of the first works to articulate a sustainable energy strategy for Australia, and while Policy Manager at the Victorian Solar Energy Council in the 1980s he played a pioneering role in introducing large-scale wind power to Australia.

3. Fang, B., Zhou, H., and Honma, I., 2006, Ordered porous carbon with tailored pore size for electrochemical hydrogen storage applications, Journal of Physical Chemistry B, ***110***, *4875-80.*

4. Oberoi, A., Andrews J., Karthik, M., D´Aguanno, B., 2015, Electrochemical hydrogen storage in activated carbons made from phenolic resin, paper presented at World Hydrogen technologies Convention, Sydney, October.

5. Wang, S., Ma, L., Gan, M., Fu, S., Dai, W., Zhou, T., Sun, X., Wang, H., Wang, H., 2015, Free-standing 3D graphene/polyaniline composite film electrodes for high-performance supercapacitors, Journal of Power Sources, ***299***, *347-55.*

6. Rana, U. A., Forsyth, M., Macfarlane, D. R. & Pringle, J. M., 2012, Toward protic ionic liquid and organic ionic plastic crystal electrolytes for fuel cells, Electrochimica Acta, ***84***, *213-22.*

ANSTO Research Infrastructure: A platform for international collaboration

Dr Miles Apperley
Head of Research Infrastructure
Australian Nuclear Science and Technology Organisation (ANSTO)
miles.apperley@ansto.gov.au

ANSTO is a public research organisation responsible for delivering specialised advice, scientific and research services as well as businesses and products primarily enabled by, or related, to nuclear science, technology and engineering. The organisation is responsible for the provision of quality advice to the Australian Government and regulators on all matters relating to nuclear science, technology and engineering. At its core ANSTO is a research organisation with programs across the themes of environment, human health and materials science and engineering. To underpin the research activity, ANSTO is custodian of a large portfolio of landmark, national and institutional based research infrastructure. The capabilities can be enabled by the operation of OPAL, Australia's research nuclear reactor (such as neutron scattering), serve to monitor and characterise nuclear systems (such materials processing and characterisation) or based on accelerator technologies (Australian Synchrotron). While serving the needs of ANSTO researchers and the Australian science and innovation sector more broadly through user focused access schemes, the infrastructure platforms enable Australian researchers to collaborate internationally. An overview of ANSTO research infrastructure capability will be provided with examples of the diversity of research that is supported and perspectives of how this enables international collaboration and engagement.

Miles joined ANSTO in 2016 following eight years managing and leading the Australian Microscopy and Microanalysis Research Facility (AMMRF), Australia's peak collaborative research facility for the characterisation of materials from the macro to the atomic length scales by means of advanced microscopy and microanalysis. He has spent more than twenty-five years planning, operating and leading research and development collaborations between industry and universities as well as multi-node, multi-disciplinary collaborative research infrastructure for the characterisation of matter (chemical, mineral, biological) across a broad range of resolution and sensitivity scales.

From 2004 to 2007 Miles was the Business Development Manager for the NANO Major National Research Facility, with the objective of increasing industry use of advanced characterisation facilities. Prior to 2004, he spent 15 years with Metal Manufactures Ltd, a large industrial products company, in a variety of technology development roles including Chief Technology Officer of Australian Superconductors, a subsidiary company established to develop and commercialise high-temperature superconductor based innovations and technologies.

He has been active in marketing and sales activities of new technologies and developing the IP and commercialisation strategies for new technologies. He has published in refereed journals, conference proceedings and trade literature and has lectured in intellectual property management and commercialisation at the University of Sydney.

Miles has a Bachelor of Metallurgical Engineering and a PhD from the University of New South Wales and extensive industry based R&D experience in collaboration with universities and national laboratories. He is a member of the Australian Microscopy & Microanalysis Society, a Graduate Member of the Australian Institute of Company Directors and an Associate Member of the Australasian Industrial Research Group.

Big Data Challenges for the Science of Small Things

Dr Amanda S Barnard
amanda.barnard@csiro.au
Office of the Chief Executive (OCE) Science Leader
Commonwealth Scientific and Industrial Research
Organisation (CSIRO)

For many years dealing with the complexity of inorganic materials, the polydispersivity of individual samples, and the persistent imperfection of individual nanostructures has been secondary to our search for novel properties and promising applications. For our science to translate into technology, however, we will inevitably need to deal with the issue of structural diversity and integrate this feature into the next generation of more realistic structure/property predictions. This issue is pervasive in materials science, but is particularly challenging in the field of nanoscience where atomic level precision is typically inaccessible (experimentally), but properties can depend on structural variations at the atomic scale. Fortunately there exists a range of reliable statistical and data-driven methods that are entirely applicable this domain; ideal for navigating and analysing enormous amount of information required to accurately describe realistic samples computationally. Combined with advances in automation and information technology the field of data science can assist us in generating, curating and analysing our big data, characterising our uncertainties, and more rapidly identifying useful structure/property relationships. Taking greater advantage of statistical and machine learning methods used in economics and bioinformatics involves thinking differently about materials research, but applied appropriately these methods can accelerate discovery. In this presentation we will explore the use of a range of data-driven methods and show, using graphene nanostructures as a case study, how the truly representative and pure nanostructures (the prototypes and archetypes) can be definitively identified and used to guide optimisation of entire polydispersed samples. We will see that, contrary to common assumptions, the lowest energy structures (the stereotypes) should not form the basis for extrapolations, and their overuse can often be misleading. This raises questions about much of the fundamental computational research in the literature based on the premise that the ground-state structure can be taken as 'typical', and sheds new light on the confounding discrepancies between computational and experimental results that hinder the translation of in silico discoveries into the lab.

Dr Amanda Barnard joined CSIRO as an ARC Queen Elizabeth II Fellow (2009–2013), and is currently an Office of the Chief Executive (OCE) Science Leader. She received her Ph.D. (Physics) from RMIT in 2003, followed by a Distinguished Postdoctoral Fellow in the Center for Nanoscale Materials at ANL (USA), and the prestigious senior research position as Violette & Samuel Glasstone Fellow at the University of Oxford (UK) with an Extraordinary Research Fellowship at The Queen's College. Dr Barnard is a Senior Associate Editor for Science Advances (AAAS), a member of the Panel of Expert Advisors (Physical Sciences) for the Nature Index (Nature Publishing Group). She has published over 180 peer-reviewed journal articles and 13 chapters, with over 5700 citations and an h-index of 40 (Google Scholar). She has previously won (among other awards) the 2009 Young Scientist Prize in Computational Physics from IUPAP, the 2009 Malcolm McIntosh Award from the Prime Minister of Australia for the Physical Scientist of the Year, the 2010 Frederick White Prize from the Australian Academy of Sciences, the 2014 ACS Nano Lectureship (Asia/Pacific) from the ACS, and in 2014 was the first woman to win the Feynman Prize for Nanotechnology (Theory) from the Foresight Institute.

Non-destructive detection and trapping of nanoscale biomolecules

Nicolas Mauranyapin, Lars Madsen, Waleed Muhammad, M. A. Taylor, W. P. Bowen
1. Centre for Engineered Quantum Systems, University of Queensland, St Lucia, Queensland 4072, Australia

Biosensors that are able to detect and track single unlabelled biomolecules are an important tool both to understand biomolecular dynamics and interactions, and for medical diagnostics operating at their ultimate detection limits. Recently, exceptional sensitivity has been achieved using the strongly enhanced evanescent fields provided by optical microcavities [1] and plasmonic resonators [2]. However, at high field intensities photodamage to the biological specimen becomes increasingly problematic. Here, we introduce an evanescent biosensing platform that operates at the fundamental precision limit introduced by quantisation of light. This allows a five order-of-magnitude reduction in optical intensity whilst maintaining state-of-the-art sensitivity and enabling shot noise limit tracking of biomolecules with Stokes radii as small as 3.5 nm. A combination of electrostatic and optical trapping allows even the smallest observed biomolecules to be stably trapped, and their motion tracked with a nanoscale precision. Surface-molecule interactions can then be monitored over extended periods, providing a mechanism to selectively differentiate between biomolecules. By reaching the quantum noise limit to precision, our approach opens the door to enhance the precision of single-molecule biosensors using quantum correlated photons [3].

[1] M. D. Baaske, M. R. Foreman and F. Vollmer, Nature Nanotechnology **9** *933-939 (2014).*
[2] Y. Pang and R. Gordon, Nano Letters **12** *402-406 (2012).*
[3] M. A. Taylor et al. "Biological measurement beyond the quantum limit" Nature Photonics **7** *229 (2013) ; M. A. Taylor et al. "Sub-diffraction limited quantum imaging in a living cell", Physical Review X* **4** *011017 (2014).*

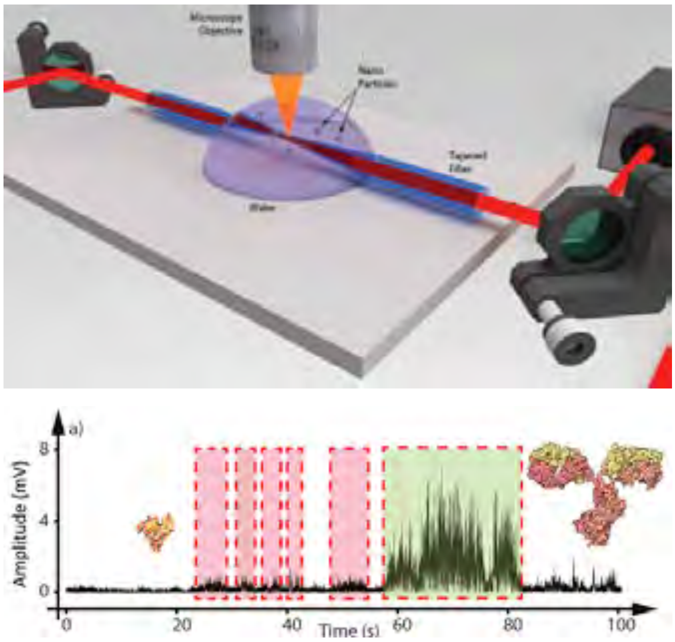


Fig. 1 Top: Apparatus for quantum-limited unlabelled biomolecule detection. Bottom: Trapping signals for (red shading) bovine serum albumin (BSA) and (green shading) anti-E-coli antibody.

Associate Professor Warwick Bowen leads the Queensland Quantum Optics Laboratory at the University of Queensland, Australia ; and is the Queensland Node Manager and Quantum Nano/Opto-mechanics Program Manager of the Australian Centre for Engineered Quantum Systems. He has an Australian Research Council Future Fellow. His laboratory undertakes research in the quantum physics of micro- and nano-scale optical devices, with the aims of both testing fundamental physics and developing quantum technologies with future applications in metrology, communication, and biomedical imaging and diagnosis; and is funded through a variety of sources including the Australian Research Council (ARC), the Air Force Office of Scientific Research (AFOSR), the Defense Advanced Research Projects Agency (DARPA), and Lockheed Martin Ltd.

Nano-scale characterisation for defence materials

Julie M. Cairney
julie.cairney@sydney.edu.au
Professor/Director
The Australian Centre for Microscopy and Microanalysis,
The University of Sydney

Advanced microscopy is essential to the development of materials for defence applications. This presentation will provide examples of work being undertaken at the Australian Centre for Microscopy and Microanalysis with defence applications.

The first of these projects involves the use of in-situ deformation in a transmission electron microscope to observe the stress induced ferroelectric rhombohedral to ferroelectric orthorhombic phase transformation in [011] cut $Pb(In_{1/2}Nb_{1/2})O3$ $–Pb(Mg_{1/3}Nb_{2/3})O3$ $–PbTiO_3$ (PIN-PMN-PT) single crystals. When these crystals are mechanically driven through the phase transformation, a voltage can be measured [1]. The crystals therefore behave as a charge source and have the potential to be used to harvest energy. Direct microscopic observations of the stress induced R-O phase change can confirm the mechanism by which this occurs, allowing the design of higher performance functional materials. This work is being undertaken in collaboration with Scott Moss at DSTO and Peter FInkel at the Multifunctional Materials Branch, Naval Research Laboratory, Washington, DC, USA.

The second project involves understanding the behavior of boron carbide, which, as a result of its high hardness, is an excellent candidate for use in personal body armor. By using atomic scale microscopy, we are aiming to explain why it undergoes a dramatic loss of ballistic performance in high-energy impacts. By using the advanced characterisation technique of atom probe tomography, we observe the breaking of individual icosahedra during field evaporation of boron carbide in a laser-assisted atom probe. Detailed analyses of the precise experimental evaporation behavior, together with quantum mechanics simulations, provide information about the relative stability of icosahedra and chains, indicating that the icosahedra in boron carbide are not as stable as previously anticipated. This result provides new insight on the structural instability of boron carbide and its shear amorphisation. This work was carried out in collaboration with Kevin Xie and Kevin Hemker at Johns Hopkins University and was sponsored by the Army Research Laboratory.

[1] WD Dong, P Finkel, A Amin, KA Cunefare, CS Lynch, Journal of Intelligent Material Systems and Structures 25 (14), 1786-1799, 2014

Professor Julie Cairney is a Professor of Engineering at the University of Sydney and serves as Director of the university core facility, Sydney Microscopy and Microanalysis. She is also the Director of the University of Sydney Node of the Australian Microscopy and Microanalysis Research Facility.

She leads a research group that focuses on the relationship between microstructure and properties of materials. She is currently investigating materials such as advanced alloys for aerospace and mining, multilayers for fuel cells, and catalyst nanoparticles for biofuel production by using atom probe microscopy, a technique that provides atomic-scale 3-dimensional maps revealing the precise composition and structure of small volumes of material.

She is the author of over 140 publications, cited 1500+ times, including a book on the subject of atom probe microscopy. She serves on the Australian Research Council College of Experts and the New Zealand Marsden Fund. She is an advisory board member for the journal Ultramicroscopy and has been elected to the Steering Committee of the International Field Emission Society (who represent the atom probe community). She is one of the youngest full professors at the University of Sydney, and one of only a handful of female professors of engineering in NSW.

Developing a platform technology for the self-assembly of functional nanoparticles

Andrew Care[a], Anwar Sunna[b], and Nicolle H. Packer[a]
andrew.care@mq.edu.au
Research Fellow
[a] ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP), Macquarie University, Sydney
[b] Department of Chemistry and Biomolecular Sciences, Macquarie University, Sydney.

Nanoparticles (NPs) show great promise as optical probes and delivery vehicles for bioimaging, diagnostics and therapeutics. However, most conventional bioconjugation techniques used to functionalise NPs with antibodies (e.g. amine-reactive crosslinking) are often laborious and inefficient. In many cases, antibodies attach to NPs with altered conformations and random orientations that cause a reduction or loss of biological activity. Furthermore, NPs have a propensity to aggregate after functionalisation, which presents potential safety concerns for *in vivo* applications.

We have established an alternative functionalisation method using a smart peptide linker sequence that displays high binding affinity towards materials that contain silica. The linker sequence can be genetically fused to a protein of interest and the resulting recombinant fusion protein (Linker-Protein) exhibits strong affinity to a range of silica-based materials. This linker system has been used to produce a Linker-Antibody Binding Protein (L-ABP) that acts as an anchorage point for the orientated immobilisation of antibodies onto the surface of silica-coated (Si-) NPs within minutes and without the need for complex surface chemical modification. Thus, L-ABP represents a potential solution to the current limitations faced in NP functionalisation.

The aim of this research is to build a platform functionalisation technology for Si-NPs based on L-ABP. This includes an investigation into the stability, biocompatibility and functionality of this technology in complex living systems (e.g. cell-labelling and targeted delivery), and in-depth characterisation of the biophysical interactions between L-ABP and the surface of Si-NPs, specifically the mechanisms underlying recognition, selectivity, and binding affinity.

Andrew Care was awarded a PhD from Macquarie University, Sydney in 2015. During this time his research focussed on the application of genetically-engineered peptides to control the self-assembly and biofunctionalisation of nanomaterials and biomolecules. This work yielded an innovative bioconjugation technology for the simple and rapid biofunctionalisation of nanoparticles for cell capture, detection and imaging; and a novel method to rapidly attach multiple lanthanides to biomolecules to impart luminescence for time-resolved bioimaging. At present, Andrew is a Research Fellow in the ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP), a transdisciplinary research centre that aims to develop innovative nanotechnologies to investigate complex living systems.
His current research interests include the design and development of new delivery platforms for biomedical purposes.

Ultrathin polymer supported metal-organic framework and graphene oxide nanocomposite membranes for gas separation

Jingwei Hou[1], Putu Doddy Sutrisna[1], Yatao Zhang[1,2], Hongyu Li[1] and Vicki Chen[1*]

1.UNESCO Centre for Membrane Science and Technology, School of Chemical Engineering, University of New South Wales, Sydney, NSW 2052, Australia

2. School of Chemical Engineering and Energy, Zhengzhou University, Zhengzhou 450001, PR China

*Presenting author: **v.chen@unsw.edu.au** (Vicki Chen); Tel: +61-2-9385 4813

The potential of using metal-organic framework (MOF) material and 2D materials such as grapheme oxide (GO) for gas separation has received wide spread interest. Using porous polymer membranes, which are easy to fabricate and mechanically stable to form gas separation devices with MOFs of GO still faces some challenges to form defect free devices. These include but not limited to poor adhesion between polymer supports, difficulty in obtaining a thin but stable coating layer, and the aggregation of MOF nanoparticles or GO in the membrane matrix.

Currently, our group has focusing on the synthesis of polymer nanocomposite membranes for gas separation via various approaches including layer-by-layer coating on polymer membrane, blending in membrane matrix, and in-situ crystallisation on supporting polymer membrane surfaces. For example, by adding the pre-synthesised ZIF-8, UiO66, MOF-74 and grapheme oxide into PEO-PA block copolymer and subsequent of coating the selective layer onto a porous membrane surface, thin nanocomposite membranes exhibited significantly improved CO_2 permeance while the CO_2/N_2 selectivity was relatively unchanged when compared with pure polymer benchmark.

Using a novel *in situ* crystallisation technique, a coherent ZIF-8 layer can also be synthesised as a coherent ultrathin layer onto the polymer membrane surfaces using a facile, rapid, one-pot approach.[1] These pure ZIF membranes were showed unusual flexibility as well as one of the highest H_2 permeances (60,000 GPU) for molecular sieving ZIF-8 membranes.

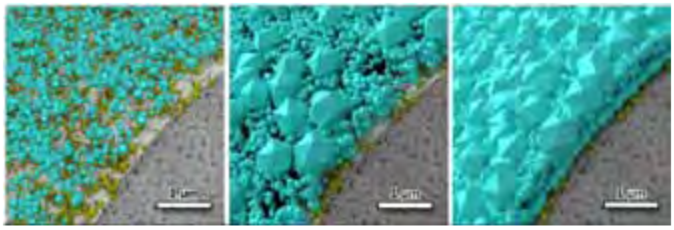


Figure 1: Nucleation of ZIF-8 to form an ultrathin MOF layer on porous polymeric substrate.

1. Jingwei Hou, Putu D. Sutrisna, Yatao Zhang, and Vicki Chen, Facilitating Formation of Ultrathin, Continuous Metal-organic Framework Membranes on Flexible Polymer Substrates using Nanostructured Titania Coating, Angewandte Chemie, 55 (2016) 3947 – 3951.

Vicki Chen is currently a professor and the Head of School of the School of Chemical Engineering at the University of New South Wales. She graduated from the Massachusetts Institute of Technology with a B.S. Chemical Engineering and the University of Minnesota with a Ph.D. Chemical Engineering. She was the Director for the UNESCO Centre for Membrane Science and Technology from 2006 to 2014. Her current areas of research interests are: colloidal and macromolecular fouling in membrane systems, membrane bioreactors, nanocomposite membranes, biocatalytic membrane processes, membrane distillation and crystallisation, antifouling functionalisation, and membrane separation for removal of greenhouse gases. In addition to numerous projects supported by the Australian Research Council, she has led projects with the CRC for Polymers, CRC for Greenhouse Gas Technologies, National Centre of Excellence for Desalination (NCEDA), and Australia Low Emission Coal R&D. She has served as a board member of the NCEDA and editor for Desalination Journal. She was also a founding board member for the Membrane Society of Australasia and is on the editorial board of the Journal of Membrane Science.

Measurement standards for nanotechnology

B. Babic, V. A. Coleman, C. Freund, J. Herrmann, Å. K. Jämting, and M. A. Lawn

1 Nanometrology, National Measurement Institute Australia, Lindfield, NSW 2070, Australia

Accurate measurements of the physical and chemical characteristics of nanomaterials and nanostructures are critical for the development of nanotechnologies, from the scientific discovery stage through to the responsible translation of the discoveries into applications and products. Nanometrology, the science of nanoscale measurement, helps to ensure that measurements of the relevant properties are quantifiably comparable. It thus not only facilitates the design and implementation of nano-enabled functionality, but also enables the evaluation of the technology's potential risks for human health and for the natural environment.

Quantifiable comparability requires an agreed reference frame, such as that provided by the international system of units (SI). Traceability of nanoscale measurements to the SI is particularly important for emerging regulations for nanomaterials that rely on measurement-based definitions. We provide an update on the development and performance evaluation of NMIA's metrological scanning probe microscope, an ultra-stable instrument that uses laser interferometry to perform SI-traceable nanoscale length measurements with sub-nanometre accuracy. In this context, we highlight the critical role of primary standards, transfer standards such as calibration artefacts, reference materials as well as documentary standards.

Realising the potential of nanostructures and nanomaterials for many applications, for example in diagnostics and therapeutics, relies on an understanding of their interactions with biological systems. Some of the most relevant fundamental nanomaterial properties for such studies include the number and/or mass concentration, chemical composition, particle size distribution, agglomeration/aggregation state, surface charge and surface chemistry. Reliable characterisation of these parameters in nanoscale systems presents numerous challenges, particularly in application-relevant matrices such as tissue, physiological fluids, food or environmental systems. No single measurement technique or instrument is capable of addressing all of these challenges, and often a combination of different measurement methods needs to be applied. Separation techniques, for example field flow fractionation, especially when combined with high-throughput, single particle-level detection techniques such as single particle inductively-coupled plasma mass spectrometry, offer a promising route to the characterisation of nanomaterials with size, shape, and compositional polydispersity, especially at low concentrations. We illustrate some of the differences and complementarities of relevant measurement techniques using practical examples, derived both from our experience at NMIA, from collaborative efforts with partners at the U.S. Food and Drug Administration's National Center for Toxicological Research, and from our participation in international laboratory comparisons. We use these examples to highlight the critical role of standards to help advance research and aid in regulatory oversight for responsible development of nano-enabled products.

