

Contents

	page
Welcome to ACES	02
From the Executive Research Director	03
From the International Advisory Board	04
Highlights of the ACES Core Funded Research Activities	08
Education and Training	14
International Profile	18
National Profile	29
Outreach Activities	31
Prizes and Awards	39
Industry/End-User Liaison	43
Management Arrangements	46
Publications	47
Performance Indicators	53
Activity Report 2009	58
Other Developments	70
Activity Plan 2010	74
Appendix 1: ACES Visitor List 2009	75
Appendix 2: ACES Media Coverage 2009	78
Appendix 3: ACES Intellectual Property Register	83
Appendix 4: ACES Staff List	84
Appendix 5: ACES PhD Student List	87

Welcome to ACES

ACES is the Australian Research Council (ARC) Centre of Excellence for Electromaterials Science. It brings together eminent scientists to develop the nano-science and nanotechnology related to the movement of electric charge within and between materials. The approach provides an alternative to varying the composition of a material to alter physical and biological properties – instead we alter dimensions and shape in the nanodomain. These processes are fundamentally important to a diverse array of phenomena important in medicine and industry. ACES is studying these processes and, in so doing, is developing improved electromaterials and applying these in energy harvesting systems, highly efficient energy storage materials and medical bionics.

Through the investigation of new nanomaterials and new theories to explain their behaviour, ACES will tackle some of the biggest challenges facing society. These include the development of renewable energy systems in the form of plastic solar cells, lightweight batteries and electronic textiles; the growth of sustainable industries which would benefit from advances in the recovery of precious metals and new corrosion protection technologies; advances

in medical science through the regeneration of damaged nerves such as in spinal injury; and the development of artificial muscles.

In early 2009 ACES was made up of components from four research organisations: the University of Wollongong (including the Intelligent Polymer Research Institute and the Institute for Superconducting & Electronic Materials), Monash University (including the Ionic Liquids group), the Bionic Ear Institute and St Vincents's Health in Melbourne. By the end of 2009 the research organisations in ACES now number 5: the University of Wollongong (including the Intelligent Polymer Research Institute and the Institute for Superconducting & Electronic Materials), Monash University (including the Ionic Liquids group), St Vincents's Health in Melbourne, La Trobe University in Melbourne and University of Tasmania.

ACES was established in 2005 and was funded by the ARC with \$12 million in federal funding over five years. ACES also received support from the NSW Department of State & Regional Development to achieve technology transfer to NSW and Australian industry. In 2009 the ARC announced that ACES will receive a further \$7.7 million in funding from July 2010 until December 2013.



ACES was established to bring together eminent scientists to develop the nano-science and nanotechnology related to the movement of electric charge within and between materials.

The Director's Message

Following the successful review of the centre in 2008, we have been able to look beyond the horizon in 2009 and to start to build the bridges that will carry us into the next phase of ACES research.

Our activities moving forward will build on our success to date in new electromaterials and their application in energy and medical bionics. The development of multifunctional nanostructured carbons based on graphene and nanotubes, as well as new metal oxide structures, will be an area of intense activity. Inherently conducting polymers and novel electrolyte formulations will provide platforms on which to incorporate and integrate appropriate functionality for energy conversion, and our capabilities in solar cell science place us in an enviable position to tackle the challenging area of water splitting.

We will also build on the novel organic bionics platforms we have produced and move towards *in vivo* studies.

Device fabrication and prototype development have often proved to be a bridge too far – as we strive to demonstrate practical feasibility and look to take our research closer to commercialisation. An exciting development during 2009 is that the IPRI node of ACES in partnership with ISEM (www.uow.edu.au/eng/research/ISEM) has been granted Federal Government funding to establish a prototyping and device fabrication facility at the Wollongong Innovation Campus (www.electromaterials.edu.au). This important new development provides an opportunity to build world class research capabilities not only in materials but in the design and fabrication of devices that use these materials.

These new capabilities add to the recently established state-of-the-art research spaces at Monash and Wollongong and the additional capabilities brought by our partner at the Graeme Clark Centre for Bionic Ear and Neurosensory Research at La Trobe University.

During 2009, Prof Graeme Clark has established a new team at La Trobe with the Director of this Centre, Prof Anthony Paolini, who will also join the ACES Bionics programme. Other important additions to the chief investigator team include Prof Mark Cook (from St Vincents, Melbourne) to our Bionics research team and Dr Marc in het Panhuis (recently appointed Future Fellow at University of Wollongong) to the Electromaterials programme. Prof Susan Dodds continues to head our ethics research team but from further south (University of Tasmania).

As we prepare to embark on 2010 we are encouraged by the steps we have taken on the research, end-user and outreach fronts during 2009. We have invested substantial time and energy into new materials synthesis, fabrication and characterisation with significant progress in the area of graphene functionalisation and a marked expansion in our fibre spinning and printing facilities and capabilities. These advances in materials fabrication have enabled significant breakthroughs in our Energy and Bionics research programs.

Once again, it has been a great pleasure to work with an extraordinarily talented group of researchers supported by staff in all of our partner organisations that share our vision.

The challenges that confront us in the areas of Energy and Bionics are complex and the potential returns to society are great. Through ACES, we have established a world renowned research team now housed in facilities with equipment and support second to none around the globe.

I think we really can say that what we can achieve is limited only by our own vision and drive – a truly privileged position- from which we aim to return substantial benefits to all who have shown faith in us.

I hope you enjoy reading the following pages that highlight some of our activities during 2009.

Regards



Professor Gordon Wallace
Executive Director of ACES



From the International Advisory Board

The International Advisory Board reviewed the 2009 progress of the ARC Centre of Excellence for Electromaterials Science (ACES) on 19th February 2010 and received a flavour of what was being planned by ACES for 2010 and beyond. Those in attendance were: Dr (Dame) Bridget Ogilvie (Chair), Prof Siegmund Roth, Prof Richard Kaner, Prof Ray Baughman, Dr Greg Smith, Dr Abid Khan, Prof Tom Kay and Ms Sharon Martin for Prof Judy Raper. The Board congratulated Gordon Wallace and the ACES team on exceeding the IAB's high expectations and were impressed by the quality and quantity of outcomes achieved by the Centre in 2009.

Key Performance Measures

The performance of the Centre has exceeded the 2009 targets as outlined in the key performance measures. In particular the Centre published 98 refereed journal articles, of which 68 (69%) were in journals with an impact factor greater than 2 and 37 (38%) where the impact factor was greater than 4; ACES research graced the covers of 11 refereed journals; recruited 8 postgraduate students; had 6 postgraduate completions; held 7 national/international workshops; received 39 invitations to international conferences; made 54 visits to leading international laboratories (in 14 different countries); published 101 media interest stories; with 41 articles in print, 34 articles online/web, 16 radio interviews and 10 TV appearances; hosted 92 international visitors (from 19 countries) and lodged 2 patents.

Progress in 2009 Electromaterials

The development of new electromaterials (1st generation), their testing in specific applications, and then refining or redeveloping further materials (2nd generation) continued as an on-going cycle.

Porphyryns have been synthesised for use as solar cell dyes and electrocatalysts. Cobalt porphyryns are the most promising electrocatalyst for oxygen reduction. Non-porphyrinic cobalt complexes have also been made. Porphyrin GD2 continues to be the best performing dye in solar cells and is still used as a standard with ACES. However, the octylphenyl analogue has been shown this year to be the best performing dye when using ionic liquids as the electrolyte. Other new dyes that have been prepared include a series of exciting new hole transport porphyryns and porphyryns with multiple binders.

Functionalised terthiophenes from ACES were combined with functionalised spiropyrans from Dublin City University (DCU) to create for the first time exciting new photochromic polythiophenes. The sensing and binding capabilities of these materials are being jointly investigated.

A range of new chemistries have been developed to produce **functionalised graphene**. Both layer-by-layer and electrophoretic deposition methods were used to assemble graphene structures. **CNT NanoWeb** can be deposited onto various substrates, including metals and carbon, for use as electrodes.

Novel **tough gel compositions** have been developed (*Advanced Materials* 2009) based on poly(vinyl alcohol) utilising the protein ferritin as a modifier; and **porous, sponge-like gels** were obtained using carbon nanotubes as a scaffold for DNA and ionic liquids as a coagulant (*Angewandte Chemie-International Edition* 2009).

Energy Conversion

This program had two streams of activity in 2009: flexible solar cells and actuators.

Dye-Sensitised Solar Cells (DSSCs):

Achievements by ACES in 2009 pave the way for the future development of low cost flexible DSSCs. A monolithic all solid state DSSC with 3.65% efficiency was prepared (*Appl. Phys. Lett.* 2009), as well as a flexible polymer-based DSSC with 4.2% efficiency (*J. Photochem. Photobiol. A: Chem.* 2009).

Work on highly conductive PEDOT and a PEDOT-based solid state DSSCs made possible the invention of a GoreTex-PEDOT membrane electrode. This electrode was used in solar cells (*Langmuir* 2009), overcoming the limitations of conventional counter electrodes. p-type DSSCs have previously shown very poor photovoltaic performance. However, a team of ACES researchers in collaboration with the University of Ulm, discovered a fundamental design concept that allows absorbed photons to be converted to positive charge carriers with a conversion rate of up to 96%, making it possible to construct tandem solar cells that exceed the performance of their individual components (*Nature* 2009).

Actuators: A collaborative venture with Korean researchers has shown enhanced motor function (both power stroke and force generated) by the attachment of fullerenes to the ends of DNA strands to produce solution-based molecular machines that respond to pH changes (*Advanced Materials* 2009).