Victoria Coleman leads the Nanometrology Section at the National Measurement Institute Australia, which holds Australia's primary standard for nanoscale dimensional measurements. The team focuses on accurate and fit-for-purpose nanoscale measurements; including developing and evaluating methods with a focus on the characterisation of nanomaterials.

Stimulating and Imaging: Integrating Non-invasive Biomedical Technologies

Stephen Crain and Paul Sowman
stephen.crain@mq.edu.au
paul.sowman@mq.edu.au
Macquarie University

This project integrates two non-invasive biomedical technologies, tDCS and MEG. tDCS is a form of non-invasive brain stimulation which delivers constant, low-current electrical stimulation to regions of interest in the cortex via electrodes attached to the scalp. A negative charge can be used to hyperpolarise neurons, decreasing their excitability. A positive charge can be used to increase excitability. In this way tDCS can be used both to enhance and to retard cognitive performance on tasks that are controlled by targeted brain areas. Furthermore, tDCS can be used as a treatment method for disorders that are characterised by abnormal brain activation, such as depression and post-traumatic stress disorder (PTSD). The next challenge in using non-invasive brain stimulation is to understand which areas of the brain are effectively stimulated by tDCS, and why some subjects respond to tDCS while others do not.

This is where MEG enters the picture. MEG is a non-invasive brain-imaging device that detects cortical activity generated in the brain whenever we process information. MEG signals are detected by specialised superconducting sensors that are cooled with liquid helium. MEG allows us to measure the contents and processes of the mind – sensations, perceptions and emotions, as well as language and other higher-level cognitive processes. MEG has proven to be a valuable tool for investigating study how the contents and processes of the mind are disrupted when the brain fails to function normally. MEG works like a sensitive detection device (e.g., a microphone) that does not produce signals of its own. MEG is quiet and noninvasive, so it is uniquely suitable for the study of human brain function in patients with neurological or psychiatric disorders. MEG has excellent spatial resolution, allowing precise localisation of brain activity during tDCS stimulation. Moreoever, MEG has exquisite temporal resolution, allowing msec accurate measurement of unfolding cognitive processes. This feature of MEG also enables us to interrogate the effects of tDCS on oscillatory functions (brainwaves), which represent fundamental units of neural computation. ▶

Stephen Crain is a Distinguished Professor of Linguistics at Macquarie University, and Director of the Australian Research Council Centre of Excellence in Cognition and its Disorders. He came to Australia in 2004 as an ARC Federation Fellow to develop brain-imaging technologies to investigate children's language and logical competence. Since, he has led international teams of researchers and engineers in developing three brain-imaging systems using MEG (magnetoencephalography): (a) the first whole-head adult system in Australasia (est. 2006), (b) the world's first MEG system to study cognitive processing in children (est. 2008), and (c) a prototype MEG system for children and adults with Cochlear Implants (est. 2013). Crain is currently the Director of the International Center of Child Language Health, in Beijing China. Crain's research is in child language acquisition, adult language processing and neurolinguistics. Most recently, he has been using MEG to investigate children's acquisition of logical expressions across languages, including Chinese.

Paul Sowman is Associate Professor in the Department of Cognitive Science at Macquarie University, and he is an Associate Investigator at the ARC Centre of Excellence in Cognitions and its Disorders. Sowman graduated with a PhD in Physiology from the University of Adelaide in 2008. Since then he has undertaken research postings at the Neuromuscular Laboratory, University of Adelaide, the Center for Sensory Motor Interaction, Aalborg University Denmark and the Center for Brain Research, Ege University Turkey. He has held fellowships from both the NHMRC fellow and ARC fellow whilst in his current position within the Department of Cognitive Science at Macquarie University in Sydney. His research uses Magnetoencephalography and non-invasive brain stimulation methods to understand cognitive processes underpinning normal and abnormal speech production. He has a particular interest in inhibitory control processes and in disorders of inhibitory control that affect speech such as stuttering and Tourette syndrome.

The present project proposal is to use MEG to monitor, analyse and predict the effects of tDCS on human brain function, and to explain individual differences in brain responses to tDCS. A future goal is to use concurrent tDCS and MEG to examine different tDCS stimulation modes for neuroimmune based enhancements in human cognitive performance.

Organic Materials Device Chemistry: Synthesis, Characterisation and Fabrication

Paul Dastoor
Centre for Organic Electronics, University of Newcastle, Callaghan, NSW 2308, Australia
Paul.Dastoor@newcastle.newcastle.edu.au

Organic electronics offers the opportunity for the development of electronic circuits and devices that can be manufactured at low cost on flexible substrates using conventional printing technologies. By contrast, the manufacture of traditional silicon-based electronic devices involves complex photolithography and deposition processes, which are multi-staged, capital equipment intensive and use environmentally hazardous materials with the consequent production of large amounts of waste.

However, the realisation of large scale printed electronics involves addressing the multiple challenges of large scale materials synthesis, characterisation of delicate organic materials and reel-to-reel (R2R) printing of organic electronic devices. Recent work at Newcastle has centred on each of these aspects of organic materials device chemistry. Firstly, rational materials synthesis and system design has led to the development of new mixed acceptor systems that are capable of delivering printed organic photovoltaic (OPV) devices at scale and a cost that is compatible with R2R processing. Secondly, our work on scanning X-ray transmission microscopy has recently been augmented by the development of the world's first functioning scanning helium atom microscope (SHeM). The completely non-damaging nature of the probing helium atoms makes the SHeM uniquely suited to imaging delicate systems on the nanoscale. Finally, recent advances in the fabrication of devices via a hybrid R2R manufacturing route has allowed the facilitation of the first R2R OPV devices in normal geometry; offering advantages in film absorption and device architecture.

Paul Dastoor is a Professor of Physics and Director of the Centre for Organic Electronics at the University of Newcastle in Australia. He received his B.A. degree in Natural Sciences and his PhD in Surface Physics from the University of Cambridge. He has been a Visiting Research Fellow at the Cavendish Laboratory Cambridge, UK, Daresbury Laboratory, Cheshire, UK and at Nanyang Technological University, Singapore. He has been a CI on grants and contracts totalling in excess of $20M and has published over 130 papers in refereed journals. His research is focussed on the development of electronic devices based on semi-conducting polymers, which offer the tantalising prospect of paints that generate electricity directly from sunlight and sensors that can be printed as flexible arrays.

Spin-based Quantum Computing in Silicon

Andrew Dzurak
Director, ANFF-NSW
School of Electrical Engineering & Telecommunications
The University of New South Wales,Sydney,2052
a.dzurak@unsw.edu.au

Quantum technologies promise to revolutionise the way information is processed by utilising devices that enable sensing and manipulation of individual electrons. ANFF-NSW supports a number of world-leading research efforts in developing semiconductor *qubit* devices for quantum computing. This talk highlights the development of silicon-based qubits supported by the Australian Research Council Centre of Excellence for Quantum Computation and Communication Technology, the Australian National Fabrication Facility, the US Laboratory for Physical Sciences, and US Army Research Office.

Spin qubits in silicon are excellent candidates for scalable quantum information processing [1] due to their long coherence times and the enormous investment in silicon CMOS technology. While our Australian effort in Si QC has largely focused on spin qubits based upon phosphorus dopant atoms implanted in Si [2,3], we are also exploring spin qubits based on single electrons confined in SiMOS quantum dots. Such qubits have long spin lifetimes T_1 = 2 s [4] and in isotopically enriched Si-28 can attain control fidelities above 99% [5], consistent with those required for fault-tolerant QC. By gate-voltage tuning the electron g*-factor, the qubit operation frequency can be adjusted [5], allowing individual addressability of many qubits. Most recently we have coupled two SiMOS qubits to realise CNOT logic gates [6] for which over 100 two-qubit gates can be performed within a two-qubit coherence time of 8 μs. I will conclude by discussing the prospects of scalability of this technology using traditional CMOS manufacturing.

[1] D.D. Awschalom et al., "Quantum Spintronics", Science *339, 1174 (2013).*

[2] J.J. Pla et al., "A single-atom electron spin qubit in silicon", Nature *489, 541 (2012).*

[3] J.T. Muhonen et al., "Storing quantum information for 30 seconds in a nanoelectronic device", Nature Nanotechnology *9, 986 (2014).*

[4] C.H. Yang et al., "Spin-valley lifetimes in a silicon quantum dot with tunable valley splitting", Nature Communications *4, 2069 (2013).*

[5] M. Veldhorst et al., "An addressable quantum dot qubit with fault-tolerant control fidelity", Nature Nanotechnology *9, 981 (2014).*

[6] M. Veldhorst et al., "A two-qubit logic gate in silicon", Nature *526, 410 (2015).*

Andrew Dzurak is one of Australia's leading experts in nanoelectronics and quantum computing technologies and is Director of ANFF-NSW, the NSW node of the Australian National Fabrication Facility. Following a PhD in Cambridge, Andrew returned to Australia in 1994 and began work on an initiative to develop a solid state quantum computer, being one of the founding members of the Centre for Quantum Computer Technology in January 2000. The centre has achieved major advances in the international effort to realize large-scale quantum information processing and expanded in 2011 to become the ARC Centre of Excellence for Quantum Computation and Communication Technology. It maintains the world's largest focused collaboration on silicon-based quantum computing and Andrew is the Centre's Work-Package Leader in this area, as well as the Lead Investigator for a major grant from the US Army Research Office in silicon quantum computing. Since 2010 Andrew has published 8 experimental papers in *Nature*, *Nature Nanotechnology* and *Nature Communications* demonstrating single atom and SiMOS spin qubits in silicon, together with reviews on spin-based qubits in both *Nature* and *Science*. In total he has published over 100 scientific papers and is a co-inventor on 11 patents. In 2011 Andrew shared the Australian Eureka Prize for Scientific Research, and in 2012 was awarded the New South Wales Science and Engineering award for Excellence in Engineering and Information and Communications Technologies.

Pushing the limits in glass properties and structures for laser, sensing and nonlinearity applications

Heike Ebendorff-Heidepriem
heike.ebendorff@adelaide.edu.au
Institute for Photonics and Advanced Sensing,
The University of Adelaide

Optical glasses have demonstrated growing interest and applications for nonlinear processing, high power lasing, quantum photonics and sensing applications due to the large variety of properties and structures that can be achieved with glass. Depending on the chemical composition, glasses exhibit a wide range of optical properties such as linear refractive indices of 1.4-2.8, nonlinear refractive indices spanning three order of magnitude over of 10^{17}-10^{20} m^2/W and transmission windows that are situated within 200nm – 20μm. Recently, incorporation of nanocrystals such as nanodiamond has gained significant attention as a pathway to add functionality to glass. This talk will review the recent progress achieved in the development of glasses with advanced properties such as significantly reduced transmission loss of tellurite and germanate glass in the mid-infrared, extended mid-infrared transmission range for fluoride glass, single photon emission in diamond-tellurite glass and optically stimulated luminescence in fluoride-phosphate glass. In addition, the talk will review progress in fabrication and applications of fibers and waveguides made from these glasses. Of particular focus are glasses, waveguides and fibers for mid-IR light delivery and generation.

Heike Ebendorff-Heidepriem received the Ph.D. degree in glass science from the University of Jena, Germany, in 1994, where she continued her research on spectroscopy and structure of optical glasses for laser applications until 2000. During 2001–2004 she was with the Optoelectronics Research Centre at the University of Southampton, UK, working on novel photosensitive glasses and soft glass microstructured optical fibres with record high nonlinearity. Since 2005, she has been with the University of Adelaide, Australia. Currently, she is one of the leaders of the Optical Materials & Structures Theme and the Deputy Director of the Institute for Photonics and Advanced Sensing at The University of Adelaide. She is also Associate Director of the Optofab Adelaide node of the Australian National Fabrication Facility. Her research focuses on the development of mid-infrared, high-nonlinearity and active glasses; glass, preform and fibre fabrication techniques, fibre optic sensors and surface functionalisation of glass. She was awarded the Woldemar A. Weyl International Glass Science Award in 2001 and a prestigious EU Marie Curie Individual Fellowship in 2001. Her research has generated over 250 refereed journal papers and conference proceedings.

New insights into the fundamental electronic transport properties of advanced semiconductor materials and devices.

Lorenzo Faraone
lorenzo.faraone@uwa.edu.au
Microelectronics Research Group (MRG)
The University of Western Australia (UWA)

Emerging electronic materials for future electronic and optoelectronic devices pose unique and difficult characterisation, optimisation and modelling challenges, demanding new experimental and analytical approaches to gain insight into their fundamental electronic properties and performance limiting mechanisms. The MRG at UWA has demonstrated that through the systematic use of a variable magnetic field Hall-effect characterisation approach, an advanced high-resolution mobility spectrum analysis (HR-MSA) methodology, and advanced numerical modelling and simulation, new knowledge and understanding can be gained into the fundamental electronic transport processes in emerging and future semiconductor materials: sub-band modulated transport in FD-SOI Si MOSFETs with ultra-thin channels; mobility distributions associated with inversion layer and "bulk" electrons in buried channel 4H-SiC MOSFETs; vertical electronic transport in InAs/GaSb superlattices; lateral transport parameters of thin InAs/GaSb superlattices on conductive GaSb substrates; and hole transport in p-type HgCdTe and p-type GaN.

Recent experimental and modelling results will be presented, which showcase the insights into the electronic transport properties of technologically important semiconductor materials, which are not possible employing conventional analysis of Hall-effect measurements at low magnetic field intensities. In particular, results of a study of hole transport in arsenic-doped p-type HgCdTe epitaxial layers with CdTe mole fraction > 0.5 will be presented, including modelling and analysis of hole scattering mechanisms which indicated that hole mobility is limited by ionised impurity scattering even at room temperature under moderate impurity compensation ratios. For low compensation, mobility characteristics were found to be limited by polar optical phonon scattering at temperatures >200K. The ionisation energy of the arsenic acceptor impurities was found to exhibit a quadratic dependence on CdTe mole fraction x for $0.2 < x < 1$.

Professor Faraone is a Member of the Order of Australia (AM), and a Fellow of the Institute of Electrical & Electronic Engineers (FIEEE), the Australian Academy of Science (FAA), and the Australian Academy of Technological Sciences and Engineering (FTSE). He has published more than 200 international journal papers on his research work, and supervised more than 30 PhD student completions. He is currently Head of the Microelectronics Research Group (MRG) at The University of Western Australia (UWA), and Director of the WA Centre for Semiconductor Optoelectronics and Microsystems (WACSOM). Prior to joining UWA in 1987, he worked primarily in the area of CMOS-based microelectronics and non-volatile memory technology with RCA Labs in Princeton, NJ, USA. Since joining UWA he has worked on compound semiconductor materials and devices, including AlGaN/GaN HEMTs, HgCdTe-based infrared sensor technology and MBE growth, as well as optical MEMS technologies for infrared applications. The research activities of the MRG also include mobility spectrum techniques for magneto-transport studies in advanced semiconductor nanostructures. This has resulted in the development of the Mobility Spectrum Analysis (MSA) technique that allows the transport properties of individual carriers in a multi-layer/multi-carrier semiconductor system to be determined accurately and unambiguously.

Nanofabrication of photonic materials

Associate Professor Mike Ford
mike.ford@uts.edu.au
Associate Dean, Research and Development
Faculty of Science, University of Technology Sydney,
Ultimo, NSW 2007, Australia

Controlled fabrication and manipulation of nanostructured wide bandgap semiconductors is an essential step in engineering of high performance photonic and optoelectronic devices with current and future generation applications in sensing, optoelectronics, secure communications and quantum computing. Here we outline work done at University of Technology Sydney (UTS) in the fields of:

- Room temperature quantum emission from bulk, nanocrystalline and 2D wide bandgap semiconductors [1,2].
- Self-assembly and top-down fabrication of hybrid structures for integrated nanophotonic devices [3].
- Direct-write fabrication and manipulation of the optoelectronic properties of non-conventional semicondoctors such as diamond and hexagonal boron nitride [4].

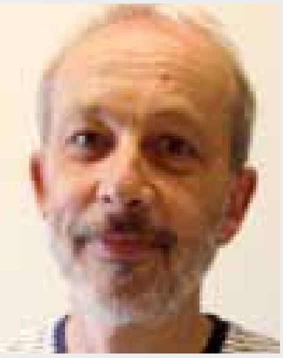
The work on quantum emitters is focused on the discovery and engineering of new sources for on-demand single photon emission at room temperature. The sources are then incorporated in device structures such as plasmonic waveguides and dielectric cavities using novel self-assembly and top-down, electron-beam-directed nanofabrication techniques. These techniques are being developed at UTS, and tailored specifically for non-conventional nanophotnic semiconductors such as diamond. Specific examples include damage-free chemical processing of single crystal diamond that enables high resolution, site-specific dry etching and surface functionalisation, fabrication of self-ordering topographic patterns, and switching of the charge states of near-surface color centers such as the nitrogen-vacancy (NV) centre.

[1] T. T. Tran, K. Bray, M. J. Ford, M. Toth & I. Aharonovich, Nature Nanotechnol. 11, 37 (2016)

[2] T. T. Tran, C. Zachreson, A. M. Berhane, K. Bray, R. G. Sandstrom, L. H. Li, T. Taniguchi, K. Watanabe, I. Aharonovich & M. Toth, Phys. Rev. Appl. 5, 034005 (2016)

[3] T. T. Tran, J. Fang, H. Zhang, P. Rath, K. Bray, R. G. Sandstrom, O. Shimoni, M. Toth & I. Aharonovich, Adv. Mater. 27, 4048 (2015)

[4] A. A. Martin, A. Bahm, J. Bishop, I. Aharonovich & M. Toth, Phys. Rev. Lett. 115, 255501 (2015)



Mike Ford is Associate Professor and Associate Dean, Research and Development, Faculty of Science. His research interests are in materials physics and most recently using quantum mechanical computer simulations to understand the electronic properties of materials, particularly 2D materials and quantum emission from defects. He is a core member of the Materials and Technology for Energy Efficiency research strength at UTS and works closely with the experimentalists in the group that fabricate these materials as described in the above abstract.

Atomically Thin Materials for Future Low-Energy Electronics

Michael S. Fuhrer
Monash Centre for Atomically Thin Materials
Monash University, Monash 3800 Victoria, Australia
michael.fuhrer@monash.edu

The last decade has seen a revolution in two-dimensional electronic systems. Atomically thin materials such as graphene and transition-metal dichalcogenides host two-dimensional electron systems with novel electronic properties. Strong topological insulators and topological crystalline insulators have metallic surface states with Dirac dispersions and spin-momentum locking. These materials are poised to revolutionise electronics and optoelectronics, providing the next generation of fast, low-power switches, transducers, sensors, and detectors.

At Monash University I direct the Monash Centre for Atomically Thin Materials (MCATM), an interdisciplinary centre with 24 researchers across six schools in science and engineering. MCATM supports research excellence in atomically thin materials at Monash through support for students and early career researchers, seed support for new interdisciplinary projects, and support for linkages with industry and international partners. I am also presently leading a bid for an Australian Research Council Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET). FLEET includes 19 chief investigators at seven Australian universities, and an additional 18 partner investigators at institutions around the world, including 11 investigators at 8 institutions in the US.

In my talk I will discuss the research goals of MCATM and FLEET as well as opportunities for international collaboration.

I received my B.S. in Physics from the University of Texas at Austin in 1990, and Ph.D. in Physics from the University of California at Berkeley in 1998 after doing research on electronic and thermal transport in high-temperature and fullerene superconductors with Prof. Alex Zettl. I remained at Berkeley as a postdoctoral researcher with Profs. Alex Zettl and Paul McEuen, working on electronic transport in carbon nanotube devices. I joined the faculty at the University of Maryland as an Assistant Professor in 2000, and from 2009-2012 was Professor, and Director of the Center for Nanophysics and Advanced Materials. In 2012 I was awarded an ARC Laureate Fellowship, and moved to Monash University as Professor of Physics in 2013, where I directs the Monash Centre for Atomically Thin Materials. I am a Fellow of the American Physical Society and the American Association for the Advancement of Science.

I studied the first carbon nanotube heterojunctions, demonstrated single-electron memory with carbon nanotube transistors, and measured the intrinsic charge carrier mobility in semiconducting carbon nanotubes and in graphene, the highest mobility semiconductors and semimetals known at room temperature. My current research interests lie in atomically thin two-dimensional materials such as graphene and transition-metal chalcogenides, where my research has elucidated the basic electronic conduction mechanisms in these novel materials. I have published over 150 scientific papers, cited collectively over 16,000 times.

Nanoporous Silica Particles in Life Science Applications

Alfonso Garcia-Bennett
alf.garcia@mq.edu.au
PhD, Australian Future Fellow, Centre for Nanoscale Biophotonics,
Chemistry and Biomolecular Sciences, Macquarie University, Sydney, Australia

Porous silica nanoparticles are successfully being developed for novel therapies in nanomedicine due to their high surface areas (above 1000m2/g), large internal pore volumes and unique nanostructures with finely controlled pore sizes for specific applications.[1] Their uses in pharmaceutics to improve drug bioavailability and formulation; to mitigate drug toxicity, to act as adjuvants in immunoregulation, in wound healing and in cellular targeting through controlled drug delivery strategies has been demonstrated.[1–3]

This presentation aims to review some of the groundbreaking work being conducted at the interface between materials science and nanomedicine using nanoporous silica particles, drawing particular attention on Structure and Function relations and how advanced characterisation methods such as those based on Electron Microscopy are enabling their introduction in a variety of industries.[4] Specific examples will be shown of the use of mesoporous nanoparticles for the pharmacokinetic control and enhancement of bioavailability of pharmaceutical drugs as well as for the delivery of peptides in the context of regenerative medicine.[5–6]

[1] Garcia-Bennett A. Synthesis, toxicology and potential of ordered mesoporous materials in nanomedicine. Nanomedicine *6(5), 867-877 (2011).*

[2] Garcia-Bennett A, Nees M, Fadeel B. In Search of the Holy Grail: folate-targeted nanoparticles for cancer therapy, Biochem Pharmacol. *81(8), 976-84 (2011).*

[3] Vallhov H, Gabrielsson S, Strømme M, Scheynius A, Garcia-Bennett AE. Mesoporous silica particles induce size dependent effects on human dendritic cells. Nano Lett. *7, 3576-82 (2007).*

[4] Fadeel B, Garcia-Bennett AE. Better safe than sorry: understanding the toxicological properties of inorganic nanoparticles manufactured for biomedical applications. Advanced Drug Delivery Reviews, *62 (3), 362-374 (2010).*

[5] Liong M, Lu J, Kovochich M, Xia T, Ruehm SG, Nel AE, Tamanoi F, Zink JI. Multifunctional inorganic nanoparticles for imaging, targeting, and drug delivery. ACS Nano. *2(5), 889–96 (2008).*

[6] Garcia-Bennett AE et al., Nanoporous materials assist advanced differentiation of transplanted mouse embryonic stem cells. Stem Cells Translational Medicine, *2(11), 906-915 (2013).*

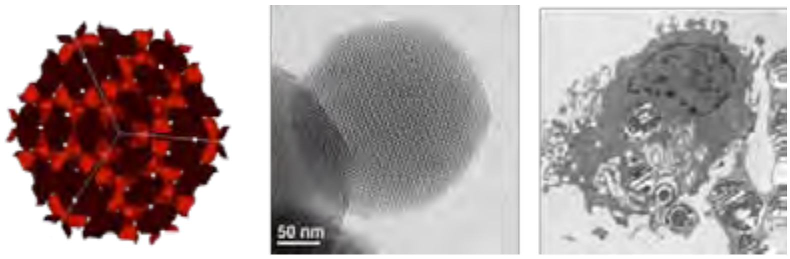


Figure 1. An electron Crystallography derived unit cell model of cubic mesocaged material (AMS-8) viewed along the [111] orientation (left). TEM image of a typical AMS-8 particle viewed along its [110] orientation (center) and its uptake within a primary human macrophage (right) as seen under the electron microscope.

I completed my PhD in Chemistry in 2003 at the University of St. Andrews (Scotland) on the synthesis and characterisation of mesoporous silica materials. Since then I have worked in Japan at Tohoku University as a post-doctoral student and Sweden, holding academic positions at Stockholm and Uppsala University. In 2004, I founded Nanologica AB, a company that manufactures and develops nanoporous silica particles for separation and pharmaceutical applications. I relocated to Australia and Macquarie University in January 2015 joining the Centre for Nanoscale Biophotonics. In December 2015 I was awarded an ARC Future Fellowship to pursue my research into the effects of the Protein Corona on nanoparticles and in particular on the development of porous particles in drug delivery applications. My research is at the centre of a global effort to implement discoveries in nanotechnology into medical therapies by understanding how the body interacts with nanoparticles, in particular nanoporous particles (zeolites, mesoporous silica, MOFs etc). I am the author of over 50 international publications in the field of Material Science and over 8 patents.

Taking Separations from the Laboratory to the Sample to the Individual

Professor Emily Hilder BSc(Hons) PhD(Tas) FRACI CChem
Emily F. Hilder[1,2], R. Dario Arrua[1,2], Esme Candish[3], Florian Lapierre[2,3], Wei Boon Hon[2,4], Robert A. Shellie[2,4], Andrew A. Gooley[2,4]
Emily.Hilder@unisa.edu.au
1 Future Industries Institute, University of South Australia
2 ARC Training Centre for Portable Analytical Separation Technologies (ASTech)
3 ACROSS, University of Tasmania
4 Trajan Scientific and Medical, Ringwood, Australia

Polymer based monoliths were introduced about 20 years ago. The relatively simple preparation, robustness, high permeability to flow, mass transfer via convection and flexible chemistry has since seen these materials used in a range of applications such as chromatography and as supports for synthesis, catalysis and immobilised enzymes. These same properties make monolithic polymers an excellent choice as materials for sampling and sample preparation, particularly for miniaturised technologies with the potential to produce cleaner extracts and facilitate rapid sample preparation for mass spectrometry (MS).

This presentation will introduce monolithic micro-sampling and separation devices developed for sampling, sample preparation and separation of complex samples, including whole blood. As an example, monolithic micro-sampling devices prepared within disposable pipette tips have been developed for in-tip blood filtration and as immobilised enzyme reactors (IMER) for protein digestion. Subsequent micro-solid phase extraction (μ-SPE) was achieved using high surface area polymer monoliths. The μ-SPE device was then directly hyphenated with both ESI-MS and nanospray-MS. Microextraction by packed sorbent (MEPS) in which the SPE phase is placed within an exchangeable needle hub integrated into an analytical syringe is also demonstrated for μ-SPE. A workflow was developed using the monolith filtration and enzyme reactor technology in combination with an at-line micro SPE-ESI-MS approach enabling both sample preparation and analysis to be completed in < 20 min, facilitating high-throughput sample analysis in a standard bioanalysis workflow. New, high surface area polymeric monolithic sorbents tailored for SPE will also be introduced and are shown to provide significant advantages over particle-based sorbents, providing greater reproducibility in the sorbent bed. In a further embodiment the selective extraction of small molecules from complex matrices such as plasma will be demonstrated, using new restricted access poly(DVB)-g-PEGMA monoliths. Examples will include those which have resulted in new commercial products (e.g. sample preparation and analytical separation columns) and new devices currently in early state commercialisation.

Professor Emily Hilder is a graduate of the University of Tasmania where she completed BSc(hons) in 1996 and her PhD in analytical chemistry in 2000. From 2000-2004 she held postdoctoral positions in the Institute of Analytical Chemistry at Johannes Kepler University (Austria) and the Materials Science Division, E.O. Lawrence Berkeley National Laboratory and Department of Chemistry, University of California, Berkeley (USA). In 2004 she joined the Australian Centre for Research on Separation Science (ACROSS) at the University of Tasmania where she held an ARC Australian Postdoctoral Fellowship from 2004-2007 and ARC Future Fellowship from 2010-2014 and was promoted to Professor in 2011. She has over 100 refereed publications, has secured almost $17.3m in competitive grant funding since 2004 and has contributed to the development of a number of commercial products.

Characterising nanoscale adhesion and friction

Professor Han Huang
Head, Nanomechanics and Nanomanufacturing Group
School of Mechanical and Mining Engineering
The University of Queensland
St. Lucia, QLD 4072, Australia
han.huang@uq.edu.au

Nanowhiskers, such as nanowires, nanotubes, and nanobelts, are key building blocks of next generation nanodevices. As a consequence, their status of adhesion to substrates and the friction forces being generated during movement are essential knowledge for device design and performance. However, the fundamental law for friction and classical theory for adhesion were established at macroscale, which is unable to explain some phenomena observed in adhesion and friction tests at nanoscale. Lacking of reliable methods for measuring nanoscale adhesion and friction also hinders our understanding of the physics involved, although great research effort has been made in recent years. There exists a great discrepancy between the measured frictional forces and theoretical predictions. In this presentation, the development of simple and reliable methods to measure adhesion and friction between a nanostructure and a substrate by use of optical nanomanipulation at The University of Queensland will be introduced. The effect of the physical origins on nanoscale adhesion and friction will be discussed.

Dr Han Huang is a Professor of Mechanical Engineering at The University of Queensland (UQ). He leads a group of researchers including 8 PhD students and 6 postdoctoral fellows, working on mechanical characterisation of nanostructures and nanomanufacturing. Prof. Huang obtained his Bachelor and Master's Degrees on mechanical engineering from Huazhong University of Science and Technology (China) and his PhD on mechanical and materials engineering at The University of Western Australia. He published over 200 refereed journal papers, which attracted over 3000 citations (leading to an h-index of 30). He also received a number of research accolades, including Australia Research Council (ARC) Future Fellow, ARC Australia Research Fellow, JSPS Invitation Fellow and Queensland International Fellow, and won the prestigious Singapore National Technology Award. Prof. Huang is a Fellow of the International Society of Nanomanufacturing. He has editorial roles in several international journals and is a steering committee member of a number of nanotechnology conferences.

The vast opportunities offered by high-quality graphene on silicon

Francesca Iacopi
f.iacopi@griffith.edu.au
Environmental Futures Research Institute,
Griffith University, Nathan 4111, Queensland, Australia

Epitaxial graphene grown from silicon carbide wafers has been for long time the only route to obtain high quality graphene directly grown at the wafer –level. While encouraging results have been obtained through thermal decomposition of hetero-epitaxial SiC films on silicon wafers, this route has to-date yet to deliver adequate graphene quality.

We demonstrate that the use of hetero-epitaxial silicon carbide films in combination with a catalytic alloy of nickel and copper enables high -quality graphene on silicon. With this approach we obtain 1-2 layers graphene with uniform coverage over 2" silicon wafers with an average ID/IG ratio as low as 0.2 +/- 0.05 [1], a substantial improvement as compared to the ratio of ~1 and above of graphene through the more conventional thermal decomposition.

This novel approach holds enormous promise for integrated applications also through the capability for straightforward graphene micropatterning through self-aligned synthesis on pre-structured silicon carbide on silicon [2]. We have already indicated the potential for this approach to fabricate a broad range of miniaturised devices such as high throughput molecular recognition for bio -sensing [3], highly –performant electrodes for on-chip supercapacitors [4], as well as nanophotonics.

This work is supported by the Australian Research Council through the Future Fellowship FT120100445, and by the AFOSR, Army RDECOM, and ONRG through the joint grant AOARD15IOA053. It is carried out in close collaboration with Dr John Boeckl, AFRL, WPAFB, OH, and Dr Joshua Caldwell, NRL, DC.

[1] F.Iacopi, N.Mishra, B.V.Cunning, D.Goding, S.Dimitrijev, R.Brock, R.H.Dauskardt, B.Wood and J.J.Boeckl, "A catalytic alloy approach for highly uniform graphene on epitaxial SiC on silicon wafers", J.Mater.Res.30(5), 609-616, 2015.

[2] B.V.Cunning, M.Ahmed, N.Mishra, A.R.Kermany, B.Wood, F.Iacopi, "Graphitized silicon carbide microbeams on silicon: wafer-level, self -aligned graphene on silicon wafers", Nanotechnology 25, 325301, 2014.

[3] O.Cooper, B.Wang, C.Brown, J.Tiralongo, F.Iacopi, "Towards label-free biosensing with silicon carbide: a review", invited paper in IEEE Access 4 (1), 1-21, 2016.

[4] M.Ahmed, M.Khawaja, M.Notarianni, B.Wang, D.Goding, B.Gupta, J.J. Boeckl, A.Takshi, N.Motta, S.E.Saddow, F.Iacopi, "A thin film approach for SiC–derived graphene as an on-chip electrode for supercapacitors", Nanotechnology 26, 434005, 2015.

Associate Professor Francesca Iacopi has nearly 20 years industrial and academic expertise in Materials Science for Semiconductor Technologies, with over 100 peer-reviewed publications and 8 granted patents. Staff Scientist at IMEC (Belgium) over 1999-2009, she took then up a year Guest Professorship at the University of Tokyo (Japan). In 2010-2011 she directed the Chip-Package Interaction strategy for GLOBALFOUNDRIES (Ca, USA), the second largest semiconductor foundry. At Griffith University she leads the Integrated Nanomaterials group, focusing on graphene and 2D materials on silicon for bio-compatible sensing technologies. She was a 2003 recipient of a Gold Graduate Student Award from the Materials Research Society, a 2012 recipient of a Future Fellowship from the Australian Research Council, and she was awarded a "Global Innovation Award" for "Processes enabling low cost graphene/silicon carbide MEMS" in Washington DC, May 2014.
In October 2015 she has been appointed to the Advance Queensland Panel of Experts, advisory panel to the State government on Science and Innovation.

From Electromaterials to Integrated 3D structures

Associate Professor Peter C Innis
innis@uow.edu.au
ARC Centre of Excellence for Electromaterials Science & Intelligent Polymer Research Institute
University of Wollongong

The exponential growth in the discovery and development of new materials, and the importance of nanostructures from them, poses some exciting challenges to those involved in device fabrication. The use of organic conductors in devices greatly opens up the possibility of new areas of application ranging from chem-sensors through to bio-medical applications. As fascinating as the properties of organic conductors are, they are only really useful when they can be seamlessly and effectively integrated with other materials to create functional devices. At ACES electroactive polymers, nanocarbons and biopolymers have been fabricated into structures such as fibres, films and coatings and subsequently assembled or even printed into functional devices. Here we will report on our advances, supported by the ANFF Materials Node, on the development of electroactive materials and composites and their subsequent fabrication into functional devices from fibres into textiles and materials based print media into 2 and 3D structures.

Under pinning these activities at ACES is the utilisation and modification of fabrication tooling supported by the ANFF. Additive fabrication (AF) techniques emerged in manufacturing industries during the mid 1980's [1]. This family of layer-by-layer fabrication techniques have been adopted as a means to reduce product development time and give improved flexibility in producing small batches of products [2]. Within the medical research field AF has received much attention as a means of on-demand automatic production of structures for implantation. At ACES we employ these technologies as a means to fabricate electrically stimulated devices. To this end, techniques such as Fused Deposition Modelling (FDM) [3], Inkjet Printing and Selective Laser Melting (SLM) have been utilised via ANFF Materials Node to facilitate processing of complex composite materials into porous and fully dense functional 3D structures.

In this presentation examples of assembly approaches of electro-materials into functional structures at ACES will be discussed.

[1] Charles Hull, "StereoLithography: Plastic prototypes from CAD data without tooling", Mod. Cast., *vol. 78 (8), pp. p38, 1988*

[2] Xue Yan, P Gu, "A review of rapid prototyping technologies and systems", Comput. Aided Design, *vol. 28 (4), pp. 307-318, 1996*

[3] Valerie Liu Tsang, Sangeeta N. Bhatia, "Three-dimensional tissue fabrication", Adv. Drug Deliver. Rev., *vol. 56 (11), pp. 1635-1647, 2004*

[4] Paul Calvert, "Materials science: Printing cells", Science, *vol. 318(5848), pp.208 – 209, 2007*

[5] Ben Vandenbroucke, Jean-Pierre Kruth, "Selective laser melting of biocompatible metals for rapid manufacturing of medical parts", Rapid Prototyping J., *vol. 13(4), pp.196 – 203, 2007*

Associate Professor Peter Innis obtained his PhD (UTS) in 1997 in the field of electrochemical processing of conducting electroactive polymers (ICPs). He has been a recipient of an Australian Research Council (ARC) – Australian Postdoctoral Fellowship (1999-2001) and an ARC Queen Elizabeth II (QEII) Fellowship (2003-07). He has extensive experience in the area of conducting polymer synthesis and their application to technologies such as intelligent electronic textiles, polymer photovoltaics, polymer actuation and sensing technologies. He has authored published 66 papers in refereed international journals, 3 book chapters and 7 patents. His publications have attracted over 1147 citations (h-index 21). At present he is the Assistant Director of the Intelligent Polymer Research Institute at the University of Wollongong and the Manager of the Materials Node of the Australian National Fabrication Facility (ANFF). The capability provided by ANFF enables users to process hard materials (metals, composites and ceramics) and soft materials (polymers and polymer-biological moieties) and transform these into structures that have application in sensors, medical devices, and nanoelectronics.

Methods to develop high performance and durable solid oxide fuel cells

Professor San Ping Jiang
Fuels and Energy Technology Institute & Department of Chemical Engineering,
Curtin University, Perth, WA 6102, Australia
s.jiang@curtin.edu.au

Solid oxide fuel cells (SOFCs) are electrochemical energy devices to directly convert the chemical energy of fuels such as hydrogen, natural gas and hydrocarbons into electrical energy. SOFC with combined power and heat has an efficiency of 70-90% and it is environment friendly with much less greenhouse gas emission. SOFCs can also be reversibly operated under electrolysis mode to store the renewable energy in the form of hydrogen fuel. However, one of the key technical barriers for the commercialisation of SOFC technologies is the high cost of the manufacture and this is particular the case of use of cobaltite-based materials in state-of-the-art yttria-stabilised zirconia (YSZ) electrolyte based SOFCs. Cobalt-containing oxides such as barium strontium cobalt ferrite (BSCF), lanthanum strontium cobalt ferrite (LSCF) and double perovskite oxides such as $PrBa_{0.5}Sr_{0.25}Ca_{0.25}Co_2O_{5+\delta}$ (PBSCaCF) and $NdBa_{1-x}Ca_xCo_2O_{5+\delta}$ (NBCaC) are typically mixed ion/electron conducting materials and are highly active as cathodes of SOFCs. However, they cannot be directly used on YSZ electrolyte cells due to the significant chemical reaction and thermal mismatch with YSZ electrolyte. As the result, a porous or dense doped ceria layer is required as a barrier or an interlayer on YSZ electrolyte film to avoid the detrimental chemical reaction at the cobalt-containing electrode/YSZ electrolyte interface. The problem is that addition of a ceria interlayer increases the cost of cell fabrication and the risk of electrolyte delamination during the long-term operation.

To tackle this key problem in SOFCs, we developed a cheaper fabrication method to use cobalt-containing perovskite electrodes on YSZ electrolyte cells without the need of ceria interlayer. The method significantly reduces the fabrication steps for SOFCs and is expected to reduce the overall fabrication cost of the cells.

Another technical barrier of SOFCs is the generally low power output at reduced operation temperatures (600-700oC). The most common method to increase the performance of SOFCs is to introduce nanoparticles to the electrodes by wet impregnation or infiltration. In this method, rigid and porous electrode scaffold on YSZ or ceria electrolytes is formed by high temperature sintering at 1000-1400 oC and then active metal or metal oxide precursor in solution are infiltrated into the porous scaffold. The metal or metal oxide nanoparticles are formed by heat-treatment at a lower temperature of 600-800oC. The main problem of the nanoparticles introduced by this method is the low stability and significant agglomeration during the SOFC operation conditions, despite the initial high performance. Most recently, we developed a method of formation of electrocatalytically active metal nanoparticles such as Pd on oxide electrode surface without the use of reducing agent. The metal nanoparticles are highly active and most importantly very stable as compared to the conventional wet solution infiltrated one.

Both methods are in the process of filing patent application and more detailed description of the methods will be available by the time of the meeting.

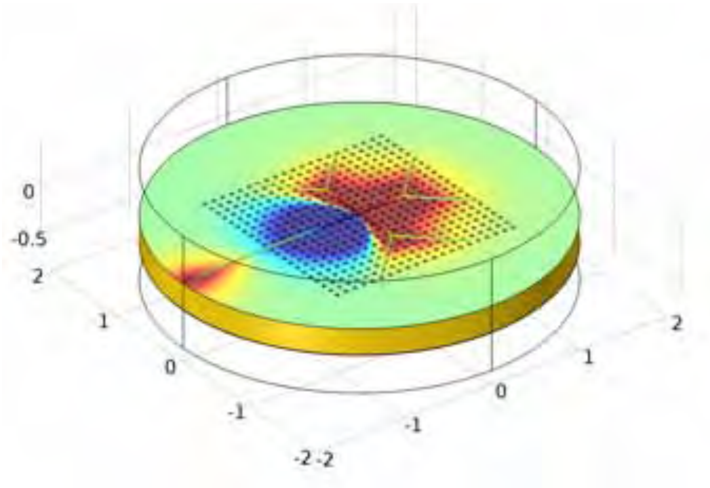
Conformable optrode for the brain/machine interface

Professor François Ladouceur, Professor Nigel Lovell and Mr Josiah Firth
f.ladouceur@unsw.edu.au
Faculty of Engineering
The University of New South Wales

The successful realisation of the technologies described herein could revolutionise the way technology is implanted in the body. To advance the neuroprosthetic field, fundamental constraints related to packaging, wiring and interfacing need to be overcome [1]. We believe that recent development at UNSW of a hybrid liquid-crystal photonics transducer [2] will provide the disruptive technology that heralds the next generation of Brain Machine Interfaces (BMI).

New classes of liquid crystals – so called deformed helix ferroelectric liquid crystal (DH-FLC) – have shown the ability to offer extraordinary sensitivity and linear response to applied electric fields down to the microvolt range. As opposed to the standard liquid crystal, which typically exhibits strong bi-stability, these liquid crystals can smoothly, continuously and passively transduce small electrical signals into the optical domain, thus affording all the advantages typically associated with optical communications networks.

This technology, entirely developed at UNSW is actively being researched and commercialised in the context of optical sensing networks [2] and has found strong support from industry e.g. in the areas of ocean monitoring (towed array sonars). We propose to apply the technology to the biomedical domain to target areas such as sensory and sensorimotor systems that enable **3D airborne navigation** and control of natural flight, e.g., in insects or bats, especially in relation to capabilities of **autonomous**



Full 3D vectorial FEM simulation of electrode array in saline bath. The branched neurons are modelled using Hodgkin-Huxley action potential model.

biological systems. This approach can also act as a laboratory-based (in-vitro) transducer for **basic scientific research**. We will review the latest fabrication and simulation advances our group has made over the past year.

1. Tsai, D., Morley, J.W., Suaning, G.J., Lovell, N.H. (2009). Direct activation and temporal response properties of rabbit retinal ganglion cells following subretinal stimulation, J. Neurophysiol. 102: 2982.

2. Z. Brodzeli, L. Silvestri, A. Michie, Q. Guo, E. P. Pozhidaev, V. Chigrinov, F. Ladouceur, Sensors at your fibre tips: a novel liquid crystal- based photonic transducer for sensing systems, Journal of Lightwave Technology, 31(17): 2940-2946, 2013.

Professor François Ladouceur is head of the photonics group within Electrical Engineering at UNSW and has played an active role in the commercialisation of photonics technologies over the past 20 years. Prof Ladouceur has a number of start-up related experiences. From 1998-2000, he acted as VP Product Management for the start-up **Virtual Photonics**. In this role he supervised the software development of VPI's global product range and participated in fund raising. Later on, he became the founding Managing Director of The **Bandwidth Foundry**, a prototyping facilities for photonics chips located in Sydney. More recently, Prof Ladouceur co-founded **Silanna** in Brisbane. Since then, Silanna has grown its presence including the buy-out of Peregrine Semiconductors based in Sydney. He is currently the acting CEO and co-founder of **Zedelef Pty Ltd** a spin-off company from UNSW.

Gradient-index optical elements for beam shaping

J R. Leger[1], G Douglass[2], S Gross[2] and M J. Withford[2]

1 Department of Electrical and Computer Engineering, University of Minnesota

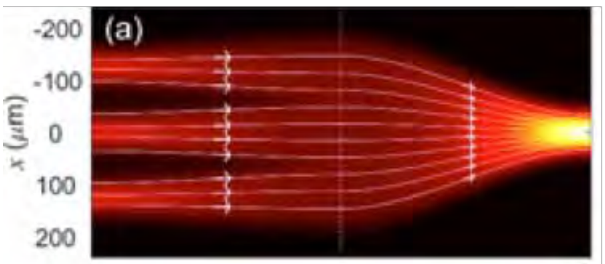
2 Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)

MQ Photonics Research Centre, Dept. of Physics & Astronomy, Macquarie University

Laser beam shaping can be performed using a variety of methods. However, some beam shaping tasks do not currently have satisfactory solutions. In particular, converting multiple Gaussian beams into a single Gaussian shape for laser beam combining remains a challenge. Recently, one of the authors (Leger) has invented a new optical design method that uses a gradient-index (GRIN) structure to perform this and other transformations (see fig.1a). The gradual conversion of the beam from three Gaussians to one combined with the additional degrees of freedom afforded by the gradient index results a highly accurate Gaussian shape (M^2 = 1.1) with a theoretical conversion efficiency of 100%. The method utilises a novel application of phase retrieval to produce an index prescription that compensates for diffraction.