DNA was also attached to carbon nanotubes, where it was demonstrated that pH changes could dramatically alter the redox properties, thereby acting like a molecular switch (*Chemical Communications* 2009). This SWNT/DNA hybrid showed controllable / switchable electrochemical activity and capacitor behaviour, which will form the basis for new intelligent electrode materials for nano-biodevices, such as a biosensor or actuator.

Mechanically robust but flexible bundles of aligned, electrospun polyurethane nanofibres that were coated with polyaniline were found to generate appreciable actuation strains (*Chemical Materials* 2009) that produced a linear actuation strain as high as 1.65% at an applied stress of 1.03 MPa in 1 M methanesulfonic acid (MSA). They were stable for up to 100 cycles and up to an applied load of 11 mN (2.263 Mpa).

The use of electrochemically generated gas was investigated for pneumatic actuation (*Sensors and Actuators B: Chemical*). A carbon nanotube electrode of 2.4 mm^3 was capable of producing 0.5 cm^3 of gas at atmospheric pressure. The work capacity based on the size of the electrode

was 5000 kJ/m^3 , nearly two orders of magnitude larger than other low voltage electrochemical actuators.

2009 saw ACES research use conducting polymer tri-layer bender-type actuators for propelling a “robotic fish” (*Smart Materials & Structures* 2009). Small, highly-mobile “swimming” robots are desired for underwater monitoring operations, including pollution detection, video mapping and other tasks. The bending actuators (2 mm wide, 25 mm long), gave fast operation in air (up to 90 Hz), and were utilised as active flexural joints on the tail fin of a fishshaped floating “boat” (*in press*). The boat had a turning circle as small as 15 cm in radius and a maximum speed of 2m/min when operating with a tail frequency of approximately 0.7 Hz.

Energy Storage

Lithium batteries have two main issues of concern: safety and cycle life. The safety aspects include fire and explosion. ACES research showed that some organic salts used in ionic liquid and plastic crystal batteries were unsafe as they were prone to thermal runaway.

1000 life cycles are required for commercial batteries. Flexible polyaniline nanofibre electrodes made in ACES exhibited a specific capacitance of 235 Fg^{-1} ; and a capacitance of 195 Fg^{-1} was retained over 10,000 charge–discharge cycles after encapsulating the electrode in Nafion. Polypyrrole doped with Nafion ions had specific capacitance of 344 Fg^{-1} ; at scan rate of 1000 mVs^{-1} , an energy density of 14.6 Whkg^{-1} and power density of

4.3 kWkg^{-1} , whilst maintaining 98% of the original capacitance after 3000 cycles (*Journal of Power Sources* 2009).

Cathode films based on multi-wall carbon nanotubes (MWCNTs) showed stable cycling behaviour and allowed up to a 10C-rate, better than either single-wall or double-wall CNTs films (*Synthetic Metals* 2009). A high discharge capacity of 94.7 mAhg^{-1} was obtained for an all-polymer battery system composed of electrodeposited polypyrrole cathode and functionalised polyterthiophene anode (*Synthetic Metals* 2009).

Using solid-state plastic crystal electrolytes in lithium metal rechargeable cells were found to improve the rate capability after a preconditioning process. 2.5% Zinc oxide (ZnO)-doped lithium iron phosphate showed a higher electrochemical reactivity for lithium insertion and extraction than the undoped material (*Journal of Alloys and Compounds* 2009).

Bionics

Research efforts were focused on the cochlear implant, and spinal cord and peripheral nerve regeneration.

Cochlear Implant: There has been concern regarding the safety of nanomaterials for biological use, from both the lay and scientific community. Therefore, the biocompatibility of composite materials containing CNTs *in vivo* was studied to determine whether they could be used safely in a physiological setting. The experimental phase is complete and the results of the chronic study are currently being evaluated.

Spinal Cord and Peripheral Nerve

Regeneration: In 2009, directed nerve fibre growth has been achieved *in vitro* (2D structures) using a novel conducting polymer/biodegradable polymer fibre platform. This provides the basis for a biodegradable nerve repair conduit consisting of a knitted sheath (electrospun with biodegradable polymer nanofibres), and an internal engineered matrix consisting of fibres for neuronal support and Schwann cell mobilisation, suspended within a hydrogel containing biofactors (*Advanced Materials* 2009). These conduits have also been tested *in vivo*, and found to promote the repair of a 1.2 cm gap created in the sciatic nerve of rats. The development of a second-generation conduit has received support from NHMRC, with funding starting in 2010.

Ethics

Work towards developing an integrated position on the development of bionics, human health and ethical relations slowed in 2009 due to the CI's relocation to the University of Tasmania in February 2009 and the resignation of the UOW based Research Fellow in January 2009. Nonetheless, the grounding research is completed and there is a good prospect for a new PhD student commencing research on this project in early 2010. As a result of the CI's move, ACES has expanded into Tasmania.

Education, Training and Outreach

The focus again this year has been to give a broad range of training opportunities in particular areas of need (identified by a process of close consultation) for post-graduate students and early career researchers, as well as providing opportunities for external participants. The Education committee ensured training opportunities brought together staff and students from different nodes of the Centre.

The DVD "Nanostructures for Electromaterials" was completed and distributed to high schools throughout the country and is on the ACES, IPRI and UOW websites. It covers the topic of electromaterials, their applications, benefits and impact on society, by addressing how nanostructured nanomaterials are used in applications for advancing the cochlear ear implant and for nerve and muscle growth.

To bring the research area of Bionics into the public arena, a High School competition 'Bionics for 2020' was launched in July. The competition was open to all High Schools in the Illawarra Region whose students had to address the question: "what new Bionic parts would you develop for humans, why and how". The competition certainly fired the imagination of both students and teachers and gained good media coverage.

ACES 2010-2013

Research Programs

Both energy and human health rank highly in the research priorities of most (if not all) industrialised countries, and electromaterials, energy, bionics and ethics will remain the foci for ACES going forward.

Electromaterials will be at the core of a wide range of technologies that will generate future energy supplies and form the basis of the bionic medical devices. This program will continue to encompass materials synthesis, fabrication and characterisation. The development of the ANFF Materials Node, led by ACES researchers, provides the opportunity to perform scaled-up synthesis of materials needed in a number of Centre programs.

The energy program will utilise advances in the design and synthesis of new light harvesting and electrocatalytic materials for applications such as energy conversion/storage and water splitting.

ACES intends to exploit cutting edge materials to ensure development of an efficient water splitting device. In addition to water splitting, polymer fuel cells and metal air battery techniques will be developed.

The Bionics program will continue to exploit new electromaterials in the areas of nerve repair and will move to construction of 3-dimensional networks and devices for *in vivo* experiments. ACES will also continue in

its quest to develop an advanced cochlear implant with improved control and sensing mechanisms towards a steerable electrode. The Ethics program will continue in its role of developing a critical social and ethical response to the emerging bionics program and nanomedicine.

End-Users

Throughout 2009, ACES partners have worked towards developing a simple, single co-ordinated shopfront approach for end-users. The ACES patent portfolio has been established and updated with technology promotion flyers and is now available (via ACE website) on selected topics.

The advent of the Australian Institute for Innovative Materials: Processing and Devices (AIIM P&D) facility at the University of Wollongong's Innovation Campus (\$40M) and the expansion of ANFF materials node in 2009 (with a further \$3.9M in equipment funding) provides a further dimension to end-user engagement for ACES researchers. Expansion of ANFF allows expansion of capabilities in the synthesis and supply of advanced organic materials for application in the different research areas as well as providing expertise via consultancies in the area of materials synthesis, processing and characterisation. Upon completion in 2011, the AIIM P&D will offer extensive and unique capabilities

in the design, development and fabrication of nanostructured electronic materials and devices for both researchers and industry.

The IAB acknowledged that the creation of the AIIM P&D facility will further enhance the opportunities available to ACES, particularly in developing even stronger collaborative end-user linkages. The IAB is also pleased to note the strong international relevance of the strategic development plan that has been produced and adopted, which is aimed at consolidating and expanding the end-user base.

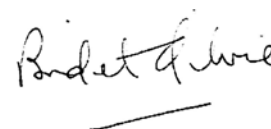
International Links

ACES has an open and vibrant research environment that ensures close interaction with other Australian and international scientists. An IAB board member is of the opinion that ACES has assembled research at the highest level of competence in several areas making it an attractive point of contact for those interested in the area. The large number of international research visits is testimony to this. ACES has truly become an International Centre of Excellence. In 2010 a global research consortium on Electromaterials Science will be established to further encourage ACES global links.

Final Comments From the Chair

"In 2009, ACES researchers have continued to perform at an outstanding level by all accepted measures. I am most impressed by the progress and by the collaborative approach, both national and international, that is one of its outstanding characteristics and source of strength. All members of the IAB enjoy their interactions with this exceptional group of scientists of whom their host universities can be really proud."

Dr (Dame) Bridget Ogilvie
(AC, DBE, FAA, FRS, FMedSci)



Chair

International Advisory Board for ACES



Highlights of the Core Funded Activities

Program 1 (P1): Electromaterials

With the ACES extension commencing in June 2010, this has enabled us to continue to discover and develop new electromaterial structures, while continuing to supply those developed in previous years to the energy conversion, energy storage and bionics programs.

The cycle between materials discovery and testing has been refined as we further identify the properties needed for our targeted applications in ENERGY and MEDICAL BIONICS.