Fabrication of complex gradient index structures poses a difficult problem. Traditional methods based on ion exchange are limited to index profiles governed by diffusion. However, the femtosecond laser direct write method pioneered by the Macquarie group is ideally suited to fabricating these devices. The FLDW technique creates localised refractive index modification that is induced via nonlinear absorption of tightly focused fs-laser pulses inside of a transparent dielectric material. By translating the sample multiple times slab waveguides of arbitrary width and length can be inscribed. We have recently shown that the strength of the index change can be varied by adjusting the pulse power (see fig. 1b). We propose to use this technique to fabricate a waveguide that performs GRIN beam shaping. We believe that this will be the first such demonstration of continuous GRIN-based beam shaping, and the first to test GRIN design methods that account for diffraction.

(a)



(b)

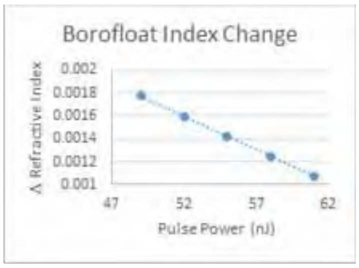


Fig 1. a) GRIN waveguide converting three Gaussian shaped laser beams into a single Gaussian-shaped beam (color corresponds to light intensity). b) Plot showing the index change in Borofloat with varying pulse power.

James Leger is the Cymer Professor of Electrical Engineering at the University of Minnesota. His current interests include coherent optical design, laser beam combining, and exotic imaging systems,. Leger is currently the senior deputy editor of Optics Express. He is the recipient of the OSA Fraunhofer Award for optical design, and is a fellow of the OSA, IEEE, and SPIE.

Recent progress in MBE infrared material research at UWA

Wen Lei, Renjie Gu, Imtiaz Madni, Jarek Antoszewski, and Lorenzo Faraone
wen.lei@uwa.edu.au
School of Electrical, Electronic, and Computer Engineering, The University of Western Australia (UWA)

The rapid development of infrared (IR) imaging applications require next generation IR detectors and their focal plane arrays to have features of lower cost, larger array format, and higher operating temperature. However, current state-of-the-art CdZnTe-based photovoltaic HgCdTe IR detectors are seriously limited by their higher cost, smaller array format size, and lower operating temperature (usually 77K) due to the lower device yield, smaller wafer size available, and larger device dark current.

In the last two decades, significant effort has been devoted to growing HgCdTe materials on Si, Ge and GaAs alternative substrates to lower the cost and increase the array format size. However, the large lattice constant/CTE (coefficient of thermal expansion) mismatch between these alternative substrates and HgCdTe results in a high density of dislocations (mid-10^6 ~ low $10^7\,cm^{-2}$), which seriously degrades the device performance of fabricated IR detectors, especially long-wave IR (LWIR) detectors. To make high performance HgCdTe LWIR detectors, the dislocation density must be controlled below the level of $5{\times}10^5 cm^{-2}$.

To enhance the operating temperature, a new n-type-barrier-n-type (nBn) structure was recently proposed to suppress dark current and enhance operating temperature of IR detectors. However, the application of nBn architecture to HgCdTe presents a serious challenge due to the difficulty in realising an ideal nBn band diagram using CdTe or HgCdTe materials (zero valence band offset, combined with a large conduction band offset).

Table 1 Material quality statistics of CdTe buffer and HgCdTe layers on both GaSb and GaAs substrates grown at UWA

Alternative substrates	CdTe buffer thickness (um)	CdTe buffer Etch pit density ($\times10^6$ cm^{-2})	HgCdTe layer Thickness (um)	HgCdTe layer Etch pit density ($\times10^6$ cm^{-2})
GaSb	3 ~ 7	5 ~ 30	4.5 ~ 5.3	2 ~ 10
GaAs	6 ~ 7	3 ~ 50	5.7 ~ 6.7	8 ~ 40

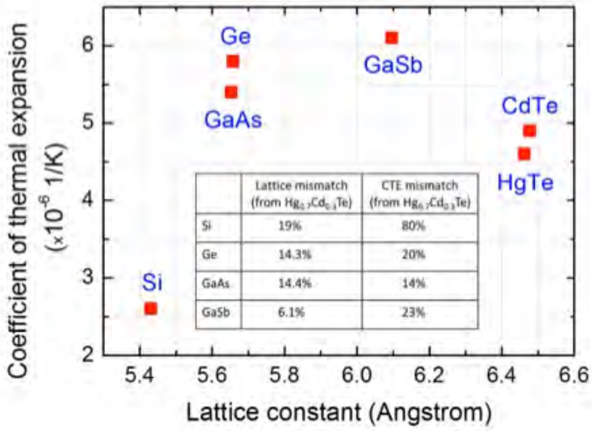


Figure 1 Lattice constant and CTE of several semiconductors discussed.

In this work, we will introduce our recent effort to reduce the cost, increase the array format size, and enhance the operating temperature of HgCdTe detectors by developing new GaSb alternative substrates, and superlattice barrier-based nBn architectures. Compared with Si, Ge and GaAs, GaSb has much smaller lattice mismatch and comparable CTE mismatch with HgCdTe as shown in Figure 1. More importantly, our recent effort at MBE growth of CdTe buffer layers and HgCdTe directly on GaSb has demonstrated that this technology can provide material of comparable quality to that on GaAs substrates, as shown in Table 1. Theoretically, the use of a HgTe/CdTe superlattice as the barrier layer has the potential to achieve an idea nBn band diagram.

Dr Wen Lei is an Associate Professor, ARC Future Fellow in the School of Electrical, Electronic, and Computer Engineering at University of Western Australia (UWA). He received his PhD degree in Semiconductor Materials and Devices in 2006, and has more than 10 years' experience in developing semiconductor thin film optoelectronic materials and devices. He received a number of national awards for his research, including ARC Future Fellowship (2013), and ARC Australian Postdoctoral Fellowship (2007). His present work mainly focuses on the epitaxial growth and characterisation of compound semiconductor materials, and their applications in optoelectronic devices, including lasers and infrared detectors.

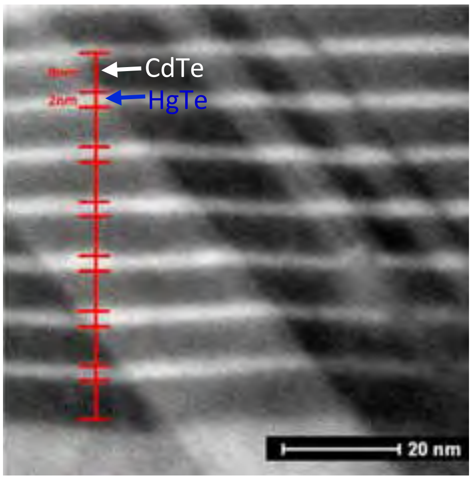


Figure 2 TEM (Transmission electron microscopy) image of HgTe/CdTe superlattice barrier in a HgCdTe nBn detector structure. Note the surface distorted observed is caused by the FIB cutting during the sample preparation process.

Despite the challenges in growth of HgTe/CdTe superlattices, our recent MBE effort has shown that high quality HgTe/CdTe superlattices have been achieved, as shown in Figure 2. These results demonstrate the great potential of GaSb alternative substrate and superlattice barrier-based nBn device architectures for developing next generation HgCdTe infrared detectors.

Surface and Interface Analysis in Renewable Energy Research

David A. Lewis
David.lewis@flinders.edu.au
Professor of Materials Science and Director,
Flinders Centre for NanoScale Science and Technology,
School of Chemical and Physical Sciences, Flinders University, Adelaide

Organic photovoltaics (OPVs) offer a number of advantages, such as fully solid state, compatible with high speed printing and production technologies, but they also a number of challenges related to efficiency and lifetime, many of which can be traced to instability in interfacial layers within the structure.

The ability to create, control and measure nanoscale structures is critical to the development of a range of new technologies. Understanding the properties of a wide range of systems that are generally thought to be "uniform", "stable" and "consistent" are proving to be critical in the development of a number of options for new, low cost energy solutions which have the potential to change the way in which we harvest and collect energy. All of the approaches rely upon multi-layer structures with layers of the order of 10 – 200 nm – a range that materials offer interesting chemical and electronic properties, but are also susceptible to subtle changes in chemistry that can drive significant performance differences.

A range of unique techniques have been used to investigate the materials that make up the layers and interfaces in these devices, including:

a) X-ray photo-, UV photo-and metastable induced electron spectroscopy (XPS, UPS and MIES). The combination of these techniques allows for analysing the electronic structure at the interface and discriminating between the outer layer and the region close to the surface;

b) neutral impact collision ion scattering spectroscopy (NICISS) for analysing the elemental composition across interfaces to a depth of about 10 nm;

c) electron microscopy.

This presentation will discuss the chemical and electronic properties of a number of interface layers within organic photovoltaic devices, with a particular emphasis on understanding the relationship between processing conditions and properties and the structures that are actually forming.

David graduated from the University of Queensland in 1986 and after a postdoc at Virginia Tech, USA, he became a Research Staff Member at IBM, T.J.Watson Research Labs. In 1998, David moved to research management positions in Adelaide with SOLA Optical, which became Carl Zeiss Vision. In 2009, David joined Flinders University where he founded the Flinders Centre for NanoScale Science and Technology which currently has over 120 researchers working in a broad range of Nanotechnology.

David's research interests are printable electronics, highly functional particles and surfaces, polymerization mechanisms and processing.

Since joining Flinders, David has co-founded two companies and created NanoConnect, a mechanism to allow companies to explore the potential of nanotechnology on their businesses since joining Flinders. David is the inventor on 50 patent families and has coauthored over 50 papers and been recognized by professional bodies for technical and professional leadership.

Recent advances in time-gated luminescence technique for biological and security applications

Yiqing Lu[1], Xianlin Zheng[1], Jiangbo Zhao[2], Dayong Jin[1,3], Robert C. Leif[4], Francisco M. Raymo[5], Jingli Yuan[6], J. Paul Robinson[7], and James A. Piper[1]
yiqing.lu@mq.edu.au

1 ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP), Macquarie University, Australia
2 ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP), The University of Adelaide, Australia
3 Institute for Biomedical Materials and Devices, University of Technology Sydney, Australia
4 Newport Instruments, 3345 Hopi Place, San Diego, USA
5 Laboratory for Molecular Photonics, University of Miami, USA
6 State Key Laboratory of Fine Chemicals, School of Chemistry, Dalian University of Technology, China
7 Purdue University Cytometry Laboratories, Bindley Bioscience Center, Purdue University, USA

Luminescent materials based on trivalent lanthanide ions offer exceptional decay lifetimes in the microsecond-to-millisecond region. They have enabled time-gated luminescence technique that employs pulsed excitation and delayed detection for high-contrast bioimaging of luminescent-labelled cells while eliminating short-lived autofluorescence and scattering light overwhelmingly present in biological samples.

We have radically extended this technique through the development of novel families of luminescent probes with tunable lifetimes (τ), i.e. the τ-dots. This has been realised on mono-dispersed upconversion nanocrystals, e.g. $NaYF_4$:Yb,Tm and $NaYF_4$:Yb,Er, with their lifetimes precisely engineered by choice of co-doping concentrations of lanthanide ions as well as nanocrystal size [1]. Another focus of effort has been on down-conversion particles incorporating lanthanide chelates and acceptor dyes. Varying the acceptor concentration results in reproducible variation in luminescent lifetime from a few tens to several hundred microseconds with excellent photostability also demonstrated [2]. This ability to encode lifetime enables typically 10 temporally-coded detection channels per spectral emission band, with the promise of high-multiplexed (>1000) detection without inter-channel crosstalk.

In parallel, we have developed a new generation of high-speed scanning microscopy which enables a complex sample to be analysed for multiple target cellular organisms or subcellular components in rapid time (<3 mins) [3]. Taking advantage of linear encoders and an autofocusing unit, we were able to pinpoint and subsequently retrieve every target with spatial precision <2 μm [4]. Specifically-designed decoding algorithms were implemented, allowing the luminescence lifetimes of individual targets to be measured accurately in real time during the rapid scanning [2].

We have applied the new τ-dots and scanning microscopy for multiplexed cellular imaging [5], rare-event pathogen detection [3], quantification of cancer biomarkers [6], multiplexed DNA assays [2], high-contrast visualisation of fingerprints [7], and security printing against counterfeiting [1].

[1] Lu Y, Zhao J, Zhang R, et al. Nat Photon 2014, 8, 32-36, doi: 10.1038/nphoton.2013.322.

[2] Lu Y, Lu J, Zhao J, et al. Nat Commun 2014, 5, 3741, doi: 10.1038/ncomms4741.

[3] Lu Y, Xi P, Piper J A, et al. Sci Rep 2012, 2, 837, doi: 10.1038/srep00837.

[4] Zheng X, Lu Y, Zhao J, et al. Anal Chem 2016, 88, 1312-1319, doi: 10.1021/acs.analchem.5b03767.

[5] Zhang L, Zheng X, Deng W, Lu Y, et al. Sci Rep 2014, 4, 6597, doi: 10.1038/srep06597.

[6] Lu J, Martin J, Lu Y, et al. Anal Chem 2012, 84, 9674-9678, doi: 10.1021/ac302550u.

[7] Guinan T M, Kobus H, Lu Y, et al. ChemPlusChem 2016, 81, 258-261, doi: 10.1002/cplu.201500546.

Yiqing Lu received his B.Eng. degree in Electronic Engineering from Tsinghua University in 2007. Interested in analytical biotechnology and instrumentation, he did a joint PhD program between Macquarie University and Tsinghua University, during which he explored a high-speed scanning cytometry technique for rapid screening of rare-event pathogens and diseased cells, and later a high-throughput strategy employing luminescence lifetimes to simultaneously detect multiple target species. He is currently a Macquarie University Research Fellow investigating new nanophotonic approaches for diagnostic instruments towards enhanced sensitivity, accuracy, speed and resolution. He is an ISAC Marylou Ingram Scholar awarded by the International Society for Advancement of Cytometry.

New Spectroscopic Protocols for Unravelling Complex Spectra

Andre Luiten
andre.luiten@adelaide.edu.au
Director of the Institute for Photonics and Advanced Sensing/Chair of Experimental Physics
www.ipas.edu.au

My research group is developing sensors and instruments for the purpose of providing new insight into the environment around us. We are making high precision measurements of time, magnetic fields, temperature, refractive index and chemical composition using high-stability frequency standards, micro-resonators, high-resolution atomic and molecular spectroscopy and frequency comb technology. We are also exploring enhanced photon-photon interactions by exploiting the power of micro-structured optical fibres to guide light over long distances in close contact with specially prepared atomic vapours. We have used both room temperature and laser cooled vapours.

In this talk we will focus on the development of novel spectroscopic protocols that have been enabled by the advent of frequency comb technology. Frequency combs allow simultaneous probing of broadband spectra with both high spectral and high temporal resolution. These techniques give an opportunity to obtain a better understanding of complex mixtures of molecular vapours. We are applying these approaches to assist in three applications: (a) broad-band, high-resolution and high signal to noise ratio measurements of gas mixtures for industrial and environmental monitoring; (b) non-invasive disease diagnosis and human condition monitoring using detection of characteristic biomarkers in human breath; (c) high time-resolution spectroscopy to follow dynamical changes in chemical mixtures.

In this presentation we will describe our approaches to extracting different information from a frequency comb measurement according to the application and will show example high-resolution spectra from $C0_2$, Cs, CH_4 and HCN.

Professor Andre Luiten is Director of the Institute for Photonics and Advanced Sensing (IPAS) and Chair of Experimental Physics at the University of Adelaide and a Fellow of the Australian Institute of Physics. Prof Andre Luiten obtained his PhD in Physics from the University of Western Australia in 1997, for which he was awarded the Bragg Gold Medal for best PhD thesis in Physics in Australia. He has held three prestigious Fellowships from the ARC. Andre was the joint inaugural winner of the WA Premier's Prize for Early Career Achievement in Science. Andre came to the University of Adelaide in 2013 to take up the Chair of Experimental Physics and a $1M South Australian Research Fellowship from the SA Premier's Fund. He published 6 book chapters and authored over 100 journal papers (with ~2,000 citations) as well as raising more than $15.5M for research. Prof Luiten's work has aimed at the development of state-of-the-art measurement instruments across many diverse fields of physics. He is particularly excited by the possibility of applying these instruments to solve real world problems, or to make measurements that were not previously possible.

Micro- and Nano-Structured Materials and Devices Fabricated by Drawing

Richard Lwin
richard.lwin@sydney.edu.au
Technical Officer
University of Sydney and ANFF OptoFab

Drawing is an important industrial-scale micro-fabrication technique that has been used to make the millions of kilometres of optical fibre deployed around the planet. It has the nearly unique feature that the structure is assembled on macro-scale and then miniaturised, providing kilometres of product inexpensively.

We have been extending this technique beyond drawing glass or polymer for guiding light. We can now draw very fine metal wires in closely packed arrays; the current limit being ~500 wires of 200nm diameter, spaced at ~500nm. Dense arrays of small wires require metals with modest melting temperatures, such as tin. We can use higher melting temperature metals but need to use larger wires, more widely spaced. We can also draw very small capillaries, and arrays of them. The materials can be silicate glasses, or a wide range of polymers, including those with low Young's modulus.

Furthermore we can combine these features into one material or device; for instance several optical waveguides together with several microfluidic channels and a dense electrode array.

The technique is particularly attractive in terms of cost. It is affordable for one-off experimental work, and can be very economical for manufacturing. Depending on the exact final structures, the fairly modest set up costs can be spread over large quantities of product.

A solution looking for a problem? Not quite, as it is already solving a number of problems. We have used the technique to make a wide range of optical fibres for applications from sensing, imaging to high speed datacoms. We have demonstrated a wide range of metamaterials and metamaterial devices. We have fabricated devices for medical research and sub-assemblies for medical devices. There seem to be many other possibilities, so perhaps this is a solution looking for more problems!

In this talk we will outline the technique, the range of possibilities and the applications we have already addressed.

Richard Lwin has researched photonics and optics for twelve years at the University of Sydney. After completing his PhD in 2007 investigating the optimisation of the microstructured polymer optical fibre fabrication process at the Optical Fibre Technology Centre, he continued as the technical officer of specialty optical fibre fabrication at the School of Physics, Institute of Photonics and Optical Science at the University of Sydney. He was also one of the founders of the spin off polymer optical fibre company, Kiriama Pty. Ltd. between 2009-2014. He is currently the facilities manager of the polymer optical fibre fabrication unit for the OptoFab Node of the Australian National Fabrication Facilities. His research includes the fabrication of microstructured optical fibres and metamaterials.

Progress in MEMS-based optical filters for spectrally adaptive remote sensing from visible, through infrared, to terahertz

Mariusz Martyniuk
mariusz.martyniuk@uwa.edu.au
Microelectronics Research Group
The University of Western Australia

Improving current state-of-the-art infrared (IR) detector and imaging focal plane array (FPA) technologies is focused on reducing cooling requirements, larger-format FPAs, extending to longer wavelengths, and/or adding tuneable spectral selectivity, which allows real-time spectral information to be gathered adaptively from multiple wavelength bands. Spectrally selective sensing results in improved target recognition and reduced false alarm rates in military scenarios, and is applicable to numerous remote sensing spectroscopy/imaging applications in civilian arenas. In order to provide a reduced size, weight and power (SWaP) solution, a micro-electromechanical systems (MEMS) based electrically tuneable optical filter technology has been developed that is compatible with individual detectors and/or large format 2-D imaging IRFPAs.

Progress is presented in the development of MEMS-based optical filter technologies capable of adaptive low-voltage electrostatic tuning of spectral selectivity in wavelength bands spanning from visible, through infrared, to terahertz parts of the electromagnetic spectrum. In particular, to complement our past reported developments in the short-wave infrared (SWIR, 1.4 – 2.5 μm) and mid-wave infrared (MWIR, 3 – 5 μm), we report on recent achievements in the near infrared (NIR, 0.7 – 1.7 μm), long-wave infrared (LWIR, 8 – 12 μm), and terahertz ranges (~1 THz or ~300 μm). In LWIR, we report spatial peak wavelength selectivity variation of less than 1.2% across 200-μm × 200-μm optical imaging areas, exceeding the requirements for passive multispectral thermal imaging applications (spectral characteristics across the entire tuning range of 8.5–11.5 μm: peak transmission above 80%, full-width at half-maximum of spectral passband of ~500 nm, and out-of-band rejection greater than 40:1). This is complemented by our recent demonstration of wavelength selectivity tuning across a 16 μm (60GHz) wide spectral band for 300 μm wavelength (1 THz) radiation.

The presented MEMS-based optical filters are applicable for hybridisation into technologies capable of mechanically robust field-portable spectroscopic chem/bio sensing, as well as for UAV-based imaging and remote sensing applications.

Mariusz. Martyniuk (Hon.B.Sc. *Toronto*, M.A.Sc. *McMaster*, Ph.D. *W.Australia*) is currently with the Microelectronics Research Group at The University of Western Australia and manages the Western Australian Node of the Australian National Fabrication Facility. His primary areas of interest encompass thin-film materials and thin-film mechanics, as well as their applications in microelectromechanical systems and optoelectronic devices. His research contributions were recognised in 2008 by the award of the inaugural Australian Museum Eureka Prize (the Oscars of Australian science) for "Outstanding Science in support of Defence or National Security".

Nanoscale patterning of supported lipid bilayers for sensor applications

Sally McArthur
smcarthur@swin.edu.au
Director, Swinburne Innovation Precinct
ANFF-Vic Biointerface Engineering Hub
Swinburne University of Technology
Hawthorn, Victoria Australia

The cell membrane encases and protects cellular components and plays an important role in transport, signalling and disease. Studying membrane behaviour is a challenging task due to the complexity and scale on which these processes occur. Supported lipid bilayers (SLBs) have provided researchers with stable and reproducible platforms to recreate cell membrane environments. The planar structure of the model means a variety of patterning techniques can be employed to recreate membrane architecture on both a micro and nanoscale. In particular, pre-patterned substrates are of great interest as they eliminate complications associated with preserving membrane integrity during patterning. Plasma polymers provide a versatile method of creating thin films with a variety of different surface chemistries. In this work we explore the behaviour of plasma coatings in aqueous conditions and the use of plasma films for creating patterned SLBs using vesicle collapse. The results demonstrate that variations in plasma polymer chemistry can be used to control lipid bilayer formation and the locations of different lipid species. Characterisation of film behaviour and bilayer formation was conducted using a variety of techniques including ellipsometry, quartz crystal microbalance with dissipation (QCM-D), confocal microscopy, atomic force microscopy (AFM) and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS).