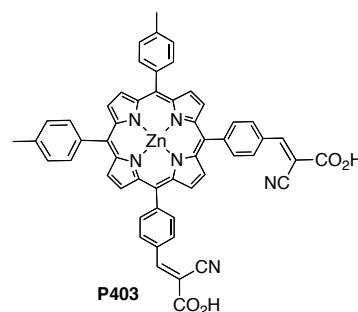
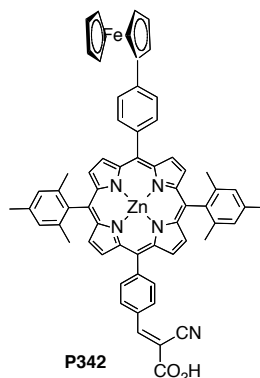
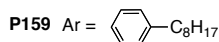
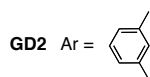
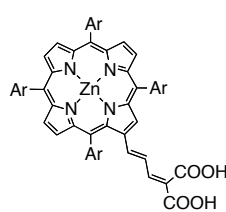
ACES materials have also been supplied to our international collaborators in New Zealand, Japan, Ireland and the US. In particular:

- ▶ porphyrins for use as solar cell dyes and electrocatalysts,
- ▶ functionalised thiophenes for batteries, capacitors, electrochromic devices and bionics,
- ▶ graphenes for solar cells, batteries, capacitors and bionics.

A selection of these materials is highlighted next but described in more detail in the Activity Report.

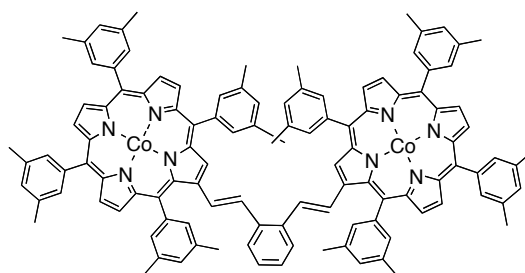
Porphyrins for solar cells

Porphyrin **GD2** continues to be the best performing dye in solar cells and therefore is still used as a standard with ACES at both Wollongong and Monash. However, the octylphenyl analogue **P159** has been shown this year to be the best performing dye when using ionic liquids as the electrolyte. Other new dyes that have been prepared include a series of exciting new hole transport porphyrins exemplified by **P342** and porphyrins with multiple binders such as **P403**.

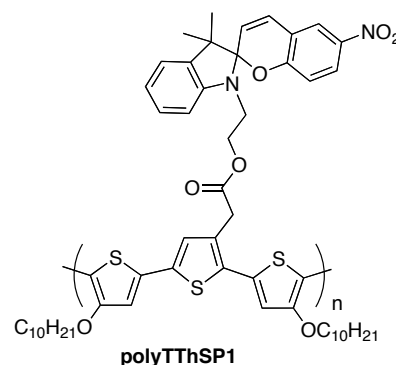


Porphyrins as electrocatalysts

Cobalt porphyrins are the most promising electrocatalyst for oxygen reduction. Control of interporphyrin distance is important. Therefore, porphyrin dimers with controlled architectures such as **P212** have been synthesised for this purpose. Non-porphyrinic cobalt complexes have also been made.



P212



polyTTSP1

Functionalised thiophenes

Functionalised thiophenes and terthiophenes and their polymers continue to be investigated for in a wide variety of applications. The most exciting new polythiophene materials were made this year with researchers at Dublin City University (DCU). In a perfect collaboration, functionalised terthiophenes from ACES were combined with functionalised spiropyran from DCU to create for the first time exciting new photochromic polythiophenes such as **polyTThSP1**. The sensing and binding capabilities of these materials are being jointly investigated.

Graphene

A range of new chemistries have been developed to produce functionalised graphene. Both layer-by-layer and electrophoretic deposition methods are being used to assemble graphene structures.

Tough Gels

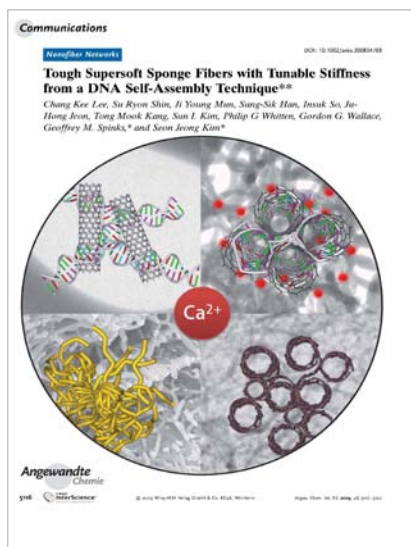
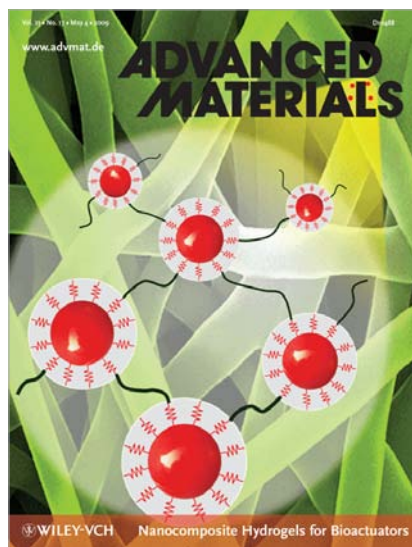
Development of tough polymer gels is important for solid electrolytes, actuators and some bionic applications. Gels are notoriously brittle, yet their high water content provides a very flexible substrate that is attractive for solid state actuators and energy storage devices. Gels are also similar to certain biological tissues, so offer potential advantages for cell growth work. ACES activities in gel synthesis have focussed on improving the mechanical strength of the gels, while maintaining low modulus and high water content. In some cases, pH responsiveness is also desired – such as in actuators. The major developments in 2009 include novel tough gels (**Advanced Materials 2009**) based on poly(vinyl alcohol) utilising the protein ferritin as a modifier. A three-fold increase in strength was achieved by addition of ferritin. This work was featured on the inside cover of *Advanced Materials*. A second major advance was the development of tough, porous, sponge-like gels. Highly porous materials are desirable for cell culture work and for implant in soft tissues,

such as cardiac muscle. The use of carbon nanotubes as a scaffold for attached DNA and ionic liquids as a coagulant enabled the fabrication of fibres that combined the properties of being very soft, porous and tough. This work was published in *Angewandte Chemie-International Edition 2009*.

Nanostructured Carbons

Optimising the ability to grow CNT NanoWeb architectures, we have developed protocols that enable CNT NanoWeb to be deposited onto various substrates, including metals and carbon for use as electrodes. The direct deposition of the NanoWeb onto carbon fibre paper provides stable and high charge-discharge performance when used in a Li-ion battery (**Energy & Environmental Science 2009**). Our Atomate CVD system has been upgraded to enable growth of larger nanoweb samples.

Novel biogel structures that were shown to be non-cytotoxic and provide a vehicle for controlled release were obtained by combining carbon nanotubes and appropriate biopolymers (**Carbon 2009**).



Program 2 (P2): Energy Conversion

Advances in Energy Conversion projects have been made possible by the development of new materials and innovative configurations of devices containing them.

Dye-Sensitised Solar Cells

A considerable number of key developments were made in the area of dye-sensitised solar cells (DSSC). A monolithic all solid state DSSC giving 3.65% efficiency was achieved (**Appl. Phys. Lett.** 2009), approaching the Centre milestone of 4% for such a device. However, a 4.2% efficient flexible polymer-based DSSC was attained using ball milling to create mechanically stable TiO_2 films on polymer electrodes (**J. Photochem. Photobiol. A: Chem.** 2009). The integration of two developments within ACES, the formation of highly conductive PEDOT and a PEDOT-based solid state DSSC, led to the invention of a Goretex-PEDOT membrane

electrode (**Langmuir** 2009). All of these achievements pave the way for the future development of low cost flexible DSSCs.

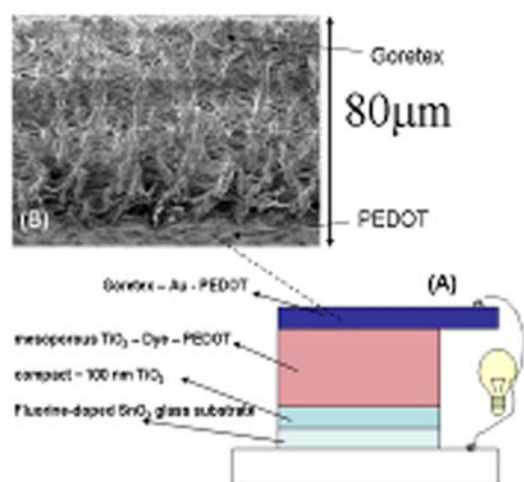
Equally significant was the publication of the first example of charge injection into TiO_2 in a DSSC from both the porphyrins in a porphyrin dimer (**J. Am. Chem. Soc.** 2009). Other highlights include the development with international collaborators in Korea and Switzerland of high molar extinction coefficient ruthenium dyes (**J. Phys. Chem. C** 2009); the use of phosphinic acids to increase the efficiency of porphyrin sensitised solar cells (**Energy Environ. Sci.** 2009); and a US patent application on dye mixtures for use in photoelectric materials (**US Prov. Patent Appl.** 60/202,164).

Dye-sensitized solar cells based on dye-sensitized hole-injection into p-type electrolytes have until recently shown very poor photovoltaic performance. A team of ACES researchers from Monash and Wollongong, in collaboration with the group of Prof. Baeuerle at the University

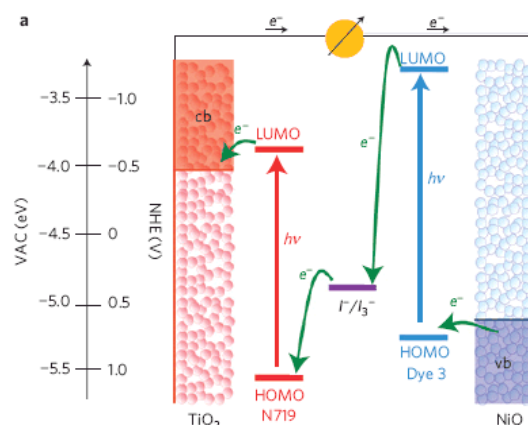
of Ulm, discovered a fundamental design concept for p-type DSSC sensitizers that allows absorbed photons to be converted to positive charge carriers, with a conversion rate of up to 96%. By combining these markedly improved p-type DSSCs with conventional photoanodic DSSCs, it was possible to construct tandem solar cells that exceed the performance of their individual components (**Nature Materials**, 2009, online publication: 29/11/2009).

The thermal stability of sensitizers is of critical importance for DSSC manufacturing processes. ACES researchers, in collaboration with CSIRO and the University of Uppsala, have revealed significant degradation of sensitizers at processing-relevant temperatures (**J. Phys. Chem. C**, 2009). The presence of humidity and oxygen during the heating period was shown to accelerate the degradation process.

Platinum nanoparticles were successfully deposited onto carbon black and carbon nanotubes (CNTs) via microwave-assisted reduction process. The novel electrode



(A) Scheme of the layer structure of a solid state dye-sensitized solar cell using photoelectrochemically deposited PEDOT as hole conductor; (B) Cross-section image of the Goretex®-Au-PEDOT electrode imaged using SEM.



Scheme for the electron-transfer processes occurring in the dye-sensitized tandem solar cell. Also shown are the approximate redox potentials and band energies of the different components.

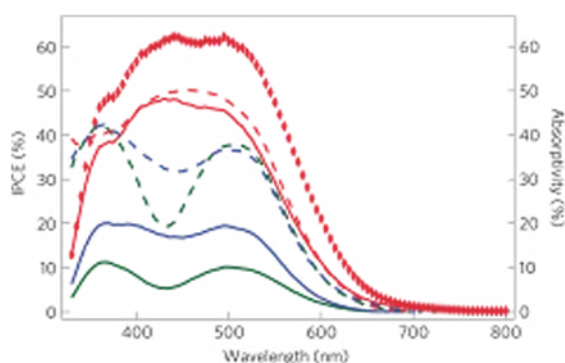
shows enhanced catalytic performance in fuel cell application using functionalised CNTs as the catalysts support materials (**Nanoscale**, 2009 available online, DOI: 10.1039/b9nr00140a). The stability of loaded Platinum (Pt)-nanoparticles was improved with increased long-term performance.

Actuators

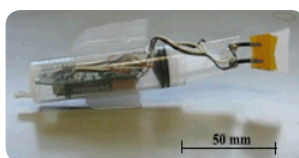
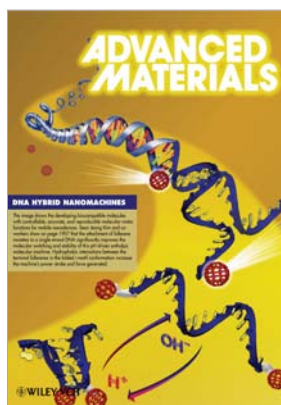
Developments in actuator systems during 2009 spanned from nano- to micro- to the macro- domain. At the smallest level, DNA was used to generate solution-based molecular machines that responded to pH changes. While these systems were previously known, ACES researchers demonstrated that enhanced motor function was possible by the attachment of fullerenes to the ends of the DNA strand (**Advanced Materials** 2009). The same type of DNA was also attached to carbon nanotubes, where it was demonstrated that pH changes could dramatically alter the redox properties, thereby acting like a molecular switch (**Chemical Communications** 2009). Bundles of aligned nanofibres

were also developed for artificial muscles. In this case, electrospun polyurethane fibres were coated with polyaniline and shown to generate appreciable actuation strains (**Chemistry of Materials** 2009). At the micro-level, progress was made in demonstrating solid state micro-cantilever actuators using conducting polymers for the first time (**J. Micromechanics and Microengineering** 2009).

Finally, at the macro-level the use of electrochemically generated gas was investigated for pneumatic actuation (**Sensors and Actuators B-Chemical** 2009), while the use of conducting polymer bender-type actuators for propelling a "robotic fish" (Figure 'NEMO') were also published (**Smart Materials & Structures** 2009). Current work is focussing on developing methods for measuring actuation in single nanofibres; on further miniaturisation of conducting polymer actuators; and on evaluating the mechanisms of actuation in gel and conducting polymers.



The IPCE (Incident photon to electron conversion efficiency) spectra of p-DSSCs assembled from mesoporous NiO electrodes (solid lines), sensitized with 3 different sensitizers: dyes 1 (green), 2 (blue) and 3 (red) as well as the percentage of incident photons that are absorbed by the dye inside the p-DSSC (absorptivity, dashed lines). The red diamonds indicate the IPCE of a mesoporous 2.3-μm-thick NiO electrode sensitized with 3.



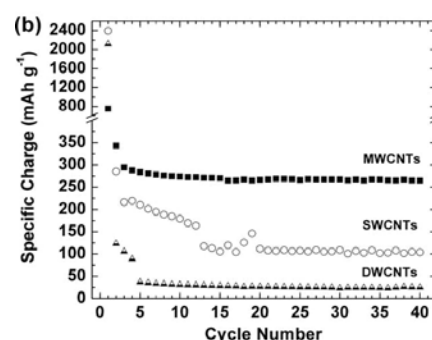
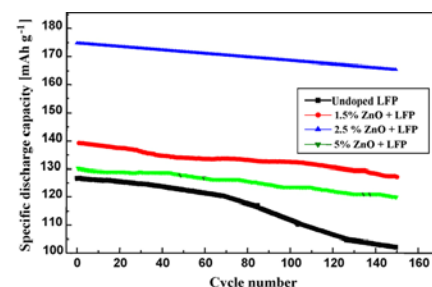
'NEMO' robotic fish prototype.

Program 3 (P3): Energy Storage

In progress towards solid flexible electrolyte materials, lithium metal rechargeable cells incorporating solid-state plastic crystal electrolytes have been investigated and found to exhibit improved rate capability after subjection to a low-current preconditioning process (**Adv. Eng. Mater** 2009, in press). A survey of the high temperature behaviour of a range of organic salts used in ionic liquid and plastic crystal batteries revealed that some, such as fluorosulfonyl imides are prone to thermal runaway and are therefore not safe for battery use (**Chem. Commun.**, 2009).

Progress towards thin film, flexible cells

Zinc oxide (ZnO)-doped lithium iron phosphate systems have been investigated to improve capacity. The CV curves show that 2.5% ZnO-doped LiFePO₄ has higher electrochemical reactivity for lithium



insertion and extraction than the undoped material. (**Journal of Alloys and Compounds 2009**).

Experiments revealed that cathode films based on multi-wall CNTs (MWCNTs) are much better than single-wall and double-wall CNTs films in terms of their electrochemical performance. The flexible MWCNT electrodes show stable cycling behavior and allow up to a 10 C-rate (**Carbon 2009**).

Polymer composite materials with high capacities and energy density characteristics have been developed (**Journal of Power Sources 2009**). Polypyrrole doped with Nafion (Nf) ions or perchlorate ions exhibits a specific capacitance of 344 or 355 Fg^{-1} , respectively. It was observed that the energy density and power density of PPy-Nf at a scan rate of 1000 mVs^{-1} were 14.6 Whkg^{-1} and 4.3 kWkg^{-1} , respectively. Cycle life experiments revealed that the Nafion-doped material retains 98% of the original capacitance after 3000 cycles.

Significant progress has been made in the development of flexible all-polymer capacitors (and batteries) based on the use of nanostructured conducting polymers (**Journal of Power Sources and Synthetic Metals 2009**). Flexible polyaniline nanofibres electrode exhibited a specific capacitance of 235 Fg^{-1} ; and a capacitance of 195 Fg^{-1} was retained over 10,000 charge-discharge cycles after encapsulating the electrode in Nafion (**Synthetic Metals 2009**). A high discharge capacity of 94.7 mAhg^{-1} was obtained for the all-polymer battery system composed of electrodeposited polypyrrole cathode and functionalised polyterthiophene anode. (**Synthetic Metals 2009**).

Program 4 (P4): Bionics

Directional growth of muscle fibres has been achieved using a conducting platform with degradable microfibre/structure. A novel bio-synthetic platform that supports *ex vivo* growth of partially differentiated muscle cells in an aligned linear orientation that is consistent with the structural requirements of muscle tissue has been constructed (**Advanced Functional Materials 2009**). These platforms consist of a biodegradable polymer fibre array spatially aligned on an organic conducting polymer (OCP) substrate. Long multinucleated myotubes were shown to form on the platform via differentiation of adherent myoblasts, which aligned longitudinally with the fibre axis to form linear cell-seeded bio-synthetic fibre constructs. The biodegradable polymer fibres bearing differentiated myotubes can be detached from the substrate during culture. The ability to remove the muscle cell-seeded polymer fibres when required provides the means by which the biodegradable fibers can be used as linear myofibre-seeded scaffold components suitable for *in vivo* implantation into muscle.

Directed growth of sensory nerves and migration of Schwann cells was shown to be enhanced by electrical stimulation using a variant version of the hybrid conducting polymer/biodegradable fibre platform used for muscle studies (**Advanced Materials 2009**). In the case of neuro-regeneration applications, the platform represents the basis for a highly versatile three-dimensional electrically conductive hybrid neural scaffold, that may be easily modified by use of any combination of OCP and biodegradable polymer microfibres. In the short term,

this hybrid platform provides an interface by which to connect neural circuitry with electronics, to promote communication between implantable electronics devices designed to rectify/adjust tissue function by interaction with the nervous system. With the development of truly biodegradable OCPs, the hybrid platform generated within the ACES Bionics activities will ultimately find application in the encouragement of effective regeneration in damaged neural tissues of the CNS and PNS.