Sally McArthur is the Director of the Innovation Precinct at Swinburne University of Technology. The precinct is a whole of university initiative focused on disruptive technology innovation through collaboration between students, staff, mentors, industry, strategic partners.

As an engineering researcher Sally has obtained approximately $16M in funding from research councils, industry and government in the UK and Australia, including the $1.8M ARC Industrial Transformational Training Centre in Biodevices launched at Swinburne in March 2015. She part of a team at Swinburne exploring new ways to link industry and academia to create a new generation of entrepreneurial, innovative and internationally connected graduates capable of driving the Medical and Manufacturing sectors forward in Australia and internationally.

Sally's personal research couples materials, surface engineering, physical science, analytical chemistry and biochemistry. Using these tools, she creates novel interfaces capable of eliciting specific physical and biological responses. These engineered surfaces enable the integration of biology into new technologies including microfluidics, biological and environmental sensors, tissue engineering and manufacturing processes. Sally's group hosts the Australian National Fabrication Facility Victoria (ANFF-Vic) Biointerface Engineering Hub, an open access facility for academic and industry researchers to gain expert support to connect biology with technology.

Enabling Technologies at the Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Dr Emma Mitchell
CSIRO

CSIRO is Australia's national research agency. It is multidisciplinary and undertakes research that benefits Australia but with a view that we are globally linked. We are organised into nine business units, one being Manufacturing. Manufacturing has a strong capability in devices, sensors and systems integration research and development. We also undertake R&D to high technology ready levels and work closely with end users and manufacturers both multinational, national and small to medium enterprises. Fabrication is a critical capability for Manufacturing.

One example of our fabrication capability is in superconducting devices and electronics. The development of high temperature superconducting electronics in CSIRO, based on our patented technique for making Josephson junctions, represents an important example of capability development with multiple applications. The fabrication and development of sensors and electronics which extends from devices with single junctions to large arrays with tens of thousands of junctions will be presented. This talk will give a very brief over view of CSIRO and Manufacturing and then outline our superconductivity research as an example of our capability and how we apply it to develop new technologies.

Emma Mitchell received a BSc degree (Hons 1A) from Macquarie University in 1992 while working as an experimental scientist at CSIRO Food Research on the biophysics of artificial membranes, surface physics of emulsions and organic monolayers. She completed her PhD on low dimensional semiconductor systems in the quantum limit at the University of NSW in 1997. She joined the CSIRO Division of Manufacturing (formerly Materials Science and Engineering) as a research scientist in 1997 focusing on the fabrication, characterization and physics of high-temperature superconducting Josephson junctions and SQUIDs. Dr Mitchell also has expertise in fabricating and measuring low-temperature superconducting sensors including niobium nanojunctions and SQUIDs and coplanar waveguide resonators. She has experience in low temperature electromagnetic transport, microwave spectroscopy and optical measurements from 77 K to 10 mK. Her current activities include leading several projects at CSIRO on the development of large arrays of YBCO Josephson junctions (tens of thousands) for applications including sensitive magnetic field detectors and broadband RF antennas.

Floating liquid marbles as a digital microfluidics platform for three-dimensional cell cultures

Nam-Trung Nguyen
nam-trung.nguyen@griffith.edu.au
Professor and Director
Queensland Micro- and Nanotechnology Centre,
Griffith University

Flotation of small solid objects and liquid droplets on water is critical to natural and industrial activities. We first report the floating mechanism of liquid marbles, or liquid droplets coated with hydrophobic microparticles. X-ray computed tomography was used to acquire cross-sectional images of the floating liquid marble and interface between the different phases. The shape of the liquid marble and the angles at the three-phase contact line was then analysed. The small floating liquid marbles follow the mechanism governing the flotation of solid objects in terms of surface tension forces. However, the contact angles and deformations of the liquid marble resemble that of a sessile liquid droplet on a thin, elastic solid. For small liquid marbles, the contact angle varies with volume due to the deformability of the interface. Two actuation mechanisms were then explored for the controlled transport of the liquid marbles: self-propulsion using solutocapillary effect and magnetic actuation. Subsequently, a novel protocol based on floating liquid marbles for three-dimensional culturing of olfactory ensheathing cells (OECs) was developed. This platform can be used to understand how OECs interact with other cells in three dimensions. Transplantation of OECs is being trialled for repair of the paralysed spinal cord, with promising but variable results and thus the therapy needs improving. To date, studies of OEC behaviour in a multicellular environment have been hampered by the lack of suitable three-dimensional cell culture models. The presence of the liquid bath increases the humidity and minimises the effect of evaporation of a liquid marble. Floating liquid marbles allow the OECs to freely associate and interact to produce OEC spheroids with uniform shapes and sizes. In contrast, a sessile liquid marble on a solid surface suffers from evaporation and the cells aggregate with irregular shapes. Furthermore, floating liquid marbles were used to co-culture OECs with Schwann cells and astrocytes, which formed natural structures without the confines of gels or bounding layers. This protocol can be used to determine how OECs and other cell types associate and interact while forming complex cell structures.

Nam-Trung Nguyen received his Dip-Ing, Dr Ing and Dr Ing Habil degrees from Chemnitz University of Technology, Germany, in 1993, 1997 and 2004, respectively. In 1998, he was a postdoctoral research engineer in the Berkeley Sensor and Actuator Center (University of California at Berkeley, USA). From 1999 to 2013, he worked as an Associate Professor at Nanyang Technological University, Singapore. Since 2013, he is a professor and the director of Queensland Micro-a and nanotechnology Centre, Griffith University. Professor Nguyen is the First Runner Up of Inaugural ProSPER.Net-Scopus Young Scientist Awards in Sustainable Development in 2009 and the Runner Up of ASAIHL-Scopus Young Scientist Awards in 2008. He is a Fellow of ASME and a Member of IEEE. His research is focused on microfluidics, nanofluidics, micro/nanomachining technologies, micro/nanoscale science, and instrumentation for biomedical applications. He published over 250 journal papers and filed 8 patents, of which 3 were granted. Among the books he has written, the first and second editions of the bestseller "Fundamentals and Applications of Microfluidics" co-authored with S. Wereley were published in 2002 and 2006, respectively. His latest book "Nanofluidics" was published in 2009. The second edition of the bestselling book "Micromixer" was acquired and published by Elsevier in 2011.

Plasma Measurements with Nanosecond Time Resolution

Sean O'Byrne
s.obyrne@adfa.edu.au
Advanced Instrumentation Group
University of New South Wales, Canberra

Ignition of combustible fuel-air mixtures by either pulsed nanosecond-duration discharge or laser spark is a relatively new and active area of research in the field of combustion. These mechanisms have the potential to provide ignition with the generation of lower NOx emissions for internal combustion engines, and shorter ignition delay times for high-speed diffusive combustion environments. In spite of these significant potential benefits, the physics and chemistry of the ignition phenomena in these two cases can be quite different to the processes involved in standard spark ignition – for the laser spark because of the very high temperatures and for the pulsed nanosecond discharge because of the non-thermal ignition processes. In both of these cases, the important processes occur on a nanosecond time scale, and there is therefore a great need for diagnostic techniques capable of measuring temperature and species concentration throughout the process with very high temporal resolution.

We present a new absorption-spectroscopy-based method [3] that is capable of making measurements of temperature and species concentrations in plasmas down to nanosecond time scales, using the absorption of light from a narrowband diode laser in a strongly-absorbing metastable state of an atomic species such as argon. The laser is detuned to various frequencies as repetitive pulses of the laser or plasma are actuated, forming an absorption measurement that provides temperature information through the width of the transition and species concentration information

[1] Brieschenk, S., O'Byrne, S., & Kleine, H. (2013). Laser-induced plasma ignition studies in a model scramjet engine. Combustion and Flame, *160(1), 145-148.*

[2] Goldberg, B. M., Shkurenkov, I., O'Byrne, S., Adamovich, I. V., & Lempert, W. R. (2015). Electric field measurements in a dielectric barrier nanosecond pulse discharge with sub-nanosecond time resolution. Plasma Sources Science and Technology, *24(3).*

[3] Manoharan, R., O'Byrne, S., & Boyson, T. (2015). Time-resolved temperature measurements in a repetitively pulsed nanosecond discharge using tuneable diode laser absorption spectroscopy. In D. Honnery, & D. Edgington-Mitchell (Eds.), Proceedings of the 7th Australian Conference on Laser Diagnostics in Fluid Mechanics and Combustion *(pp. 147-153).*

Associate Professor Sean O'Byrne received his PhD in Physics from the Australian National University in 2002. After graduating, he worked as a National Research Council Postdoctoral Fellow at the NASA Langley Research Center on spectroscopic measurements in supersonic combustors, and as a New South Innovation Fellow at the University of New South Wales, Canberra working in spectroscopic diagnostics of hypersonic flows. He has patents pending in the field of laser-based flow measurements and biomedical sensor technologies, and led the team that produced a laser-based hypersonic inlet sensor for the 2013 SCRAMSPACE scramjet test, as well as producing the first demonstration of laser spark ignition in a supersonic combustor. A/Prof. O'Byrne's research interests include rarefied hypersonic flow, plasma ignition and sensor design for extreme environments. He has co-authored 90 publications, including book chapters, technical reports, journal and conference papers.

Developing Nanostructured Electromaterials for Energy Applications

David L. Officer
ARC Centre of Excellence for Electromaterials Science, Intelligent Polymer Research Institute, University of Wollongong,
Northfields Avenue, Wollongong NSW 2522, Australia.
davido@uow.edu.au

The creation of the next generation of electrochemical devices requires the precision assembly of nano-/micro-dimensional components into macroscopic structures to deliver unprecedented device performance. This in turn demands control of the structure of the electromaterials that will make up the device components. To this end, we are exploring ways to create nanostructured electromaterials and investigating their potential for use in a variety of energy-related applications.

For example, we have been synthesising porphyrins and evaluating them as light harvesting dyes or catalysts typically through attachment to an inorganic or organic semiconductor. The key to controlling the properties of these electromaterials is to be able to systematically vary the porphyrin chromophore by substitution and metallation, as well as the linker and binding group, changing the arrangement of the functionality on the substrate. Thus, interactions of water soluble porphyrins with conducting polymers leads to water splitting devices and iron porphyrins with ionic liquids to efficient CO_2 reduction.

In many of these applications, more efficient devices can be fabricated using nanostructured substrates. To address this, we are investigating the use of nanostructured materials such as graphene and molybdenum disuphide.

Therefore, in this lecture, we will present our progress in designing and using nanostructured electromaterials based on porphyrins, spiropyrans, nanostructured carbons and functionalised conducting polymers in energy applications.

David Officer is Professor of Organic Chemistry in the Intelligent Polymer Research Institute and the ARC Centre of Excellence for Electromaterials Science (ACES) at the University of Wollongong. He obtained his PhD in Chemistry at Victoria University of Wellington, Wellington, New Zealand in 1982 and joined the lecturing staff at Massey University in 1986 after three years research work in organic chemistry at the Australian National University and as an Alexander von Humboldt Fellow at the University of Cologne, Cologne, Germany. During his 21 years at Massey University, he became founding Director of the Nanomaterials Research Centre and Professor in Chemistry in the Institute of Fundamental Sciences at Massey University, New Zealand.

David joined ACES in 2007 and leads the Electromaterials research theme in ACES, developing new materials including spiropyrans, porphyrins, polythiophenes, nanocarbons and polymer composites. He is also responsible for organic materials synthesis, including graphene synthesis, in the Materials Node of the Australian National Fabrication Facility and leads the Polymers for Solar Cells Program in the Australian Cooperative Research Centre for Polymers.

David has published more than 160 papers in the areas of porphyrins, conducting polymers, nanomaterials and nanostructured carbons, and solar cells. In 2004, he was awarded the New Zealand Institute of Chemistry HortResearch Prize for Excellence in the Chemical Sciences.

Illuminating mRNA and proteins in new ways with nanoparticles and chemical conjugates

Lindsay M Parker
Lindsay.parker@mq.edu.au
Postdoctoral Research Fellow
Macquarie University Centre for Nanoscale Biophotonics

Despite significant advancement in the methodology used to conjugate, incorporate and visualise fluorescent molecules at the cellular and tissue levels, biomedical imaging predominantly relies on the limitations of established fluorescent molecules such as fluorescein, cyanine and AlexaFluor dyes. These fluorescent dyes are highly susceptible to photobleaching and compete with cellular autofluorescence, making biomedical imaging unreliable, difficult and time consuming in many cases. We are developing better tools to image inflammation in cells and the central nervous system using targeted mRNA transcripts and antibodies labelled with fluorescent nanoparticles or chemical chelates that have indefinite photostability and/or have clear signal discrimination against tissue/cell autofluorescence. We have used *in situ* hybridisation (ISH) with Alexafluor fluorescent dyes (FISH), fluorescent nanodiamonds (DISH), luminescent lanthanide (LISH) and Superdot upconversion nanocrystals (SuperFISH) to recognise targeted mRNA transcripts in biological specimens. We have similarly used immunohistochemistry with these nanoparticles and the luminescent chelate to recognise protein targets. Our findings will compare and discuss the advantages of each system relative to established fluorescent dyes for mRNA and protein imaging in biological systems.

I obtained a Bachelor of Science (Psychology) in 2006 from Michigan State University and then worked in the field of cardiovascular neuroscience for 9 years, initially researching innervation of the heart and vasculature during hypertension at Michigan State University with Professors David Kreulen and Gregory Fink. I completed a PhD in Advanced Medicine in 2014 at Macquarie University under A/Prof. Ann Goodchild. I described the distribution of Gα subunit mRNA in the brainstem and adrenal glands of hypertensive rats and central autonomic neuron pathways activated following severe physiological stressors, distinguishing neurochemical mRNA and protein codes for neurons in the brainstem and spinal cord that regulate adrenaline release and blood glucose levels during glucoprivation and hypotension. Post-PhD I have continued researching neural regulation of physiological stressors and have also identified neurochemical changes in brain pathways regulating methamphetamine addiction. I ran the Macquarie University Australian School of Advanced Medicine biomedical imaging microscopy unit from 2013 to 2015, training and supervising more than 100 academic staff and students in immunohistological sample preparation techniques and light microscopy. Since 2015 I have held a post-doctoral research fellowship in the multidisciplinary Centre for Nanoscale Biophotonics under Professor Nicki Packer. I am now using advanced microscopy techniques for mRNA and protein identification in order to develop new tools for biologists that decrease or eliminate current biomedical imaging limitations such as tissue autofluorescence and photobleaching.

Scalable cellular engineering via ultrasonic microfluidic vortex shedding

Ryan S. Pawell and Matthew A. Burkhardt
rpawell@indeetx.com
Indee. Inc. in San Francisco, CA, United States
Indee. Pty. Ltd. in Prahran, VIC, Australia

Cell-derived gene therapies (CDGTs) – cell-based therapies requiring an intracellular delivery step – offer the opportunity to radically impact patient outcomes across several challenging disease areas. A potential limitation in the application and distribution of these therapies is their ability to be manufactured in a scalable and affordable manner.

The aim of our work is to address this problem by developing an intracellular delivery platform that scales up and out to meet the demands of the diseased patient populations by delivering functional macromolecules (DNA, RNA, endonucleases, etc.) to therapeutically- relevant cell types (HSCs, iPSCs, T-Cells, etc.). Microfluidic devices offer a solution as they enable the precise processing of cells. Microfluidic devices may be manufactured with existing semiconductor infrastructure: the semiconductor industry developed the ability to manufacture large volumes of parts with micron scale features. Select microfluidic designs can scale to 10 million devices per year. In this abstract, we describe a prototype microfluidic device with a 10 mm x 5 mm x 0.7 mm footprint utilising micro post array geometries to induce ultrasonic microfluidic vortex shedding. These fluid dynamics disrupt the cell membrane in a manner that allows the device to process up to 10 million cells per second with a 7 mm x 1.5 mm x 40 μm flow cell.

Here, we demonstrate delivery of fluorescently labeled dextrans (3-, 10- and 70-kDa), purified Cas9 protein, and Cas9 encoding mRNA to Jurkat cells. Dextran delivery resulted in up to 13.4% delivery efficiency with 85.0% to 90.3% viability. This work demonstrates ultrasonic microfluidic vortex shedding may be used to deliver therapeutically relevant macromolecules to Jurkat cells with within the context of clinical CDGT development. The high cell viability percentage, cell processing speeds, and mass manufacturing capabilities of our microfluidic chip platform offer a promising path towards large-scale clinical manufacturing of *ex vivo* CDGTs.

Ryan Pawell is an Eagle Scout, engineer, inventor and scientist turned biotech startup founder and CEO. He completed a Bachelors of Science at the University of California, Santa Barbara and worked with NuVasive and Inogen on medical device development. More recently, Ryan raised a meaningful amount of both private and venture financing to develop microfluidic devices for manufacturing cell-derived gene therapies. Ryan is a graduate the NSW Health Ignition Medical Program and the IndieBio San Francisco Accelerator Program. Ryan also enjoys surfing in his spare time.

Progress in understanding complex surfaces using ToF-SIMS and multivariate analysis

Paul J. Pigram
p.pigram@latrobe.edu.au
Director, Centre for Materials and Surface Science
La Trobe University, Melbourne, Australia

There are significant challenges in investigating the molecular nature of complex surfaces and interfaces. Modern fabricated structures and devices from the medical, biochemical, semiconductor, sensors, photonics and electromechanical systems domains all may exhibit compositional complexity and features on a length scale of less than 100 nm.

The rapid growth in research, development and deployment of biological systems and organic electronic systems, (for example in photovoltaic and LED applications), requires particularly sophisticated approaches for the characterisation of complex, soft multilayered materials and devices. This presentation reports progress in the molecular characterisation of materials and systems at the nanometre scale using time-of-flight secondary ion mass spectrometry (ToF-SIMS), and related techniques. The emerging role of argon gas clusters in depth profiling soft organic electronic structures and biomaterials will be explored.

Multivariate analysis techniques such as principal components analysis (PCA) and the creation of artificial neural networks (ANNs) allow large datasets aggregating information from a variety of sources to be interrogated and complex relationships with the dataset to be revealed. This presentation also reports progress in understanding complex biological surfaces using ToF-SIMS and multivariate analysis.

Paul Pigram is a Reader and Associate Professor in Physics at La Trobe University. His research interests are directed to understanding interactions at surfaces, the creation of functional molecular structures including polymeric sensors, tailored surface chemistries and nanoparticles for drug delivery, and molecular characterisation of these surfaces.

Paul completed a Ph.D. in applied physics (1991) at the University of Sydney. After a postdoctoral appointment at the University of New South Wales in the field of surface science, he took up a faculty position in physics at La Trobe University in 1995. Paul is the Director of the *Centre for Materials and Surface Science* (CMSS), a centre hosting a world class surface analytical capability including XPS, ToF-SIMS, UPS, AFM (ambient), UHV SPM, and contact angle analysis.

Paul was Head of the Department of Physics at La Trobe University 2008 – 2014. He is a member of the Collaboration Committee of the multi-institutional Melbourne Centre for Nanofabrication (a part of the Australian National Fabrication Facility ANFF). Paul has been Associate Dean (Research) for the Faculty of Science, Technology and Engineering, and Physics, Chemistry and Earth Sciences cluster leader within La Trobe in the *Excellence in Research for Australia* (ERA), national research assessment exercise.

ARC Centre of Excellence for Nanoscale BioPhotonics

Prof Jim Piper
jim.piper@mq.edu.au
Director, Macquarie University Node CNBP
Macquarie University, NSW 2109

CNBP seeks to make key advances in the basic sciences underpinning nanoscale biophotonics and apply these to create new solutions to biological and biomedical sensing using optical techniques coupled with nanomaterials and molecular biology ("Windows on the Body"). The Centre is hosted at University of Adelaide and has major nodes at Macquarie University in Sydney and RMIT University in Melbourne. Established in August 2014, CNBP now has more than 100 research scientists and graduate students in a highly multidisciplinary team spanning physics, materials, chemistry, molecular biology, biomedical science and engineering. In addition to the discovery research program, CNBP has a strong focus on 3 biomedical applications areas, namely cardiovascular science, neuropharmacology and embryology, and a strong orientation towards translation of our research results for the benefit of human health. This presentation will outline the research program and highlight a number of key advances and challenges to be faced, especially in the interfacing of new generation nanoprobes to the biology.

Professor Jim Piper completed his PhD in atomic physics at University of Otago, NZ, in 1971 and subsequently undertook postdoctoral research in physics of lasers at the Clarendon Laboratory, University of Oxford, UK. He was appointed Lecturer at Macquarie University in 1975 and in 1984 became Professor of Physics. In 1988 he became Director of the Australian Research Council Special Research Centre for Lasers and Applications, and he has subsequently been a Chief Investigator of ARC Centre of Excellence for Ultrawide-bandwidth Devices for Optical Systems, and ARC Centre of Excellence for Nanoscale BioPhotonics, for which he is currently Director of the Macquarie University Node. His research interests are in laser and optical physics, and photonics including applications in biology, medicine and engineering. He is author or co-author of over 320 international refereed journal articles, book chapters, and published conference papers, as well as inventor or co-inventor of 14 awarded patents, including 10 US patents. From 2003-2013 Professor Piper was Deputy Vice-Chancellor (Research) at Macquarie University. He has received a number of awards for his contributions to optics and laser physics, and was elected Fellow of the Optical Society of America in 1994. In 2006 he was Carnegie Centenary Professor, awarded by the Carnegie Trust Universities of Scotland, and most recently (2014) was invested as a Member of the Order of Australia (AM) for his contributions to higher education, particularly research in applied laser physics.

High-resolution imaging in hard-to-access locations

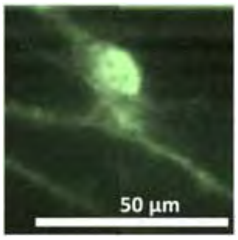
Martin Ploschner, Denitza Denkova, James A. Piper and **Ewa M. Goldys**
ewa.goldys@mq.edu.au
ARC Centre of Excellence for Nanoscale BioPhotonics
Macquarie University

Dr Martin Ploschner, Dr Denitza Denkova, Prof James Piper and Prof Ewa Goldys from the Australian Research Council Centre of Excellence for Nanoscale Biophotonics (www.cnbp.org.au) in Sydney, Australia are interested to work with US partners to develop new, ultra-compact technology for imaging objects and regions that are difficult to access. The technology – based on optical fibres as thin as a single strand of hair – will lay the foundations for the next generation of borescopes for inspection of aircraft engines and industrial turbines. The technology will also precipitate a revolution in the field of minimally-invasive endoscopes, where it will enable imaging and optical control of deep regions of the living brain.