Our work into the use of neurotrophin-loaded organic conducting polymers to promote neurite outgrowth has continued. Dramatic synergistic effects being observed when both NT-3 and BDNF are incorporated into polypyrrole as this platform is used to provide both direct electrical stimulation and a method of controlled release (**Journal of Controlled Release 2009**). This extension of work demonstrates the applicability of the conducting polymers as platforms to release multiple growth factors, with the two growth factors used here being particularly chosen for cochlear and spinal applications.

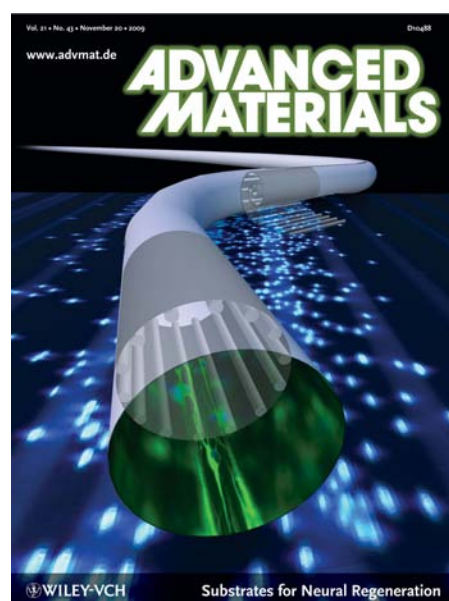
The first work describing the use of neurotrophin-loaded conducting polymers in animal models has been conducted (**Biomaterials 2009**). It was found that the controlled release of neurotrophins from conducting polymer substrates on cochlear implants improved the number of neurons remaining after deafening of the animals. The small mass of neurotrophin released reached and affected the neurons after release in the cochlear duct, which shows great promise for the cochlear application of released neurotrophins. It also suggests that applications in spinal cord regeneration via neurotrophin release could be successful.

ACES CIs were invited to provide a PERSPECTIVE article for the prestigious journal *Science* on the electrode-cellular interface (**Science 2009**).

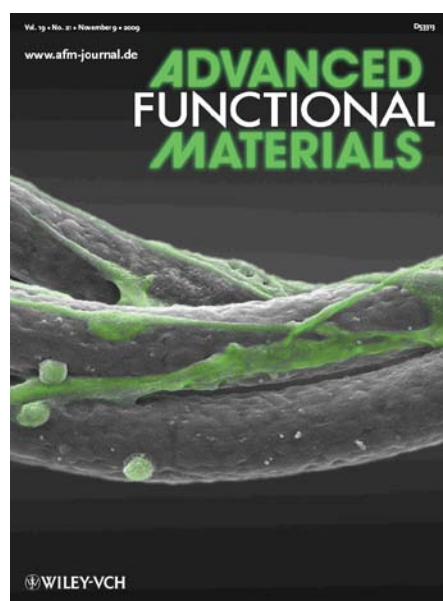
NHMRC funding has been obtained for Nerve Repair and Epilepsy drug release materials. This research is complimentary to a newly established collaboration with Stephen Livesey and development of a biologically-informed neuro matrix for peripheral nerve and spinal cord repair. These foci will be developed using 3-D printing paradigms with a translational clinical outcome target within 3 years. In addition, the nerve repair studies form part of a clinical translational pipeline which will facilitate the incorporation of ACES Bionics devices into common surgical practice. For the spinal cord repair studies, collaborative agreements have been made with surgeons who currently operate on chronic spinal cord injury in people [Jim Faed (NZ), Gustavo Moviglio (Argentina) and Carlos Lima (Portugal)].

Program 5 (P5): Ethics

Work towards this milestone has proceeded at a slower pace than originally intended due to the CI's move to the University of Tasmania in February 2009, the resignation of the UOW based Research Fellow in January 2009, and the delay in transfer of ACES funds to Tasmania which has prevented the appointment of a new Research Fellow. Nonetheless, the grounding research is completed and there is a good prospect for a new PhD student commencing research on this project in early 2010.



Neuronal axons (green) growing on wet-spun PLA:PLGA fibres within the proposed 3-D structure being developed for Peripheral Nerve Repair.



Muscle cells (green) growing on wet-spun PLA:PLGA fibres.



The trio whose Perspectives article was published in *Science* are (from left) Dr Simon Moulton, Prof Gordon Wallace and (inset) Prof Graeme Clark.

ACES Education and Training

The goals for 2009 have been to conduct training programs for staff and research students in the area of ethics in research, further workshops on the characterisation of nanomaterials, and a range of other specific training and education programs through seminar programs and short courses. The focus again this year has been to give a broad range of training opportunities for postgraduate students and early career researchers as well as provide opportunities for external participants. Particular areas of need for ACES researchers have been identified via a process of close consultation. As in previous years, attention has been given to ensure the training opportunities organised have brought together staff and students from different nodes of the Centre, thus facilitating cross-fertilisation of ideas and collaboration. Another highly successful related activity has been close integration of Centre activities at the Wollongong node with the Nanotechnology undergraduate degree.

In addition, there has been significant progress in our general public education and outreach program with the official opening

of our educational exhibition in the area of Electromaterials and their impact on society. This has been done in collaboration with the Wollongong Science Centre.

Specifically, during 2009 the following special events and workshops/short courses have been organised and successfully run:

- ▶ Electrochemistry week (Wollongong, February)
- ▶ Actuators for Bionic and Biomimetics (Wollongong, May)
- ▶ Assembly and Characterisation of Batteries and Capacitors (Wollongong, June)
- ▶ Bio AFM Workshop (Wollongong, August)
- ▶ In-house workshop on working with the media (Wollongong, September)
- ▶ Assembly and Characterisation of Solar Cells (Wollongong, November)
- ▶ IPRI/Chemistry Annual Conference (Nowra, November)
- ▶ Media Workshop (Monash, November)
- ▶ Challenges in Solar Cell Characterisation Forum (Wollongong, November)

- ▶ Printing of Bio Related Structures (Wollongong, December)
- ▶ Ethics in Research and Publishing Workshop (Wollongong, December)
- ▶ Training for the Research Information System (RIS), an online tool used to store information about publications (Wollongong, December)

Full reports on most of these events are to be found on the ACES website: (www.electromaterials.edu.au/news), whilst a summary and excerpts of some of the activities carried out are given below.

There is a constant (and growing) pressure on researchers to publish their research in peer-reviewed journals. A very relevant workshop was held, in Wollongong on 1 December, on the ethical issues in scientific publication: peer review, publishing ethics and the integrity of the scientific record.

The Workshop, attended by approximately 30 people, was convened and led by Prof. Susan Dodds (ACES), who introduced some of the issues associated with publication and the responsibilities of researchers, publishers, research institutions and



The panel sitting at the ACES ethics workshop (L to R): Dr Wendy Lipworth, Prof Susan Dodds, Prof Will Price and Dr Andrew Minett.

research funding bodies as they arise in the *Australian Code for the Responsible Conduct of Research*.

Dr Wendy Lipworth, from the Centre for Values, Ethics and Medicine at the University of Sydney, extended the discussion to the quality of the peer review process as a means of ensuring that the best research is published, noting the many limitations her research uncovered in the editorial and review process in medical journals (where the findings often directly inform clinical practice). The workshop then concluded with a lively panel discussion during which a number of case studies on ethical issues in publishing were debated.

A forum entitled "Challenges in Solar Cell Characterisation: Theory, Spectroscopy and Devices" was hosted by ACES in Wollongong on November 16-17. The forum workshop was organised by Prof David Officer and Dr Attila Mozer, leaders of solar energy research strength at ACES/IPRI. Featured speakers included Prof Keith Gordon (University of Otago New Zealand),

Prof Shogo Mori, (Shinshu University, Japan), and Prof Officer (ACES/IPRI). Forum participants discussed the scientific challenges to making solar power a more efficient and attractive proposition, and possible routes to achieving this. Following the presentations and panel discussions, a hands-on session, was provided.

An in-house workshop on fabrication and characterisation of batteries and supercapacitors was successfully hosted by ACES in June. More than 20 people from ACES/IPRI and ACES/ISEM attended the workshop. Following lectures covering the relevant background knowledge, a hands-on session was held where the attendees were shown the procedures for making batteries and supercapacitors, and how to characterise and test those cells.

ACES held a number of major outreach and education events to celebrate National Science Week in August. A public lecture by ACES senior researcher and bionic ear pioneer Prof Graeme Clark was hosted by ACES in conjunction with the University

of Wollongong and Wollongong Science Centre. In his lecture, titled "Big thinking, small technologies" Prof Clark took the audience through some of the implications of nano-bio-technology, including how it may help with spinal cord repair, drug delivery and the development of a visual prosthesis – the bionic eye, and his collaborative research with ACES (read more about this event in the Outreach section of this report).

The ACES Education Committee developed the inaugural High School competition 'Bionics for 2020', which was launched in July. The competition sponsored by ACES/IPRI, The Faculty of Science, the Wollongong Science Centre and supported by RACI, was open to all High Schools in the Illawarra Region whose students had to address the question: "what new Bionic parts would you develop for humans, why and how". They were asked to either write an essay or create a poster. Individual or Group Entries were accepted.



Dr Benny Kim (ACES/IPRI) explaining the workings of a supercapacitor



Prof. Liu (ACES/ISEM) with some of the researchers and students in attendance at the in house workshop.



Professor Graeme Clark (centre) with ACES Executive Director Professor Gordon Wallace (left), and Science Centre Director Glen Moore.

The competition certainly fired the imagination of both student and teachers and gained good media coverage. Winners were awarded their prizes by Prof Graeme Clark. The individual and group winners were also invited to enjoy a morning tea with staff and students from ACES/IPRI and participate in a guided tour of the IPRI laboratories. The winning entries were on public display for the day at the Science Centre.