This proposed work is enabled by major advances in the management of light in a multimode optical fibre made by Dr Ploschner. These have been described in a recent publication "Seeing through chaos in multimode fibres" by Martin Ploschner *et al* Nature Photonics 2015 (DOI: 10.1038/NPHOTON.2015.112), attached here for your convenience.

This type of mode management makes it possible to image objects accessible only through very small holes. As an example, please see the images of three members of our team sitting in a locked dark room and accessed via an optical fibre with a diameter of 125μm. Individuals can be clearly distinguished.

Imaging of deep neuronal tissue is also possible. As an example, please see the image of a neuron expressing GFP as imaged through the same, 125μm in diameter, fibre.



Dr Martin Ploschner works as a Research Fellow of the recently established Australian Research Council Centre of Excellence in Nanoscale Biophotonics (http://cnbp.org.au), based at the Macquarie University, Sydney, Australia.

His research spans the field of microendoscopy based on multimode optical fibres. His landmark results include the demonstration of imaging through multimode fibre endoscope design that can be flexed and bent. This constitutes a milestone in the microendoscopy research. Bending and flexing capability is crucial for imaging of moving conscious animals and places microendoscopy into an ideal position to tackle one of the last frontiers in biology – imaging deep in the brain of fully conscious animals subjected to environment stimuli. His current research activities range from ultrafast beam-shaping in complex media, non-invasive light-sheet microscopy at the tip of a needle, to compressive sensing imaging in the microendoscopy setting.

Microfluidics in Structured Arrays for Dilution-Free Analysis

Craig Priest
craig.priest@unisa.edu.au
Foundation Fellow
Future Industries Institute, University of South Australia
SA Node Director
Australian National Fabrication Facility

Microfluidic platforms have been in transition from fundamental research to real-world applications, with many systems now being designed for integration into point-of-use technologies. The long-standing argument that most microfluidic systems resemble a "chip-in-a-lab", rather than the envisaged "lab-on-a-chip", technology is gradually fading as improved integration of optical, electrical, and micromechanical systems develop. Functions previously driven by relatively large off-chip equipment, such as flow, sensing, and analysis, are increasingly performed on capillary-driven disposable paper-based analytical devices.

While paper may be low-cost, it has its limitations. For example, non-aqueous sample phases may react with printed paths or the paper itself. Embedding optical components for advanced and quantitative sensing is not practicable. Our research has investigated a capillary-driven microfluidic system capable of precisely defined and automated sample delivery (rate and volume; 600 nL in a few seconds), known optical properties (quartz glass, tailored optical path lengths), and ease of use. The functionality of the chip relies of microscale quartz pillars that drive and contain the fluid flow to yield a precise, reproducible liquid film of sample (14 µm thick over cm^2 areas). Our experiments have demonstrated dilution-free analysis of high concentration samples (e.g. precious metals and dyes) for loaded sample volumes from 2 -10 µL. Phase transfer and precipitation has also been investigated, demonstrating that modified chips could deliver in-field analysis of aqueous, non-aqueous, and multi-phase systems.

Dr Priest is a Foundation Fellow at the Future Industries Institute and SA Node Director of the Australian National Fabrication Facility (ANFF-SA). He completed his PhD in Materials and Minerals at the University of South Australia (UniSA) in 2004 and then joined the Max Planck Institute for Dynamics and Self-Organization, Germany, to study droplet-based microfluidic systems. He is now leading a research group at the Future Industries Institute, UniSA, working on interfacial science in micro/nanofluidic devices and related environments and works closely with industry partners in minerals, water, and manufacturing. Dr Priest's research is funded through the ARC Discovery Project and Linkage Project schemes, the SA Government's Premier Science and Industry Fund, and through direct projects with domestic and international industry partners. He has published 3 book chapters, more than 50 journal articles, and filed IP. Dr Priest was a member of the SA Government Premier's Science and Industry Council from 2012-2014. He was awarded the SA Government's Tall Poppy of the Year – Early Career Researcher Award in 2011.

Advances in atom probe tomography for sophisticated materials characterisation

Simon P. Ringer*, Julie M. Cairney, Rongkun Zheng, Anna Ceguerra and Andrew Breen
Australian Centre for Microscopy & Microanalysis, University of Sydney, Sydney, NSW 2006, Australia.
*simon.ringer@sydney.edu.au

Atom probe tomography is at the centre of core research facilities at the University of Sydney, which provide an ecosystem for enabling research and innovation. Atom probe tomography has the unique capability of generating accurate, elementally resolved, atom-by-atom 3D data from a specimen.

Our ambitious research effort focuses on technique development including advanced analysis and reconstruction techniques for sophisticated forms of analysis not available in commercial software. One approach is known as lattice rectification [1]. While the spatial resolution of APT is high, it is generally not able to resolve the complete lattice structure of a crystalline material. In this unique approach, latent crystallographic information within the data is used to infer the site occupancy of the detected atoms to create accurate 3D lattice models of the sample. These models are amenable to atomic simulations and can be used to predict the properties of the sample material.

We have been able to capture atomic scale data from nanoparticles ~10 nm in size with single atom sensitivity [2]. As the performance of nanoparticles depends on their size, shape, chemical composition and, critically, their atomic-level structure, this success contributes entirely new information to dramatically enhance the rational design of nanoparticles thereby creating new applications in communications, energy and healthcare.

Having a limited field-of-view (FOV), atom probe tomography routinely gathers data only from the core of a sample. Therefore, where the shell of the specimen is also the region of interest, the capacity to analyse the full tip can be crucial. Our recent study of epitaxially grown III–V nanowires showed that the presence of a flat conducting substrate positioned only micrometres away from the tip apex alters the field distribution and ion trajectories, allowing the entire specimen to be analysed [3]. By simply adjusting the specimen preparation methodology the FOV is increased.

[1] Moody, Michael P., et al., Atomically resolved tomography to directly inform simulations for structure–property relationships, *Nat Commun, 5 (2014).*

[2] Xiang, Y., et al., Long-chain terminal alcohols through catalytic CO hydrogenation. *Journal of the American Chemical Society,. 135(19): 7114-7117 (2013).*

[3] Sichao Du et al., Full tip imaging in atom probe tomography *Ultramicroscopy 124, 96–101(2013)*

Simon Ringer is Professor of Materials Engineering and Director of Core Research Facilities, at the University of Sydney. Simon was Chair of the 52nd Field Emissions Symposium 2010, Co-Organiser of the 9th Asia Pacific Microscopy Congress 2008 and Symposium Organiser of the 6th PRICM 2007. Simon Ringer is a Fellow of the Institution of Engineers Australasia, and is presently Vice-President of the International Field Emission Society.

FlexeGRAPH: Bulk Graphene and 2D materials production and applications

Professor Tim Senden
director.rspe@anu.edu.au
Director, Research School of Physics and Engineering
Australian National University, Canberra ACT 2601

Graphene is the next generation wonder material due to its unique combination of superior mechanical, electrical, thermal and optical properties in comparison to current state of the art materials. This is driving commercial interest in the production and applications of graphene across many diverse industries including in health, water, energy, defence, construction and electronics.

Currently, no methods exist for producing scalable quantities of graphene without destroying many of the inherently interesting properties. Even fewer methods have the flexibility to tailor the interfacial properties of graphene allowing its use across market segments. Out of the group led by A/Prof Shannon Notley and developed at ANU is high quality, defect free graphene (FlexeGraph) produced with the design flexibility to functionalise the properties fit for end user purpose at unprecedented volumes. The FlexeGraph production process has led to a step change in the cost profile of graphene materials making volume applications now within reach. The advanced manufacturing process is also suitable for other atomically thin crystalline materials, commonly referred to as 2D materials, further distinguishing our IP from competitors.

The primary advantages of FlexeGRAPH graphene and 2D materials are:

1. Low cost.
2. Supply certainty for volume applications.
3. Unrivalled quality on a volume scale.
4. Tailored interfacial properties fit for customer purpose.

We have partnered with many research institutions in Australia and internationally to technically validate our graphene materials in novel applications including water purification, foam reinforcement and electrode manufacure. The flexibility in our process gives us the agility to respond to specific customer needs rather than supplying a generic graphene material.

In addition to supply of graphene and 2Ds, we are developing our own in house specific applications to take to market in thermal management. We have developed and protected enabling technology in thermoset resins, phase change materials and thermal transfer fluids with the breadth demonstrating the flexibility of the material to industry partners.

Tim is the Director of the Research School of Physics and Engineering at ANU.
With research interests in surface chemistry and he was part of the successful research development that led to the foundation of Lithicon, a company recently acquired by FEI.
Tim has many years of experience in IP protection and commercialisation strategies.
He is an integral part of the FlexeGRAPH team providing strategic leadership and technical guidance in dispersion science for downstream applications.

Using Additive Manufacturing to Tailor the Properties of Spacecraft Structures

Dr Sean Tuttle
s.tuttle@adfa.edu.au
Senior Lecturer
UNSW Canberra

UNSW Canberra Space is applying $10M of university investment to building capacity and capability for ground-based and in-orbit space research and space technology development and demonstration. A team of some 25 scientists and engineers has been assembled that includes an accumulated 100+ years of space mission experience underpinned by ground-based science, and supported with space environment simulation facilities, space surveillance telescopes, a satellite ground station, physics-based numerical simulation codes, and more.

One area of research focusses on the use of additive manufacturing techniques to tailor the material properties of structural elements for spacecraft. The key research aspects relate to the properties of the materials produced – the additive manufacturing enables the modification of these properties in ways which is not always possible when using monolithic, homogeneous materials. The areas under research include enhancement of the thermal properties of inexpensive, non-traditional materials to enable their use in nano- and microsatellite construction, thereby allowing, for example, high power densities to be accommodated, or improved thermal control of instruments. Another aspect being studied is different mechanisms to tailor the Rayleigh (or modal) damping of structural members, thus allowing, for example, the removal of disturbance vibrations in the measurement spectrum of an instrument. Yet another focus is on a range of modifications which can be made to printed materials to enhance their ability to shield internal spacecraft components from ionising radiation.

Fundamental aspects of the behaviour of the modified materials (such as inter-layer and interstitial mechanical interactions) are being studied using both experimental and numerical techniques. The additive manufacturing is largely the enabling technology, rather than the focus of the research; however, some work will target the development of the manufacturing techniques themselves.

Dr Sean Tuttle is currently a Senior Lecturer at the University of New South Wales in Canberra. He is a principal space systems engineer who has worked on more than 25 different scientific, earth observation and interplanetary missions in Europe. He has experience across all project phases from initial studies to post-launch diagnosis. He worked on the Rosetta mission for 6 years, leading the thermal design team for this mission of cold extremes. Later on, he led the thermal design of the Mercury Transfer Module, part of the extremely hot BepiColombo mission to the planet Mercury. His research interests include the development of novel technologies to improve the design of spacecraft for challenging missions, finding novel uses for space to improve life on Earth, systems engineering in the space context and mission design. Dr Tuttle is the coordinator of the two space masters programmes at UNSW Canberra and is a member of Engineers Australia's National Committee for Space Engineering and the Australian representative for Unisec-Global (the global university space engineering consortium).

Nanostructured Silicon in Nanomedicine

Nicolas H. Voelcker*
ARC Centre of Excellence in Convergent BioNano Science and Technology
Future Industries Institute, University of South Australia,
GPO Box 2471, Adelaide, SA 5001, Australia
*nico.voelcker@unisa.edu.au

This talk will explore the application of nanostructured silicon including porous silicon and silicon nanowires in localised drug delivery, optical and electrochemical biosensors and tissue engineering. We are have grant-funded collaborations in place with UCSD and Texas Christian University. The silicon-based materials we are fabricating have high surface area of up to several hundreds of square meters per gram, facilitating loading of considerable amounts of bioactives. Second, pore size can be tailored over a wide range, spanning from the nano- to the microscale. Being able to 'dial in' a certain pore size allows for facile optimisation of topographical cues for attachment, guidance, proliferation and differentiation of target cells. At the same time, the rate of diffusive release of drugs can be tuned by adjusting the pore size. Third, the materials are biocompatible and biodegradable, undergoing oxidative hydrolysis in aqueous medium at a rate that is easily tunable by means of the surface chemistry from hours to months [1]. A diverse range of surface chemistries is available for this material, some of which are amenable to surface patterning, formation of surface-bound gradients and formation of silicon-polymer hybrid materials [2,3]. Finally, thin films, membranes and particles of porous silicon display interferometric reflectance and photonic effects, which are responsive to binding of target biomolecules [4]. This talk will first introduce nanostructured silicon material properties and fabrication and characterisation aspects, including describing strategies for nano- and microscale patterning and gradient formation [5]. This will be followed by an overview of the recent biomaterial applications including examples of the use as a biodegradable biomaterial for ocular tissue engineering [6]. Drug delivery applications for targeted cancer therapy and the therapy of ocular diseases will be highlighted [7,8,9]. Finally, the use of nanostructured silicon in chronic wound diagnostics and theranostics will be discussed [10].

[1] S.P. Low et al. Biomaterials, 27 (2006), 4538-4546.

[2] Y.L. Khung et al., Controlled drug delivery from composites of nanostructured porous silicon and poly(L-lactide), Nanomedicine, 7 (2012), 995-1016.

[4] A. Jane et al. Trends in Biotechnology, 27 (2009), 230-239.

[5] M. Sweetman et al. Advanced Functional Materials, 22 (2012), 1158-1166.

[6] S. Kashanian, et al. Acta Biomaterialia, 6 (2010) 3566–3572.

[7] E. Secret et al., K. Advanced Healthcare Materials, 2 (2013), 718-727.

[8] H. Alhmoud et al., Advanced Functional Materials, accepted 21.11.2014 10.1002/adfm.201403414.

[9] B. Delalat et al. Nature Communication,. 6 (2015), 8791.

[10] F.S.H. Krismastuti et al. Advanced Functional Materials, 24 (2014), 3639-3650.

Professor Nicolas H. Voelcker. After completing his BSc at the University of Saarland (1993) and his MSc at the RWTH Aachen (1995) in Germany, Nico completed a PhD thesis (1999) in polymer surface chemistry at the DWI Leibniz Institute for Interactive Materials under Professor Hartwig Höcker. He received postdoctoral fellowships to work in the area of bioorganic chemistry under Professor Reza Ghadiri at the Scripps Research Institute in La Jolla, California. In 2001 he became a Lecturer at Flinders University in Australia, an Associate Professor in 2006 and a full Professor in 2008. From 2008-2011, he was the Associate Head of the Faculty of Science and Engineering at Flinders University. Since 2012, he is a Professor in Chemistry and Materials Science at the Mawson Institute of the University of South Australia. Since 2015, he is Strand Leader of the Future Industries Institute. Since 2014, he is also Node Leader in the Australian Research Council Centre of Excellence in Convergent Bio-Nano Science and Technology.

Interfacing Biomolecules with Nanomaterials: Elucidating Structure/Property Relationships

Tiffany R. Walsh
tiffany.walsh@deakin.edu.au
Institute for Frontier Materials,
Deakin University,
Geelong VIC 3216, Australia.

The interface between biomolecules (peptides, proteins and nucleic acids) with materials surfaces and/or nanoparticles can be found in a diverse range of areas including: self-organised metamaterials for photonic and plasmonic applications, biosensing, catalysis, energy generation and harvesting, and nano-medicine. A pivotal factor to successful exploitation of these interfaces is the ability to resolve and control the structures of these biomolecules in the surface-adsorbed state. In partnership with experimental characterisation, molecular simulations can bring complementary insights into these interfacial structures. Our team specialise in the development and deployment of advanced molecular simulation techniques for the purpose of elucidating these insights at biomolecule/materials interfaces [1-5].

Meaningful molecular dynamics simulations of these bio-interfaces are challenging, as is the connection with experimental characterisation. Here, we summarise our current and developing collaborations with key U.S partners in meeting these goals. Updates will be provided on our progress from our current AFOSR grant in this area in partnership with the University at Buffalo (SUNY) and the University of Miami. We also detail collaborative developments with staff at the Air Force Research Labs (AFRL) Human Performance Wing.

1. *N. M. Bedford et al. and T. R. Walsh,* J. Amer. Chem. Soc., **138**, *540-548 (2016)*

2. *L. B. Wright, J. P. Palafox-Hernandez, P. M. Rodger, S. Corni and T. R. Walsh,* Chem. Sci. **6**, *5204-5214 (2015).*

3. *Z. Tang, J. P. Palafox-Hernandez et al. and T. R. Walsh,* ACS Nano **7**, *9632 (2013).*

4. *Z. E. Hughes. S. M. Tomasio and T. R. Walsh,* Nanoscale, **6**, *5438 (2014).*

5. *J. P. Palafox-Hernandez et al., T. R. Walsh and M. R. Knecht,* Chem. Mater. **26**, *4960 (2014).*

After graduating with a B.Sci (Hons) from the University of Melbourne, **Tiff Walsh** earned her PhD degree in theoretical chemistry from the University of Cambridge, U.K. as a Cambridge Commonwealth Trust scholar. Following a Glasstone Fellowship in the Dept. of Materials at the University of Oxford, in 2002 she joined the faculty of the University of Warwick in the Dept. of Chemistry. In 2012 Tiff returned to Australia to the Institute for Frontier Materials at Deakin University, where she is currently Professor of Bio/Nanotechnology. Her research interests focus on computational modelling of the interface between soft matter and solid surfaces, using molecular simulations. She was appointed to join the Australian Research Council (ARC) College of Experts in 2015.

Shrinking the Telescope: replacing bulk optics with 3D integrated photonics

Integrated photonic chips represent a vital part of modern society. Indeed the Internet is enabled by photonic chips that convert an optical signal into the electrical one that connects with our computers. Photons, the elementary particle of light, can be characterised by 6 different traits: velocity (or phase), brightness, wavelength, polarisation, spatial mode and orbital angular momentum. Many applications that require compact size, low loss, thermal and vibration stability, AND seek to exploit one or more of these traits can only be realised using photonic chips that manipulate light in all 3 spatial dimensions.

Ultrafast laser inscription has been shown to be a viable fabrication platform for realising 3D photonics. This field has grown significantly in the last 10 years with over 50 research groups and several commercial enterprises currently active in this pursuit world-wide. Their target applications encompass classical and non-classical optics, waveguide and fibre lasers, telecommunications, astronomy, bio-photonics and sensing.

3D photonics has triggered new innovation in the design and engineering of next generation telescopes. An Australian team comprising members from Macquarie University, the University of Sydney and the Australian Astronomical Observatory have been pioneering the development of new photonic based devices that will ultimately reduce the size and cost of the detection and analysis instruments used on major astronomical facilities, both terrestrial and space based platforms. These devices include integrated photonic spectrographs and integrated interferometric imagers, both intended for exo-planet discovery and tested on large diameter telescopes on Mauna Kea, Hawaii. The same concepts are now being pursued via a new collaboration involving Lockheed-Martin and University of California-Davis, and numerous European consortia. In this presentation I will review the emerging international effort developing novel 3D photonics based imaging systems and highlight some of our recent on-telescope results.

Michael Withford is a CORE Professor at Macquarie University, Sydney, Australia. He leads both the Macquarie University node (web.science.mq.edu.au/groups/cudos/) of Australian Research Council (ARC) Centre of Excellence: Ultrahigh-bandwidth Devices for Optical Systems (CUDOS) and the OptoFab Node (optofab.org.au) of the Australian National Fabrication Facility. He holds several patents and has published over 130 refereed journal papers and several hundred conference papers. He is an Associate Editor for Optics Express and an OSA Fellow.

Quantum Engineering with Quartz

Dr Matt Woolley
m.woolley@unsw.edu.au
UNSW Canberra

Precise measurement is crucial to scientific and technological progress. For example, the development of atomic frequency standards at NIST Boulder provided the enabling technology for their subsequent experiments with trapped ions, which now provides the leading platform for quantum simulation. Such quantum simulations are expected to enable the solution of otherwise computationally intractable problems in materials science and chemistry.

In the case of solid-state systems, *quartz* bulk acoustic wave devices exhibit ultralow mechanical losses. This, coupled with the piezoelectric nature of quartz, has led to their widespread use as a stable, narrow-linewidth frequency standard for electronic oscillators. The exceptionally low mechanical losses achievable in quartz oscillators also make them an extremely attractive platform for experiments and devices in the emerging field of *quantum electromechanics*.

In quantum electromechanics, the mechanical motion of the macroscopic device itself is treated as a quantum mechanical observable, leading to the possibility of coherent superpositions, entanglement and so on. Such devices have attracted considerable interest for both the study of fundamental physics (quantum mechanics with macroscopic degrees of freedom, tests of the limits of quantum mechanics, relativity, and even physics beyond the Standard Model), and device applications (precision force and field sensing, microwave-to-optical interfaces, coherent interfaces for quantum information processing, and high-frequency gravitational wave detection).

However, the ultralow losses of quartz oscillators make them difficult to measure and control in the quantum regime. Coupling to their motion using conventional methods such as modulation of the capacitance of a resonant circuit, or the radiation pressure of an optical field, is very weak.

Here we propose and thoroughly analyse a hybrid quartz-superconductor quantum electromechanical system composed of a quartz bulk acoustic wave oscillator coupled to a superconducting quantum two-level system known as a transmon, via an intermediate LC electrical circuit. Ground-state cooling of the quartz oscillator via resonant piezoelectric coupling to the LC circuit, which is itself sideband cooled via coupling to the transmon, is shown to be feasible. The fluorescence spectrum of the qubit, containing motional sideband contributions due to the couplings to the oscillator modes, is obtained and the imprint of the electromechanical steady-state on the spectrum is determined. This allows the transmon to function both as a cooling resource for, and transducer of, the quartz oscillator. Experimental work towards the implementation of the system is under way. Technological capabilities enabled by the creation of such a device shall be discussed.

Dr Woolley completed was awarded a PhD in Theoretical Physics by the University of Queensland in February 2011. His thesis was completed under the supervision of Professor Gerard Milburn, a pioneer in theoretical quantum optics. He undertook postdoctoral research in Canada, with a joint appointment between the groups of Professors Aashish Clerk (a leading authority on the theory of quantum electromechanical and quantum electronic systems) at McGill University and Alexandre Blais (a pioneer in the theory of quantum computation using superconducting electrical circuits) at the Université de Sherbrooke. In September 2012 he began his current appointment as a Lecturer at UNSW Canberra.

Dr Woolley's research interests are in the theory of engineered quantum systems; specifically, on the theory of quantum electromechanical and optomechanical systems, and superconducting quantum electrical circuits. He uses techniques from theoretical quantum optics and condensed matter theory, in combination with techniques from electromagnetics, signals and systems, and control theory, in the invention, design and analysis of engineered quantum systems. He collaborates closely with leading experimental groups, aiming to both motivate and guide their work, and explain existing experimental results.