An extension of the Bionics 2020 competition was conducted at Sydney Grammar School. On 20 November, Prof Geoffrey Spinks gave a talk entitled "Our Bionic Destiny", attended by approximately 100 students (from years 7-12) and parents. Entries in this second Bionics 2020 competition (from years 7, 8, 9 & 10) showed insightful knowledge of Bionics.

Getting science and research into the news and how to ensure it is accurately reported, was the subject of the ACES Media Seminar held at IPRI in Wollongong on 18 September. The seminar, organised by ACES Communications Coordinator Leanne

Crouch, was attended by 40 ACES staff and students and covered many aspects of dealing with the media. Invited to present at this workshop were Bernie Goldie, Manager of the University of Wollongong's Media Unit and the Deputy Editor of the Illawarra Mercury Newspaper, Carol Johnstone. They provided insights into the traditional role of the media and to the global social media revolution. Participants were also made aware of the broad range of media options: from the internet, to multimedia to podcasts, to Wikipedia, Facebook and Twitter as opportunities for scientists and researchers to broadcast their message to a global audience.

A similar event was held in Melbourne on 9 November for ACES. This was done in conjunction with Monash University's Centre for Synchrotron Science who hosted a Workshop for students and staff from ACES/Monash and 7 PhD students from ACES/IPRI.

Talks from ACES staff included a session on grant writing by Prof Maria Forsyth (ACES/Monash); tips for getting science and

research into the media and how to ensure it is accurately reported by Leanne Crouch (ACES); a session on commercialising Research by Chris Gilbey (Director of Strategic Development: ACES); and an insight into intellectual property laws by PhD student Tim Khoo (ACES/Monash).

Participants were later taken on a tour of the Australian Synchrotron before being presented with a number of sessions introducing the capacities of the Synchrotron, and its relevance to ACES research.

In addition to the above workshops and special events, there have been active seminar programs at both Monash and Wollongong, with regular (one-per-week) external and internal speakers on a wide range of topics for students and research workers, as well as internal seminar series at both nodes for students to present to their peers. This has also enabled visiting staff from Monash to present to Centre members at Wollongong and vice-versa, resulting in effective exchange of ideas and education. In addition, in Wollongong monthly program



Bionics for 2020 Competition winning group from Macquarie Fields High School; 'the Awesome Foursome' and 'Aussie Pride' are pictured with their science teacher Rebecca Toll and the UOW Dean of Science, Professor Will Price.

meetings are held in both the materials and bionics programs to discuss current research problems and to offer possible solutions.

Further significant progress has been made in the educational outreach area with the completion of the new animated DVD called "Nanostructures for Electromaterial". The DVD covers the topic of electromaterials, their applications, benefits and impact on society, by addressing how nanostructured nanomaterials are used in applications for advancing the cochlear ear implant and for nerve and muscle growth. The DVD has been distributed to high schools throughout the country and it has also been placed on the ACES, IPRI and UOW websites.

In August 2009 there was the formal opening of the first stage of an education exhibition, *Nanomaterials for Energy*, at the Wollongong Science Centre. The iDome is the centre piece first stage of this Wollongong Science Centre exhibit and is a partnership between ACES and the Wollongong Science Centre. Seven modules are featured in the segment and include

graphical and animated molecular visualisation modules, providing a 180-degree view of nanotechnology and the advanced electromaterials used by ACES as well as a virtual tour (360-degree view) of ACES / IPRI laboratories at the Innovation Campus.

Progress is being made towards implementation of stage 2 of the exhibit which will add to the range of items on the iDome facility and build around it a variety of informative packages using a number of different media. ACES is currently looking at further sponsorship/joint partnership to enable a project manager to be employed. This will focus on the use of new materials in energy conversion such as in solar cells or artificial muscles, energy storage in new types of batteries and capacitors, and medical bionics.



Timothy Khoo (ACES/Monash PhD student) and Prof. Maria Forsyth at Monash University's Workshop.



At the Monash Centre for Synchrotron Science.



iDome exhibit at Wollongong Science Centre.

International Profile

ACES continues to attract research scientists from around the globe and participates in a number of active international research collaborations. During 2009, ACES produced 98 refereed publications, with some 40 of these involving international collaborators. The Centre has established an international research network that will help realise our scientific ambitions.

This section reports on:

- ▶ International Symposia (4) hosted/co-hosted by ACES
- ▶ International collaborations: listed country by country
- ▶ International invited presentations given by ACES researchers

International Symposia Hosted/Co-Hosted by ACES

(i) Nanostructured Electromaterials Symposium (Wollongong, 4-6 February 2009)

The latest developments in electromaterials and how they can be applied to the way we live and work were presented and explored at the 2009 Electromaterials Symposium. The symposium focused on nanostructured electromaterials and their applications in the areas of energy and health. International experts from Ireland, Canada, USA, UK, Japan and Korea spoke on the application and performance of these electromaterials in areas as diverse as corrosion protection, chemical sensors, fuel cells, batteries, biosensors, artificial muscles and medical bionics.

Prof. Siegmund Roth (Max Planck Institut für Festkörperforschung, Germany) and Prof. Richard Kaner (University of California, Los Angeles, USA) discussed carbon nanotubes and graphene, describing how they can be characterised and processed into useable formats for practical applications.

Prof. Rose Amal (University of NSW) described how the development of highly efficient photocatalytic nanoparticles and systems for water and air purifications, self cleaning surfaces and clean energy can address the energy, water and environment

issues facing our society. Prof. John Madden (University of British Columbia) discussed electrodes attractive for use in storage of electrostatic energy, actuation and solar cell harvesting, while Dr Gerry Sweigers (CSIRO Molecular and Health Technologies) described "bio-inspired" catalytic solar water splitting research.

In the health area Prof. Mario Romero-Ortega (University of Texas at Arlington, USA) described his recent studies on the use of nerve growth factors to guide sensory nerves to specific target areas. Ultimately, this should lead to the improvement of the neural control of robotic prosthetic devices used by amputees.

Post doctoral researchers from ACES also presented highlights from their research on dye sensitised solar cell technologies, conducting platforms for muscle and nerve regeneration, and biocompatibility studies of carbon nanotubes. The final session focused on end-users of electromaterials science and included presentations from Defence Science and Technology Organisation, Australia, Aqua Diagnostic Australia, The HEARING CRC and Hearworks Pty Ltd, Cap-XX Pty Ltd, Boston Scientific and CSIRO Energy Technology, Australia. For the full report see <http://electromaterials.edu.au/news/2009febsympreport.pdf>

Our heartfelt thanks to the sponsors who supported the 2009 ACES Symposium: The Hearing Co-operative Research Centre, the Co-operative Research Centre for Polymers, CSIRO and BlueScope Steel.

(ii) 3rd Congress on Ionic Liquids “COIL3” (Cairns 31 May – 4 June 2009)

Prof Doug MacFarlane and Dr Jenny Pringle (ACES) organised the 3rd Congress on Ionic Liquids. Ionic Liquids have become of intense interest in the electrochemistry and electromaterials fields as electrolytes in batteries, solar cells, electrowinning and nanomaterials synthesis. The meeting is the main international gathering held every two years in the Ionic Liquids area and attracts researchers from a wide variety of fields - around 400 delegates attended from 35 countries, of which 150 were students. The conference consisted of 42 invited presentations from top researchers in the field and around 350 posters. Major sponsorships were received from Merck, the Air Force Office of Scientific Research, CSIRO, Monash University and ACES.

(iii) International Symposium on Renewable Energy Storage and Conversion Technologies (Wollongong, 18-20 November 2009)

This International Symposium was jointly hosted by the Institute for Superconducting and Electronic Materials (ISEM) and ACES, and supported by the UOW Energy Futures Networks and the Korean World Class University Centre for Next Generation Battery, South Korea. This symposium provided the 100 participants, the opportunity to discuss a wide range of new scientific findings in the area of renewable energy storage and conversion technologies. It also served as a high level platform for all participants to establish new collaborations.

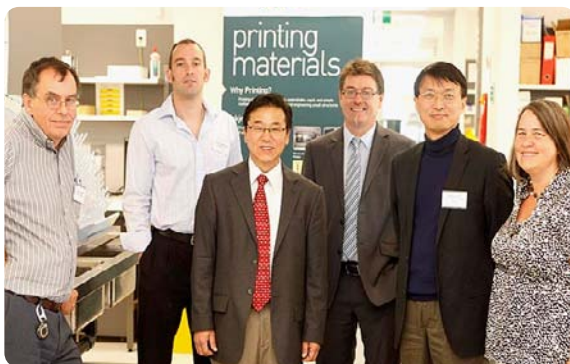
(iv) Printing of Bio-Systems and Electronics: the Next Generation of Bionics (Wollongong, 3-4 December 2009)

The use of printing in producing electronics devices has grown in recent years, and the development of new materials for bionics is a rapidly developing field. The workshop explored the convergence of these two exciting fields and the opportunities thereby created to enable the printing of bionic devices. Interest was demonstrated in the audience mix which included, 5 international, 12 national and 9 industry representatives.

Prof. James Yoo from Wake Forest Institute for Regenerative Medicine, USA, spoke about the use of inkjet printers in the development of functional tissues for clinical applications. Other international speakers included visiting US printing expert Prof Paul Calvert, Prof Gyoujin Cho (Sunchon National University, Korea), Dr Jan Sumerel (Fujifilm Dimatix, USA) and Prof Niyazi Serdar Sariciftic (University of Linz, Austria). The workshop was sponsored by ACES, the Australian Research Network for Advanced materials (ARNAM), Fujifilm Dimatix and Labcyte Inc.