Predictive Materials Properties through the Establishment of Bio-inspired Rational Design Rules

Nicholas M. Bedford
Nicholas.bedford@nist.gov
National Institute of Standards and Technology, Boulder, CO 80305

Nanotechnology has become ubiquitous with advanced technologies in various fields of societal importance, including medical treatment, alternative energy and environmental remediation. Unfortunately, nanomaterials development is most commonly achieved through Edisonian approaches, wherein rational synthetic strategies are lacking yet sorely needed for technological advancement. To circumvent such commonplace strategies for materials development and discovery, a fundamental understanding between atomic-scale structure and properties is paramount. In this regard, nanoscale materials can be particularly difficult to fully characterise at this length scale. Electron microscopy can provide 2D atomic-scale structural information with limited sample statistics, while traditional XRD characterisation and analysis is difficult given the inherent lack of long-range periodic order in nanoscale materials.

In this talk, atomic-scale structure/function relationships of series of nanoscale materials will be explored, with a particular emphasis on catalytic nanomaterials. Using a combination of X-ray absorption spectroscopy (XAS) and atomic pair distribution function (PDF) analysis coupled to high-energy X-ray diffraction (HE-XRD), atomic-scale nanomaterial models are generated using advanced structural modeling methods. These nanoparticle configurations, created solely from experimental structural data, can then be used to assess properties as a function of atomic-scale structural disorder, particular at the nanomaterial surface. Examples to be discussed include peptide-enabled monometallic and bimetallic nanocatalysts, where PDF and XAS analysis indicate sequence-dependent effects on surface disorder and/or chemistry, which directly impact catalytic properties. In addition, preliminary in-situ HE-XRD electrochemical and gas phase catalysis experiments will be discussed, illustrating the capability to probe atomic-scale structure during various stages during catalysis. Overall, the presented examples and underlying methodology highlight routes to enable rational nanomaterials design through understanding fundamental structure/function relationships.

Nicholas Bedford received a BS in Physics and a BS in Chemistry from Central Michigan University (CMU) in 2007. From there, he immediately went on to the University of Cincinnati (UC) to receive a doctorate in Materials Science in 2011, studying environmental and energy applications of electrospun polymeric nanofibers in Dr Andrew Steckl's laboratory. During his time at the UC, he also performed research at the Air Force Research Laboratory (AFRL) under the guidance of Dr Rajesh Naik. Following his doctoral studies, he was award a National Research Council postdoctoral fellowship award to study structure/function relationships of peptide enabled nanomaterials with Dr Rajesh Naik at AFRL. During this postdoc, he also served as a visiting scholar in the University of Miami's chemistry department, working in Dr Marc Knecht's laboratory. He is currently a postdoc in the Applied Chemical and Materials Division at the National Institute of Standards and Technology (NIST), studying nanoscale materials using synchrotron radiation techniques.

The Air Force Office of Scientific Research (AFOSR)

Thomas Christian
Director
Air Force Office of Scientific Research (AFOSR)

As a directorate of the Air Force Research Laboratory (AFRL), AFOSR continues its mission to expand the horizon of scientific knowledge through its leadership and management of the U.S. Air Force (USAF) basic research program. We discover, shape, and champion basic science that profoundly impacts the future of the USAF by identifying breakthrough research opportunities on a global scale. Since 1951, AFOSR has selected, sponsored, managed, and transitioned revolutionary basic research technologies relevant to USAF needs, to the Department of Defense and industry.

AFOSR's current investment in basic research programs is distributed among approximately 1,400 grants and contracts to more than 200 academic institutions, 150 industry contracts and more than 200 research efforts within AFRL. AFOSR also collaborates with other government basic research agencies such as Office of Naval Research, Army Research Office, the Defense Advanced Research Projects Agency, the Defense Threat Reduction Agency, the National Science Foundation (NSF), and the Department of Energy. AFOSR also has a robust international outreach program, with offices in the United Kingdom (EOARD), Japan (AOARD), and Chile (SOARD).

The focus of AFOSR is on research areas that offer significant and comprehensive benefits to our national warfighting and peacekeeping capabilities. These areas include:

- Aero-Structure Interactions and Control
- Energy, Power and Propulsion
- Complex Materials and Structures
- Complex Electronics and Fundamental Quantum Processes
- Plasma Physics and High Energy Density Nonequilibrium Processes
- Optics, Electromagnetics, Communication, and Signal Processing
- Information and Complex Networks
- Decision Making
- Dynamical Systems, Optimisation, and Control
- Natural Materials and Systems

Dr Thomas F. Christian, a member of the Senior Executive Service, currently serves as Director for the Air Force Office of Scientific Research (AFOSR), where he guides the management of the entire basic research investment for the Air Force. Dr Christian leads a staff of 200 scientists, engineers and administrators in Arlington, Va., and foreign technology offices in London, Tokyo and Santiago, Chile. Each year, AFOSR selects, sponsors and manages revolutionary basic research that impacts the future Air Force. AFOSR interacts with leading scientists and engineers throughout the world to identify breakthrough opportunities; actively manages a $510 million investment portfolio encompassing the best of these opportunities; and transitions the resulting discoveries to other components of the Air Force Research Laboratory, to defense industries and to other federal agencies. The office's annual investment in basic research is distributed among over 200 leading academic institutions worldwide, 100 industry-based contracts, and more than 250 internal AFRL research efforts.

Dr Christian entered federal service in 1968 as an aerospace engineer at the Warner Robins Air Materiel Area, Ga., where he designed depot structural repairs to C-130 and C-141 aircraft returning from Southeast Asia. Following completion of his doctoral research in 1973, he worked in both the nuclear power and manufacturing industries. In 1980, he re-entered federal service at the Warner Robins Air Logistics Center, establishing an organic durability and damage tolerance analysis capability for the C-130, C-141 and F-15 weapon systems. Dr Christian became the technical adviser for the System Program Management Division and served on several national technical committees of the American Institute of Aeronautics and Astronautics.

As Chief Engineer for the Special Operations Forces System Program Office, he managed major modifications to the AC-130H and MH-53J weapon systems and a joint MH-60G flight test program with the Australian Defense Forces. He also served as Director of the 402nd Software Maintenance Group. Dr. Christian moved to the Aeronautical Systems Center at Wright-Patterson AFB, where he became the Director of Engineering for the Agile Combat Support Systems Wing. He provided systems engineering direction for aging aircraft, combat electronics, life support, propulsion and simulator systems with an annual budget of $3 billion. He then became a Senior Level executive as the Technical Adviser, Systems Engineering, at the Aeronautical Systems Center, where he provided technical oversight and advice to the highest Air Force and government officials concerning the $11 billion aeronautical enterprise's annual acquisitions. He then went on to become the Director at the Air Force Center for Systems Engineering, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Prior to his current position, Dr. Christian served as the Associate Deputy Assistant Secretary (Science, Technology, and Engineering) responsible for assisting the DAS(ST&E) in development and formulation of Air Force Science, Technology, and Engineering strategy and policy spanning systems engineering; environmental safety and occupational health; industrial preparedness; and functional management of more than 14,000 military and civilian scientists and engineers.

Functional Energy Materials: From 1D and 2D Polymers to 3D Carbon Nanomaterials

Liming Dai
Liming.Dai@case.edu
Kent Hale Smith Professor, Case School of Engineering
Case Western Reserve University

It is estimated that the world will need to double its energy supply by 2050. With the rapid increase in the global energy consumption, there is a pressing need for clean and renewable energy alternatives. Polymers have been traditionally used as electrically insulating materials: after all, metal wires are coated in plastics to insulate them. Various *conjugated* macromolecules with alternating single and double bonds can now be synthesised with unusual electrical and optical properties through the p-electron delocalisation along their 1D backbones. Due to the molecular rigidity of conjugated backbones, however, most unfunctionalised conjugated polymers are intractable (i.e., insoluble and/or infusible). Nevertheless, a number of synthetic methods have been devised to produce conjugated polymers with the processing advantages of plastics and the optoelectronic properties of inorganic semiconductors for optoelectronic device applications, including polymer photovoltaic cells [1].

Having conjugated all-carbon structures, carbon nanomaterials, including 1D carbon nanotubes (CNTs) and 2D graphene, also possess certain similar optoelectronic characteristics as conjugated macromolecules, apart from their unique structures and associated properties (e.g., surface/size effects) [2]. With the rapid development in nanoscience and nanotechnology, graphitic carbon nanomaterials (e.g., 1D CNTs, 2D graphene) have been playing a more and more important role in the development of efficient energy conversion and storage devices, including solar cells, fuel cells, supercapacitors and batteries [2-6]. The combination of the unique physicochemical properties of graphitic carbon nanomaterials with comparable optoelectronic properties of appropriate conjugated macromolecules has yielded some interesting synergetic effects. Therefore, considerable efforts have recently been made to utilise graphitic carbon nanomaterials, along with polymers, as energy materials, and tremendous progress has been achieved in developing high-performance energy conversion and storage devices based on graphitic carbon nanomaterials and conjugated polymers [7]. More recently, some 2D conjugated polymers and certain 3D graphitic carbon architectures (e.g., CNT-graphene pillared networks, graphene foams) have been demonstrated to show additional advantages for efficient energy conversion and storage [8,9].

[1] Dai L. "Intelligent Macromolecules for Smart Devices", Springer-Verlag: Berlin, 2004.
[2] Gong K, Du F, Xia Z, Dustock M, Dai L. Science 2009, 323, 760.
[3] Yu D, Zhang Q, Dai L, Chen Y. et al., Nat. Nanotechnol. 2014, 9, 555.
[4] Dai L, Xue Y, Qu L, Choi H J, Baek J B. Chem. Rev. 2015, 115, 4823.
[5] Zhang J, Zhao Z, Xia Z, Dai L. Nat Nanotechnol. 2015, 10, 444.
[6] Shui J, Wang M, Du F, Dai L. Sci. Adv. 2015, 1, e1400129.
[7] Xu J, Chen Y, Dai L. Nat. Commun. 2015, 6, 8103.
[8] Dai L. Acc. Chem. Res. 2013, 46, 31.
[9] Lu W, Baek JB, Dai L. (Eds.) "Carbon Nanotechnology for Advanced Energy Systems", Wiley, 2015.

Liming Dai joined Case Western Reserve University (CWRU) in fall 2009 as the Kent Hale Smith Professor in the Department of Macromolecular Science and Engineering. He is also director of the Center of Advanced Science and Engineering for Carbon (CASE4Carbon). Dr Dai received a BSc degree from Zhejiang University in 1983, and a PhD from the Australian National University in 1991. He accepted a postdoctoral fellowship from the Cavendish Laboratory at the University of Cambridge, and two years later became a visiting fellow in Department of Materials Science and Engineering at the University of Illinois at Urbana-Champaign. He spent 10 years with the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Melbourne, Australia. Before joining the CWRU, he was an associate professor of polymer engineering at the University of Akron and the Wright Brothers Institute Endowed Chair Professor of Nanomaterials at the University of Dayton.

Effects of Nanomaterials in Biological Systems

Saber Hussain
Senior Scientist and Nanotoxicology Group Lead, Molecular Bioeffects Division
Air Force Research Laboratory
Wright-Patterson Air Force Base, Ohio

Dr Saber Hussain's current research efforts are focused on elucidating the biological response and application potential of engineered nanomaterials (ENM), in the range of 1-100 nm, with novel physical and chemical properties. These physico-chemical properties emanate from interfacial features at the nano-scale and result in distinct electrical, mechanical, optical, and magnetic characteristics that are unique from their bulk counterparts. Fundamental studies currently underway involve nanomaterial interactions with living systems including in vitro and in vivo studies, intracellular fate; uptake, translocation, distribution, and potential toxicity of NMs. This research will facilitate a better understanding of the nano-cellular interface, provide in-depth analyses of adverse effects on in vivo biological systems, and enable development of theoretical aspects of predictive bio-response models. The research premise will aid in novel nanobiotechnology and nanotoxicology model development and thus enable safe implementation of nanomaterial products.

Saber Hussain is Senior Scientist and Nanotoxicology Group Lead in the Molecular Bioeffects Division, Wright-Patterson Air Force Base, Ohio. He is a fully affiliated Professor of Pharmacology and Toxicology, Wright State School of Medicine, Dayton, OH. Dr Hussain began (1987) his scientific career as a toxicology research fellow at the highly regarded Indian Institute of Chemical Technology (IICT) and received his doctorate degree in 1991. Here, his novel exploration of heavy metal biotransfer between different proteins in complex biological environment led to a series of prestigious research fellowships in Italy, Switzerland, and the U.S.

Dr Hussain joined the Air Force Research Laboratory at Wright-Patterson AFB in 1999, where his research interests transitioned into elucidating fundamental interaction of engineered nanomaterials with biological system with a special focus on developing nanodevices and evaluating potential toxicity arising from the physicochemical properties of nanoscale structures. His research addressing biomolecular interaction of nanomaterials and its associated toxicity has resulted in author/co-authorship of 100 peer-reviewed publications, several book chapters, and above 200 technical abstracts. He is currently an Associate Editor of Toxicological Sciences and serves as an editorial member of several other toxicology journals including Nanotoxicity Journal. He is a Fellow of the Academy of Toxicological Sciences and Fellow of US Air Force Research Laboratory. He serves as an expert reviewer for several government and private organisations. Dr Hussain has been the recipient of SOT-AstraZeneca traveling lectureship award and numerous scientific awards and has established a strong collaborative network with over 25 organisations of national and international repute.

AFOSR International Enterprise

Colonel Timothy J. Lawrence, PhD
Director, International Office
Air Force Office of Scientific Research (AFOSR)

The mission of the Air Force Office of Scientific Research International Office (AFOSR/IO) is to discover world-class fundamental research of interest to the US Air Force, and to bridge and build mutually beneficial relationships between scientists overseas and scientists in the United States that will result in the acceleration of S&T achievement.

To enhance AFOSR's research portfolio with the latest scientific and engineering advancements around the world, the International Office consists of four geographically strategic divisions. The European Office of Aerospace Research and Development (EOARD), in London, United Kingdom, provides coverage of Europe, the Eurasia, the Middle East, and Africa; the Asian Office of Aerospace Research and Development (AOARD), in Tokyo, Japan, has an area of responsibility that includes Asia, India, and Pacific Rim countries, including Australia and New Zealand; the Southern Office of Aerospace Research and Development (SOARD), in Santiago, Chile, provides coverage throughout the Latin American region; and the International Office North (AFOSR/ION), as part of AFOSR in Arlington, VA, serves as the Washington DC liaison for AFOSR's international activities.

Col. Timothy J. Lawrence is Chief, International Science Program Office, Air Force Office of Scientific Research (AFOSR) and Commander, Detachment 16, Air Force Research Laboratory, European Office of Aerospace Research and Development and Installation Commander (EOARD), RAF Blenheim Crescent, London, UK. Col. Lawrence, a native of Waterloo, Iowa, graduated with a Bachelor of Science from the US Air Force Academy in 1988, Master of Science from MIT in 1991, and a PhD from the University of Surrey (UK) in 1998. His PhD research led him to receive the Thomas Hawksley Gold Medal from the Institute of Mechanical Engineering in 1999. That research, coupled with swimming the English Channel, led him to be named one of the top 10 outstanding young people of the world in 2001 by the World Jaycees.

Col. Lawrence has served at the Air Force Research Laboratory's directorates in Edwards AFB and London as an advanced space propulsion engineer and space technology liaison officer. He authored a textbook on nuclear propulsion in 1995. At USAFA, he was director of the Department of Astronautics Space Systems Research Center where he worked on the design, assembly, and flight programs of FalconSAT-2, FalconSAT-3, and FalconSAT-5 small satellites. Col Lawrence spent eight and a half months in Kabul, Afghanistan where he was a mentor to the Afghan Dean of the National Military Academy Afghanistan.

Organic Materials Chemistry

Charles Lee
Program Manager, Organic Materials Chemistry Program
Air Force Office of Scientific Research (AFOSR)

The goal of this research area is to achieve unusual properties and behaviors from polymeric and organic materials and their inorganic hybrids through a better understanding of their chemistry, physics and processing conditions. This understanding will lead to development of advanced organic and polymeric materials for future U.S. Air Force applications. This program's approach is to study the chemistry and physics of these materials through synthesis, processing control, characterisation and establishment of the structure properties relationship of these materials. There are no restrictions on the types of properties to be investigated but heavy emphases will be placed on unusual, unconventional and novel properties. Research concepts that are novel, high risk with potential high payoff are encouraged. Both functional properties and properties pertinent to structural applications will be considered. Materials with these properties will provide capabilities for future Air Force systems to achieving global awareness, global mobility, and space operations. Current interests include photonic materials, semiconducting materials, materials with novel properties and synthesis of novel nanostructures.

Current interests include photonic polymers and liquid crystals, polymers with interesting electronic properties, and novel properties polymers modified with nanostructures. Applications of polymers in extreme environments, including space operation environments, are of interests. Material concepts for power management, power generation and storage applications are of interest. In the area of photonic polymers, research emphases are on materials whose refractive index can be actively controlled. These include, but are not limited to, third order nonlinear optical materials, electro-optic polymers, liquid crystals, photorefractive polymers and magneto-optical polymers. Examples of electronic properties of interest include conductivity, charge mobility, stretchable electronic materials, electro-pumped lasing and solar energy harvesting. Controlled growth and/or self-assembly of nanostructures into well-defined structures (e.g. carbon nanotubes with specific chirality) or hierarchical and complex structures are encouraged.

Organic based materials, including inorganic hybrids, with controlled magnetic permeability and dielectric permittivity are also of interest. Material concepts that will provide low thermal conductivity but high electrical conductivity (thermoelectric), or vice versa, (thermally conductive electrical insulator) are of interest. Nanotechnology approaches are encouraged to address all the above-mentioned issues. Approaches based on biological systems or other novel approaches to achieve material properties that are difficult to attain through conventional means are encouraged. Concepts of excited state engineering to control the flow of energy within a material or molecule are of interest. Concepts of single molecules that combine different moieties with various functionalities to perform complex functions as in a rudimentary electronic or photonic circuit for novel applications are welcome.

Charles Lee received a B.S. degree in Chemistry from Western Illinois University, and a Ph. D. degree in Chemistry from University of Wisconsin-Madison. After spending time at University of Southern California as a postdoctoral fellow, he joined University of Dayton Research Institute. He later joined the Materials Laboratory of the Air Force as a research scientist, conducting in house research as a Research Group Leader in the Polymer Branch and the Composite Branch, and managing roadmaps in various technology areas. He moved to the Air Force Office of Scientific Research (AFOSR) and managed the Polymer Chemistry Program and the Polymer Matrix Composite Program at AFOSR.

He is currently the Program Manager of the Organic Materials Chemistry Program. He was awarded the Cleary Award given by the Air Force Materials Laboratory for research for Chemorheological Studies of Matrix Resins. He was elected as Air Force Research Laboratory (AFRL) Research Fellow for his contributions to Functional Organic Materials research. He was elected as Fellow of The Optical Society of America (OSA); The Society for the Advancement of Material and Process Engineering (SAMPE); and The International Society for Optical Engineering (SPIE) and American Association for the Advancement of Sciences (AAAS).

NCI Alliance for Nanotechnology in Cancer Program and Resources for Cancer Nanotechnology Research

Stephanie A. Morris
morriss2@mail.nih.gov
Program Director
Office of Cancer Nanotechnology Research
Center for Strategic Scientific Initiatives
National Cancer Institute/National Institutes of Health

The National Cancer Institute (NCI) is developing exploratory research programs focused on the integration of advanced technologies to provide the scientific foundation required to advance cancer research and care. In particular, nanotechnology may improve cancer outcomes by producing new and beneficial approaches to cancer research, detection, diagnosis, and treatment. NCI is investigating nanotechnology-based approaches through support of individual and program-directed multidisciplinary research projects such as those under the umbrella of the Alliance for Nanotechnology in Cancer (Alliance) program. Founded in 2004, the Alliance program aims to develop and deploy nanotechnologies that have practical clinical applications. Encompassing the public and private sectors, the Alliance has made significant advances in the development of cancer-related nanodevices and multifunctional nanoplatforms by bringing together materials scientists and engineers with cancer biologist and clinicians to work together as multidisciplinary teams. An overview of this program's infrastructure and representative accomplishments will be presented, as well as current funding opportunities. This includes a description of Alliance interactions with other NCI/NIH initiatives that leverage their capabilities towards collaborative efforts. There will also be a discussion of resources available to the broader nanotechnology community, including the Nanotechnology Characterization Laboratory and relevant data sharing resources.

Dr Stephanie Morris is a Program Director in the National Cancer Institute (NCI) Office of Cancer Nanotechnology Research (OCNR) within the Center for Strategic Scientific Initiatives. She joined OCNR in 2012 and manages nanotechnology research awards that are part of the Alliance for Nanotechnology in Cancer program. She also participates in the development of new NCI research initiatives and is a member of several NIH/interagency committees and working groups, especially those focused on nanoinformatics.

Prior to joining OCNR, Dr Morris performed her postdoctoral work at NCI in the Laboratory of Receptor Biology and Gene Expression, where she focused on the genome-wide activity of chromatin remodeling enzymes involved in nuclear receptor function and oncogenesis, and was funded by a UNCF-Merck Postdoctoral Fellowship. She was a Ford Predoctoral Fellow and received her Ph.D. in Biochemistry and Biophysics from the University of North Carolina at Chapel Hill, where she studied the transcriptional role of histone-modifying enzymes. Before pursuing her graduate studies, Dr Morris worked at the Albert Einstein College of Medicine, where she directed an Analytical Ultracentrifugation Facility in the Laboratory of Macromolecular Analysis and Proteomics. She graduated from Wesleyan University in Middletown, Connecticut with a B.A. in Biology, and Neuroscience and Behavior.

Convergence of Engineering and X: An Alternate Dynamic Perspective (X = Oncology)

Larry A. Nagahara
Whiting School of Engineering
Johns Hopkins University

The 20th century brought us the 'Digital Revolution' that transformed our everyday lives through the introduction and use of innovative technologies such as cell phones, computers, internet, etc. In the case of healthcare, a similar transformation occurred by way of medical imaging (e.g., MRI and CT) and the development of antibiotics (penicillin). While these two examples in medicine produced tremendous impact, the benefits are seen in 'reactive-centric' medicine – wait for the disease/symptom to present itself first and then resolve it. There is currently an ongoing shift in healthcare to go from being 'reactive' to being more 'preventive' – where maximising prevention occurs by identifying and treating the root cause of the disease. Unfortunately, the root cause of many diseases (e.g., cancer) is not known and thus requires alternate approaches and novel technologies that enable a more 'dynamic' resolution to current reactive practice. Dynamic approaches are common concepts in engineering and lend itself well to being incorporated with healthcare. New paradigms are necessary for these novel concepts and practices to be accepted and ultimately adopted.

In this talk, examples of blending systems level perspective will be presented to illustrate that fostering the development of innovating and promising approaches could lead to a paradigm shift in the way we understand and ultimately and treat various types of diseases.

Dr Larry Nagahara is currently the Associate Dean for Research (ADR) in the Whiting School of Engineering (WSE) and Research Professor in the Department of Chemical and Biomolecular Engineering at Johns Hopkins University (JHU). Previously, he was the Associate Director within the Division of Cancer Biology at National Cancer Institute (NCI)/National Institutes of Health (NIH), where he directed and coordinated programs and research activities related to expanding the role of the physical sciences and engineering in cancer research. This included the largest federally-funded program dedicated to the convergence of physical and life sciences, namely the NCI's Physical Sciences–Oncology Initiative. In addition, Dr Nagahara served as the Nanotechnology Projects Manager for the NCI's Alliance for Nanotechnology in Cancer program.

Before joining NCI, Dr Nagahara was a Distinguished Member of the Technical Staff at Motorola and led their nanosensor effort. He has published over 95 technical papers, 3 book chapters, and over 25 patents issued/filed in these fields. He is also a Fellow of the American Association for the Advancement of Science (AAAS), American Institute for Medical and Biological Engineering (AIMBE), American Physical Society (APS), IEEE, and a former member of Motorola's Scientific Advisory Board.

Energy Harvesting Materials and Systems

Shashank Priya
spriya@vt.edu
Robert E. Hord Jr Professor & Turner Fellow
Mechanical Engineering
Virginia Tech University

Novel material properties open the possibility of developing new components and systems. These new components and systems require sustainable power to operate. This synergy between the materials – energy – smart systems has provided the new paradigm for innovation driving the emergence of efficient and high performance architectures. Some examples illustrating these platforms will be provided in this presentation covering solar, thermal, wind and vibration energy harvesting. One such platform being the self-powered structural health monitoring and automation control nodes. The vast reduction in the size and power consumption of sensors and CMOS circuitry has opened the opportunity to develop on-board power sources that can replace or extend the life of the batteries. In some applications such as sensors for structural health monitoring in remote locations, geographically inaccessible temperature or humidity sensors, the battery charging or replacement operations can be tedious and expensive. Logically, the emphasis in such cases has been on developing the on-site generators that can transform any available form of energy at the location into electrical energy.

Another example platform being the on-body energy harvesters that can passively capture the wasted energy while assisting the human actions. The harvested energy could be used to recharge the batteries or monitor the physical health. The presentation will provide advances made in our laboratory in harvesting and processing the energy harvested on variety of civilian and defense relevant platforms. In-depth discussion of the design, modeling and testing procedures will be provided to illustrate the strategy behind achieving high power density and efficiency.

Shashank Priya is currently Robert E Hord Jr. Professor in the department of mechanical engineering and Turner Fellow in the college of engineering. His research is focused in the areas related to multifunctional materials, energy and bio-inspired systems. He has published over 300 peer-reviewed journal papers and more than 50 conference proceedings covering these topics. Additionally, he has published more than five book chapters, five US patents, and five edited books. He is the founder and chair of the Annual Energy Harvesting Workshop series (www.ehworkshop.com). He is currently serving as the chief editor of journal "Energy Harvesting and Systems", editorial board member of journal integrated ferroelectrics and advisory board member of journal of dielectrics. He is also serving as the member of the Honorary Chair Committee for the International Workshop on Piezoelectric Materials and Applications (IWPMA). Shashank has received several awards including: Alumni award for excellence in Research 2014, Fellow American Ceramic Society 2013, Turner Fellowship 2012, Dean's Research Excellence Award 2011, and AFOSR Young Investigator Award.

Engineering the MAX phases and Their Composites for Extreme Environments

Miladin Radovica, Ibrahim Karamana and Gwenaelle Proustb
mradovic@temu.edu
a Department of Material Science and Engineering, Texas A&M University, College Station, TX 77843, USA
b School of Civil Engineering, University of Sydney, Sydney, NSW, Australia

A new class of carbides and nitrides with nanolaminated structure – known as the MAX phases – has challenged typical description of ceramics since they possess unusual, and sometimes unique, set of properties.[1,2] Like typical ceramics, the MAX phases are elastically stiff, good thermal and electrical conductors, resistant to chemical attack, and have relatively low thermal expansion coefficients. Mechanically, however, the MAX phases cannot be more different when compared to typical ceramics because they are relatively soft and most readily machinable, thermal shock resistant and damage tolerant. Some of the MAX phases – notably Ti_2AlC and Ti_3SiC_2 – are refractory and oxidation, fatigue and creep resistant. At room temperature, they can be compressed to stresses as high as 1 GPa and fully recover upon removal of the load, while dissipating ≈ 25% of the mechanical energy.[2,3] From more than 60 different MAX phases, Ti_2AlC is considered to be one of the best candidates for applications in extreme environments because of its excellent corrosion/oxidation resistance in air and water vapor at high temperatures, due to the formation of spallation-resistant layer of Al_2O_3 with crack healing capabilities.[4] In this paper the emphasis will be given to the engineering of Ti_2AlC and its composites for application in extreme environments. The effects of processing and microstructure on mechanical properties (stress-strain response, brittle-to-plastic transition temperature and creep resistance) and oxidation resistance is summarised in more detail. The challenges and advantages of processing the MAX phase composites with different metals (Al, Mg, NiTi, etc.) and other ceramics (SiC and Alumina fibers) for extreme environments are also discussed.[5,6]

1. M Radovic, MW Barsoum; American Ceramics Society Bulletin 92 (3), 20-27, (2013)

2. MW Barsoum, M Radovic; Annual review of materials research 41, 195-227, (2011)

3. R Benitez, WH Kan, H Gao, M O'Neal, G Proust, M Radovic; Acta Materialia 105, 294–305, (2016)

4. S Basu, N Obando, A Gowdy, I Karaman, M Radovic; Journal of the Electrochemical Society 159 (2), C90-C96 (2011)

5. L Hu, A Kothalkar, G Proust, I Karaman, M Radovic; Journal of Alloys and Compounds 610, 635-644, (2014)

6. L Hu, M. O'Neal, V. Erturun, R. Benitez, G Proust, I Karaman, M Radovic; Scientific Reports, under review, (2016)

Miladin Radovic received his Ph.D. in Materials Engineering from Drexel University, Philadelphia, USA, in 2001 and joined Oak Ridge National Laboratory as postdoctoral fellow after that. In 2006 he joined Texas A&M University as assistant professor, where he was promoted to associate professor with tenure in the Department of Materials Science and Engineering with adjunct position in the Department of Mechanical Engineering in 2012. He was also a guest scientist at National Institute of Standards and Technology, Gaithersburg, MD from 1999 to 2001 and visiting associate professor at University of Sydney in 2013. Dr Radovic's research interests are related to the processing of advanced structural and multi-functional ceramics and ceramic composts for extreme environments and characterisation of their thermal properties and mechanical behavior. He is author or co-author 6 book chapters and invited review papers, over 110 peer-reviewed publications. He was recipient of the CAREE award from National Science Foundation in 2011, Herbert H. Richardson Faculty Fellowship from College of Engineering at Texas A&M University in 2013, and International Collaboration Award from the University of Sydney in 2013. He is currently serving as Materials Science and Engineering Graduate Program Director and Associate Department Head at Texas A&M University.

Superconducting Quantum Interference Filter (SQIF) Technology for Deep-Space Microwave Communications Applications

Robert Romanofsky
NASA Glenn Research Center

With SQIF technology, we are entering the regime where hv ≈ kB Te – quantum zero-point fluctuations will play a more dominant role in determining behavior than the more familiar thermal fluctuations. The noise temperature of a SQIF scales as 1/√N, where N is the number of SQUID loops in the series-parallel array structure. Hence, Te can be made arbitrarily small – a "noiseless" receiver. SQIF technology promises quantum limited performance (analogous to photon counting) at microwave frequencies. In a projected Mars to Earth communication link, power densities at the Earth's surface might be about 10^{-16} W/m^2. The electric field *E* is about 10^{-7} V/m (and the displacement flux density D is 10^{-18} C/m^2). The corresponding magnetic field strength H is 10^{-9} A/m (with a magnetic flux density B of 10^{-15} Wb/m^2). Conventional SQUIDs can detect levels lower than one flux quantum (*h/2e*) or roughly 10^{-15} Wb, and SQIF technology can be orders of magnitude more sensitive than this. Examples of SQIF arrays implemented using the HYPRES Nb superconductor integrated circuit fabrication process with a 4.5 kA/cm^2 Josephson junction critical current density will be described.

Dr Romanofsky has been employed by the NASA Glenn Research Center for approximately 30 years. He was detailed to NASA headquarters in 1990 as program manager for superconductivity and RF communications and subsequently served a three month collateral assignment in the White House Office of Science and Technology Policy. His expertise is in the fields of microwave device technology and antennas, cryogenic electronics and high-temperature superconductivity, and microwave applications of thin ferroelectric films.

He authored chapters in Low-Temperature Electronics-Physics, Devices, Circuits and Applications (Academic Press, 2000), the 4th edition of the Antenna Engineering Handbook (McGraw-Hill, 2007), and Ferroelectric Thin Films at Microwave Frequencies (Research Signpost, 2010) and has over 100 technical publications. He holds seven patents, and is a recipient of NASA's Exceptional Service Medal, the Federal Executive Board "Wings of Excellence" award, Rotary National Stellar Space Award, NASA's Exceptional Technology Achievement Medal, Two IR&D 100 Awards, the Federal Laboratory Consortium 2010 Award for Excellence in Technology Transfer, and the Air Force Exemplary Civilian Service Medal. Dr Romanofsky was inducted into the Space Technology Hall of Fame in 2013. In addition, Dr Romanofsky has been an Adjunct Professor at the Cleveland State University since 2000. From October, 2010 through September, 2011 he was detailed to the National Security Space Office in Washington DC and served as acting Chief of Advanced Concepts. Dr Romanofsky was appointed as Senior Technologist in the Communications and Intelligent Systems Division in 2016.

DAY 1, MAY 23 | SYDNEY AUSTRALIA
Tyree Room | John Niland Scientia Building | University of New South Wales

Time	Topic	Speaker
8.15am–8.30am	*Transport from Crowne Plaza, Coogee to UNSW*	
8.30am–9.00am	Registration	
9.00am–9.15am	Welcome and Introduction	**Mrs Rosie Hicks**, Chief Executive Officer *Australian National Fabrication Facility* **Prof Mary O'Kane** *NSW Chief Scientist & Engineer*
9.15am–9.30am	Joint International Initiatives	**Dr Sofi Bin-Salamon** International Program Manager *Air Force Office of Scientific Research*
9.30am–9.45am	Opening Remarks	**Prof Les Field** Senior Deputy Vice-Chancellor and Senior Vice President, *UNSW* Secretary Science Policy, *Australian Academy of Science*
9.45am–10.00am	The Air Force Office of Scientific Research	**Dr Thomas Christian**, Director *Air Force Office of Scientific Research*
10.00am–10.30am	AFOSR International Enterprise	**Col Timothy Lawrence**, Director *AFOSR International Office*
10.30am–11.00am	BREAK	
11.00am–11.30am	NASA's Glenn Research Center	**Dr Robert Romanofsky** Senior Technologist *NASA Glenn Research Center*
11.30am–12.00pm	Convergence of Engineering and Oncology	**Dr Larry Nagahara** Associate Dean Engineering *Johns Hopkins University*
12.00pm–12.30pm	NCI Alliance for Nanotechnology in Cancer Program and Resources for Cancer Nanotechnology Research	**Dr Stephanie Morris** Program Manager National Cancer Institute, *NIH*
12.30pm–1.30pm	LUNCH	
1.30pm–2.00pm	Australian Research Infrastructure: A platform for international collaboration	**Dr Miles Apperley** Head of Research Infrastructure, *ANSTO*
2.00pm–2.30pm	Enabling Technologies at the Commonwealth Scientific and Industrial Research Organisation (CSIRO)	**Dr Emma Mitchell** Principal Research Scientist, *CSIRO*
2.30pm–3.00pm	ANFF – A Platform for Internation Collaboration	**Mrs Rosie Hicks**, Chief Executive Officer *Australian National Fabrication Facility*
3.00pm–3.30pm	BREAK	
3.30pm–3.45pm	Australian University Perspective	**Warwick Dawson** Director, Research Strategy & Partnerships, *UNSW Australia*
3.45pm–4.15pm	Centre for Nanoscale Bio Photonics ARC Centre of Excellence	**Prof Jim Piper** CNBP Node Leader *Macquarie University*
4.15pm–4.45pm	Spin-based Quantum Computing in Silicon	**Prof Andrew Dzurak** Scientia Prof & ANFF-NSW Director *UNSW Australia*
5.00pm	ADJOURN	
5.00pm–6.30pm	**Welcome Drinks** **Venue**: Tyree Room/Balcony	
6.45pm	*Transport from UNSW to Crowne Plaza, Coogee*	

DAY 2, MAY 24 – SESSION 1: MATERIALS SCIENCE Tyree Room | John Niland Scientia Building		
Time	**Topic**	**Speaker**
8.00am–8.30am	*Transport from Crowne Plaza, Coogee to UNSW*	
8.30am–9.00am	Functional Energy Materials: From 1D and 2D polymers to 3D Carbon Nanomaterials	Prof Liming Dai *Case Western University*
9.00am–9.20am	FlexeGRAPH: Bulk Graphene and 2D materials production and applications	Prof Tim Senden *Australian National University*
9.20am–9.40am	Ultrathin polymer supported metal-organic framework and graphene oxide nanocomposite membranes for gas separation	Prof Vicki Chen *UNSW Australia*
9.40am–10.00am	The vast opportunities offered by high-quality graphene on silicon	A/Prof Francesca Iacopi *Griffith University*
10.00am–10.20am	Atomically Thin Materials for Future Low-Energy Electronics	Prof Michael Fuhrer *Monash University*
10.20am–10.50am	BREAK	
10.50am–11.20am	Energy Harvesting Materials and Systems	Dr Shashank Priya, Robert Hord Prof and Turner Fellow *Virginia Tech University*
11.20am–11.40am	Nanostructured Solid State Hydrogen Storage Materials	A/Prof Francois Aguey-Zinsou *UNSW Australia*
11.40am–12.00pm	Surface and Interface Analysis in Renewable Energy Research	Prof David Lewis *Flinders University*
12.00pm–12.20pm	Towards a 'proton battery' with an integrated carbon-based hydrogen-storage electrode	Prof John Andrews *RMIT*
12.20pm–12.40pm	Methods to develop high performance and durable solid oxide fuel cells	Prof San Ping Jiang *Curtin University*
12.40pm–1.00pm	Measurement standards for nanotechnology	Dr Victoria Coleman *National Measurement Institute*
1.00pm–1.40pm	LUNCH	
1.40pm–2.00pm	AFOSR Organic Materials Chemistry Program	Dr Charles Lee Program Manager, Organic Materials Chemistry Program, *AFOSR*
2.00pm–2.20pm	Organic Materials Device Chemistry: Synthesis, Characterisation and Fabrication	Prof Paul Dastoor *University of Newcastle*
2.20pm–2.40pm	From Electromaterials to Integrated 3D structures	A/Prof Peter Innis *University of Wollongong*
2.40pm–3.00pm	Developing Nanostructured Electromaterials for Energy Applications	Prof David Officer *University of Wollongong*
3.00pm–3.30pm	BREAK	
3.30pm–3.50pm	Pushing the limits in glass properties and structures for laser, sensing and nonlinearity applications	Prof Heike Ebendorff-Heidepriem *University of Adelaide*
3.50pm–4.10pm	Micro- and Nano-Structured Materials and Devices Fabricated by Drawing	Dr Richard Lwin *The University of Sydney*
4.10pm–4.30pm	Plasma Measurements with Nanosecond Time Resolution	A/Prof Sean O'Byrne *UNSW Australia*
4.30pm–5.15pm	Panel Discussion Closing Remarks Tyree Room Dr Sofi Bin-Salamon International Program Manager, AFOSR & Mrs Rosie Hicks, CEO Australian National Fabrication Facility	
5.15pm	MEETING CONCLUDES	
5.30pm	*Transport from UNSW to Crowne Plaza, Coogee*	

DAY 2, MAY 24 – SESSION 2: PHYSICS Galleries 1 Room | John Niland Scientia Building		
Time	**Topic**	**Speaker**
8.00am–8.30am	*Transport from Crowne Plaza, Coogee to UNSW*	
8.30am–9.00am	Superconducting Quantum Interference Filter (SQIF) Technology for Deep-Space Microwave Communications Applications	Dr Robert Romanofsky *NASA Glenn Research Center*
9.00am–9.20am	Conformable optrode for the brain/machine interface	Prof Francois Ladouceur *UNSW Australia*
9.20am–9.40am	High-resolution imaging in hard-to-access locations	Dr Martin Ploschner *Macquarie University*
9.40am–10.00am	New insights into the fundamental electronic transport properties of advanced semiconductor materials and devices	Prof Lorenzo Faraone *University of Western Australia*
10.00am–10.20am	Quantum Engineering with Quartz	Dr Matt Woolley *UNSW Australia*
10.20am–10.50am	BREAK	
10.50am–11.20am	Shrinking the Telescope: replacing bulk optics with 3D integrated photonics	Prof Michael Withford *Macquarie University*
11.20am–11.40am	Gradient-index optical elements for beam shaping	Prof James Leger *University of Minnesota*
11.40am–12.00pm	Nanofabrication of photonic materials	A/Prof Mike Ford, *UTS*
12.00pm–12.20pm	Progress in MEMS-based optical filters for spectrally adaptive remote sensing from visible, through infrared, to terahertz	A/Prof Mariusz Martyniuk *University of Western Australia*
12.20pm–12.40pm	Recent progress in MBE infrared material research at UWA	A/Prof Wen Lei *University of Western Australia*
12.40pm–1.00pm	Big Data Challenges for the Science of Small Things	Dr Amanda Barnard, *CSIRO*
1.00pm–1.40pm	LUNCH	
1.40pm–2.00pm	New Spectroscopic Protocols for Unravelling Complex Spectra	Prof Andre Luiten *University of Adelaide*
2.00pm–2.20pm	Progress in understanding complex surfaces using ToF-SIMS and multivariate analysis	A/Prof Paul Pigram *La Trobe University*
2.20pm–2.40pm	Using Additive Manufacturing to Tailor the Properties of Spacecraft Structures	Dr Sean Tuttle *UNSW Australia*
2.40pm–3.00pm	Characterising nanoscale adhesion and friction	Prof Han Huang *University of Queensland*
3.00pm–3.30pm	BREAK	
3.30pm–3.50pm	Engineering the MAX Phases and their Composites for Extreme Environments	Prof Miladin Radovic *Texas A&M University*
3.50pm–4.10pm	Advances in atom probe tomography for sophisticated materials characterisation	Prof Simon Ringer *The University of Sydney*
4.10pm–4.30pm	Nano-scale characterisation for defence materials	Prof Julie Cairney *The University of Sydney*
4.30pm–5.15pm	**Panel Discussion** Closing Remarks Tyree Room Dr Sofi Bin-Salamon International Program Manager, AFOSR & Mrs Rosie Hicks, CEO Australian National Fabrication Facility	
5.15pm	MEETING CONCLUDES	
5.30pm	*Transport from UNSW to Crowne Plaza, Coogee*	

DAY 2, MAY 24 – SESSION 3: BIOMEDICAL SCIENCES AND HUMAN PERFORMANCE Galleries 2 Room | John Niland Scientia Building		
Time	**Topic**	**Speaker**
8.00am–8.30am	*Transport from Crowne Plaza, Coogee to UNSW*	
8.30am–9.00am	Effects of Nanomaterials in Biological Systems	Dr Saber Hussain Senior Scientist and Nanotoxicology Group Lead, Human Performance Directorate, *Air Force Research Laboratory*
9.00am–9.20am	Non-destructive detection and trapping of nanoscale biomolecules	Prof Warwick Bowen *University of Queensland*
9.20am–9.40am	Stimulating and Imaging: Integrating Non-invasive Biomedical Technologies	Prof Stephen Crain *Macquarie University*
9.40am–10.00am	Nanostructured Silicon in Nanomedicine	Prof Nicholas Voelcker *University of South Australia*
10.00am–10.20am	Nanoporous Silica Particles in Life Science Applications	Dr Alfonso Garcia-Bennett *Macquarie University*
10.20am–10.50am	BREAK	
10.50am–11.20am	TBC	Research Scientist, Human Performance Directorate *Air Force Research Laboratory*
11.20am–11.40am	Nanoscale patterning of supported lipid bilayers for sensor applications	Prof Sally McArthur, *Swinburne University*
11.40am–12.00pm	Interfacing Biomolecules with Nanomaterials: Elucidating Structure/ Property Relationships	Prof Tiffany Walsh, *Deakin University*
12.00pm–12.20pm	Predictive Materials Properties through the Establishment of Bio-inspired Rational Design Rules	Dr Nicholas Bedford *National Institute of Standards and Technology*
12.20pm–12.40pm	Photoswitchable bioprobes	Prof Andrew Abell, *Adelaide University*
12.40pm–1.00pm	Discussion	
1.00pm–1.40pm	LUNCH	
1.40pm–2.00pm	Taking Separations From The Laboratory to the Sample to the Individual	Prof Emily Hilder *University of South Australia*
2.00pm–2.20pm	Developing a platform technology for the self-assembly of functional nanoparticles	Dr Andrew Care *Macquarie University*
2.20pm–2.40pm	Recent advances in time-gated luminescence techniques for biological and security applications	Dr Yiqing Lu *Macquarie University*
2.40pm–3.00pm	Illuminating mRNA and proteins in new ways with nanoparticles and chemical conjugates	Dr Lindsay Parker *Macquarie University*
3.00pm–3.30pm	BREAK	
3.30pm–3.50pm	Scalable cellular engineering via ultrasonic microfluidic vortex shedding	Ryan Pawell, *Indee Inc.*
3.50pm–4.10pm	Microfluidics in Structured Arrays for Dilution-Free Analysis	Dr Craig Priest *University of South Australia*
4.10pm–4.30pm	Floating liquid marbles as a digital microfluidics platform for three-dimensional cell cultures	Prof Nam-Trung Nguyen *Griffith University*
4.30pm–5.15pm	Panel Discussion Closing Remarks Tyree Room Dr Sofi Bin-Salamon International Program Manager, AFOSR & Mrs Rosie Hicks, CEO Australian National Fabrication Facility	
5.15pm	MEETING CONCLUDES	
5.30pm	*Transport from UNSW to Crowne Plaza, Coogee*	

www.anff.org.au