At the 3rd Congress on Ionic Liquids



Speakers at the Workshop included ARC Professorial Linkage Fellow, Prof Paul Calvert, Prof James Yoo and Prof Gyoujin Cho, and Dr Jan Sumerel, seen here with Prof. Gordon Wallace and Dr Marc het in Panhuis.



Hands-on demonstrations were a hit at the Printing of Bio-systems and Electronics workshop, Dec 2009.

Collaborations by Country

Canada

Professor Doug MacFarlane visited the Department of Chemistry at the University of Waterloo Canada in July 2009 for collaborative discussions.

China

Collaborations with Shanghai Jiao Tong University continued to strengthen. In August 2009, Dr Jun Chen (ACES) visited Shanghai to review the progress of the on-going DEST Inter-Linkage Project. Dr Chen also visited East China University of Science and Technology in order to further build up collaboration from 2010 based on conducting polymer composites.

Prof. HK Liu (ACES) spent 2 weeks in China (28 June until 14 July) visiting various collaborators at Shanghai University, East China University of Science and Technology, Institute of Physics, the Chinese Academy of Science, and Northeastern University.

Dr. Z.P. Guo (ACES) visited East China University of Science and Technology and Fudan University from 29 June to 10 July. The collaboration with the Shanghai University has resulted 3 papers in 2009 (see journal article 113 and refereed

conference papers 3 & 4 in publications section). The collaboration with Fudan University has resulted one paper in 2009 (journal article 130 in publications section).

PhD student Peter Sherrell spent 3 weeks at Shanghai Jiao Tong University, in September, using their advanced microwave reduction system to synthesise carbon-platinum composites, under a DEST Inter-Linkage Project. Whilst visiting China, Peter gave an oral presentation on "Optimisation of Carbon Nanoweb Architectures for Nano-Energy Applications" at the International Conference of ChinaNano2009 held in Beijing (1-4 September).

For three weeks in July Prof. H.L. Wang from Beijing Normal University and his student spent time working with Prof Hugh Brown (ACES) in Wollongong on gels. Dr Sureyya Saricilar (ACES) then visited Beijing Normal University in December 2009, spending 3 weeks with Professor H. L. Wang.

Dr Yimei Yin, from Shanghai Jiao Tong University, visited ACES for three months and worked with Dr Jun Chen on the collaboration project on nanostructured active composite materials for SOFC application. This visit was supported by the ARC discovery project, DP0877348.

Dr Yong Kong from the Department of Applied Chemistry, College of Chemistry and Chemical Engineering at Jiangsu Polytechnic University, Changzhou, China visited ACES for 6 months to carry out research on making all-polymer batteries composed of biocompatible materials.

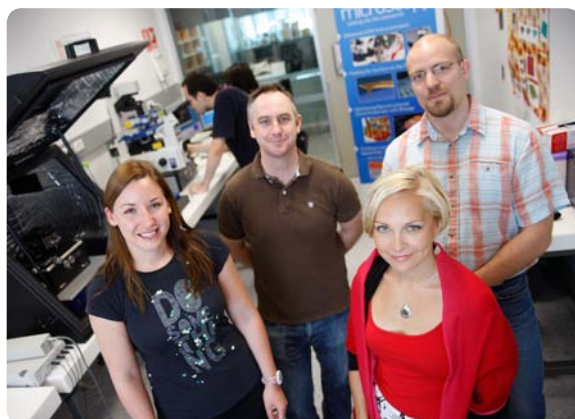
Two 12 month collaborative visits with ACES/ISEM were completed in 2009. Mrs. Limei Fan, from the University of Electronic Science & Technology of China, completed her visit with ACES in April and Dr Xianjun Zhu from the Central China Normal University in June.

ACES/ISEM hosted many international visitors from China. On 29 January they hosted Mr Jiangfeng Wu, Manager, DLG battery (Shang Hai) CO Ltd, and Dr. Yao Chen, the General Manager of DLG battery (Shang Hai) CO Ltd, who returned again in May (15 May). They also hosted Prof Yu Chen Zai from the Northeastern University (30 April – 1 May) and A/Prof. Yun Long Xu from East China University of Science and Technology (Shanghai) for 2 months (Feb – April).

Finland

Suvi Haimi and Aliisa Pali from the Regea-Institute for Regenerative Medicine, University of Tampere, Finland, and Jani Peltto, a fellow from VTT Technical Research

Finnish visitors Suvi Haimi, Aliisa Pali, and Jani Peltto, carried out atomic force microscopy experiments with Dr Michael Higgins



Centre of Finland, visited IPRI in November. As well as presenting lectures on their research, they also carried out atomic force microscopy experiments with Dr Michael Higgins on the collaborative project: "The effects of polypyrrole based polymers and electric environment on adipose stem cell attachment, viability, and proliferation".

France

PhD student Torben Daeneke (ACES) worked with collaborators in France (Strasbourg) and Switzerland (Lausanne), for 10 weeks commencing in June.

ACES PhD student, Shannon Little, spent September at the Centre de Recherche Paul Pascal in Bordeaux, France, on a collaborative project with Nicholas Mano's research group to produce a high power density biofuel cell. Whilst in France, Shannon attended the International Symposium on Functional Nanomaterials, presenting a poster on "Carbon NanoWeb Electrodes for Enzymatic Direct Electron Transfer".

Germany

Dr Udo Bach gave a presentation and had a meeting at Bosch headquarters in Stuttgart on 15 June. The discussion centred on the

joint application to the Victorian Consortium for Organic Solar Cells and included a lab visit.

Prof Leone Spiccia spent time in July visiting the research group of Prof Metzler-Nolte; Dr Gasser; Dr Schatzschneider (Bochum University) in Germany.

Dr Udo Bach visited Prof Baeuerle at the University of Ulm, Germany, holding discussions about collaboration on dye-synthesis on 15 September.

ACES PhD student, Ben Mueller, spent a week working on AFM-Raman measurements of graphene in Prof. von Klitzing's department at the Max Planck Institute for Solid State Physics in Stuttgart, Germany, in November. Prof von Klitzing won the Nobel Prize in Physics in 1985.

Dr Udo Bach visited Prof. L. Schmidt Lab –Mende at the Ludwig Maximilian University in Munich on 6 December.

Hong Kong

Dr. Jiazhao Wang (ACES) visited the Hong Kong University of Science & Technology, in July for two weeks, to initiate the collaborative project entitled "Production of Carbon Nanotube and CNT Application as Catalyst Support and Advanced Material for Energy Storage". This project is being

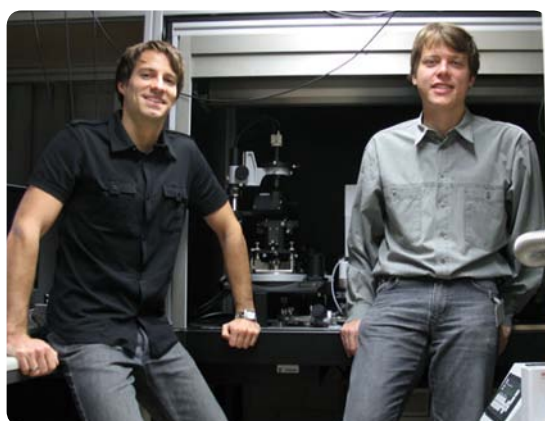
funded by Hong Kong under the Innovation and Technology Support Programme (ITP/026/08NP).

Ireland

Prof Tony Killard, from the National Centre for Sensor Research at Dublin City University (DCU) carried out research at ACES in October. He combined his expertise in electrochemical sensors with Prof Calvert and IPRI on conducting polymer nanomaterials in the project to allow printed sensors and biosensors to be integrated into electronic devices creating "miniaturised smart systems".

Dr Robert Byrne, a post-doctoral researcher from the National Centre of Sensor Research at DCU, was awarded a STTF Fellowship to work with Prof David Officer on synthesis and characterisation of photochromic terthiophenes. He spent several weeks working in Wollongong during February.

A series of visits by PhD researchers from Ireland is building upon these already strong research links. Students Emer Lahiff and Silvia Scarmagnani worked in the ACES labs in February. Silvia worked on the functionalisation and characterisation of polymeric microspheres and polyaniline nanofibres with spiropyran photochromic.



Ben Mueller (right) in Prof. von Klitzing's department at the Max Planck Institute for Solid State Physics in Stuttgart, Germany.



Prof. Tony Killard (left) from Dublin City University undertaking research at the Innovation Campus with Prof. Gordon Wallace.

These followed visits from Elaine Spain to Wollongong in December 2008 to work with Dr Lynn Dennany on a biosensor for mastitis detection and by Martina O'Toole, also in December 2008, to work with Dr Rod Shepherd on ink jet printing.

Ms Eimear Ryan, a PhD student from the National University of Ireland, was awarded a 2009 Endeavour Research Fellowship to visit ACES for 5 months. She worked with Dr Simon Moulton, using conducting polymers to deliver anionic drugs that are insoluble in water.

Deirdre Sheridan, administrative assistant at Dublin City University, visited Wollongong for 2 weeks in November to train and participate in the administrative operations of ACES; taking special interest in the organisation of international symposia.

Dr Scott McGovern travelled to Dublin City University, in March to work with collaborators on the WANDA Linkage Project. Development of the image recognition program was undertaken for use in the WANDA robotic fish. Testing was undertaken on the software in 'real world' environments to ascertain the best regime for use of the program (lighting, colour

detection, etc). These interactions have led to plans to incorporate a range of sensors on the fish.

Scott again visited Ireland in September to attend the International Symposium on Functional Nanomaterials, held on the 10-11 September, at DCU. A highlight was the successful Irish launch of the robotic fish called "WANDA" by Scott and DCU collaborators. In particular, a demonstration of WANDA's object recognition and detection capabilities using wireless video-imaging software was presented. This led to discussions with potential industry partners, including IBM and Foster-Miller, on future collaboration ACES research.

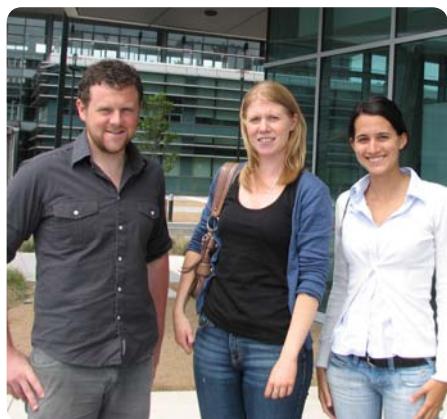
Dr Michael Higgins gave invited talk at the International Symposium on Functional Nanomaterials, on "Dynamic Polymer Interfaces for Controlling Protein and Cellular Interactions" and showcased work being carried out within the Bionics Research Program of ACES, in September 2010. The aim of the symposium was to act as a platform to present the latest advances in cutting edge nanomaterials research. Two ACES PhD students, Shannon Little and Robert Breukers, presented posters.

Robert Breukers worked with Prof. Dermot Diamond and Dr Robert Byrne at NCSR for 1 month (August -September). His research focused on the synthesis, polymerisation and characterisation of spiropyran functionalised terthiophenes for use in sensors.

Dr Lynn Dennany (ACES) worked with Prof Forster at DCU in September to obtain energy transfer and electron transfer data utilising TCSPC and low temperature emission data on Ru porphyrins covalently attached to fullerene molecules. The studies have provided useful information on the quenching pathways of a ruthenium porphyrin attached to a fullerene molecule. Whilst visiting Lynn gave a Seminar Series Presentation "Tuning electron and energy transfer in polyelectrolytes".

Japan

ACES has a fruitful on-going collaboration with Prof. Shogo Mori (Shinshu University, Japan), Prof. Akihiro Furube and Dr. Ryuzi Katoh (AIST, Tsukuba) in Japan. This collaboration is mainly focused on evaluating the efficiency limiting factors of porphyrin-sensitised TiO_2 solar cells by using various transient optical and electrical



Robert Byrne, Emer Lahiff and Silvia Scarmagnani from DCU in Ireland, outside AIIM building in Wollongong.



Ms Eimear Ryan, a PhD student from the National University of Ireland worked at IPRI with Dr Simon Moulton, using conducting polymers to deliver anionic drugs.



Deirdre Sheridan, administrative assistant at Dublin City University, pictured with Phil Smugreski (ACES)

probes. The partners from Tsukuba joined this collaboration in 2009 bringing experimental skills in femtosecond pump-probe measurement, which is one of the best set-ups in the world.

With this collaboration there are 3 main sub-projects:

- ▶ Investigation of the injection efficiency in porphyrin dimer-sensitised TiO_2 solar cells. For the first time efficient injection in a dimer-sensitised solar cell has been demonstrated (*J. American Chem Soc*, 2009). A further two publications are in preparation to be submitted in 2010.
- ▶ The injection limitations in various porphyrin-sensitised solar cells depending on molecular structure. A clear correlation between injection efficiency studied using fs-TAS and the device efficiency has been observed hence a paper is currently in preparation.
- ▶ As a follow up to the paper published in *Chemical Communications* in 2008, the effect of a zinc atom versus free-base porphyrin on the recombination dynamics in the porphyrin-sensitised solar cell has been undertaken in 2009.

Our Japanese collaborators have attended and presented talks at both the ACES Symposium held in February 2009, and the

ACES Solar Cell Characterisation Workshop held in November 2009. In addition ACES PhD student, Matt Griffith, has recently been awarded a Prime Minister's Award which will allow him to spend 6 months in 2010 with Prof. Mori in Japan.

Korea

Links between ACES and Korean researchers were bolstered by a number of visits, collaborative projects, grants and awards. ACES Executive Director Prof Gordon Wallace was appointed to join eminent world scientists in a newly-formed international collaborative research project named "World Class University". Supported by a \$1 million grant from the Korean Ministry of Education, Science and Technology, Prof Wallace will collaborate with researchers and students at Hanbat National University to prepare a variety of electrode materials for use in energy conversion and energy storage systems.

In January, NSW Minister for Science and Medical Research, Jodi McKay, announced that ACES would be the first funding recipient of a joint technology program between the NSW Government and the

South Korean province of Gangwon. The \$100,000 grant will promote research in new technologies.

Mr Hwi Won Kang, a Senior Research Engineer from PARU Co. Ltd, Suncheon, South Korea, worked with ACES/IPRI researchers for 3 months, starting in January, on gravure printing of solar cells. In addition, Gwangyong Lee, an under graduate student in the Printed IC Lab, Department of Chemical Engineering at Suncheon National University, focused on Ink-jet printing of electronic devices, with the view to prepare a novel electrode with enhanced performance and low production cost for solar cell and supercapacitor applications.

In February, a visit to Wollongong by Prof Ko Jang Myoun and Jeong Ho Park from Hanbat National University, marked the start of a collaboration to prepare a variety of electrode materials to be used in energy conversion or energy storage systems. This visit is the first in a series of transfers of staff and students between the two institutions.

There were also many visits by ACES researchers to Korea. Prof Gordon Wallace and Dr Byung Kim visited Korea in March and April 2009 to build further on the



Irish launch of the robotic fish called "WANDA" by Dr Scott McGovern and collaborators from the NCSR



UOW Vice-Chancellor Gerard Sutton, NSW MP Noreen Hay, NSW Minister for Science and Medical Research Jodi McKay, ACES Director Gordon Wallace, UOW Deputy Vice-Chancellor (Research) Judy Raper pictured at the announcement that ACES received funding for a joint technology program with Gangwon.

collaboration between ACES and Korean partners and national institutes, following the announcement of the World Class University partnership in February. Prof Wallace returned to Korea in July to visit Korean universities and research institutes where he provided a number of presentations and discussions, including:

- ▶ presentation on recent ACES findings in the Bionics area at a mini symposium organised by Prof. Seon Jeong Kim
- ▶ presentation at the newly formed department for "Printed Electronics" at Suncheon University, where ACES has a number of collaborative projects with Prof. Cho
- ▶ presentation on Organic Bionics to Prof. Park Yungwoo's research group at Seoul National University; and collaborative research discussions with Prof. Park (Gangwon) on the use of novel TiO_2 structures for energy storage
- ▶ Keynote address at a World Class Universities event aimed at building research and commercial collaborations

An additional visit in November to Korea by Prof Wallace, Prof Leon Kane-Maguire, Prof David Officer and Dr Jun Chen built upon these growing collaborative links. These four

ACES researchers and Dr Byung Chul Kim conducted a two day 'Conducting Polymer School' at Hanbat University in Daejeon.

New Zealand

In February, four ACES researchers, Drs Pawel Wagner, Attila Mozer and Sanjeev Gambhir and PhD student Robert Breukers, attended the fourth MacDiarmid Institute Conference - Advanced Materials and Nanotechnology 4. They presented lectures ranging from the use of functionalised polythiophenes as scaffolds for cell growth and in solar cells to the synthesis and use of porphyrin monomers and dimers in solar cells.

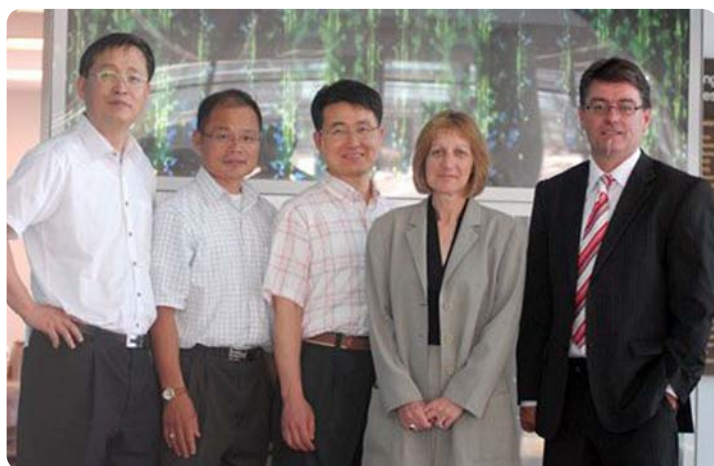
As part of the International Consortium on Solar Cells (ICOS) research program, Drs Wagner and Mozer met with Professor Keith Gordon (University of Otago) and PhD student Mr. Samuel Lind to discuss Wollongong-Otago ICOS research projects on dye-sensitised solar cells. This resulted in a very successful visit by Sam Lind to the ACES laboratories later in July to further the joint research. This has resulted in a *J. American Chemical Society* paper with

Japanese collaborators on porphyrin-based solar cells, also involving collaboration with Imperial College researchers.

Other interactions with Prof Gordon, linking material synthesis/characterisation and device construction at the ACES with quantum mechanical calculations and Raman spectroscopy at the University of Otago for solar cells and light emitting diodes, continue to be very productive. Some of this work is funded by a New Zealand Royal Society Marsden grant and a Foundation for Research Science and Technology International Investment Opportunities Fund (IIOF) grant. Prof David Officer (ACES) met with Prof Gordon in New Zealand in November to discuss the research for this and other grants.

Phillipines

Ms Karen Santiago, from the University of Santo Tomas, Philippines spent 2009 in ACES working with Dr Toni Campbell on long term controlled release of a drug from a biodegradable substrate, where the drug was loaded by ink-jet printing techniques.



Prof Gordon Wallace and Deputy Vice-Chancellor (Research) Prof Judy Raper with (from far left) Professor Ko Jang Myoun (Hanbat University, Korea), Dr Byung Kim (IPRI) and Jeong Ho Park (Hanbat University) after the announcement that the Korean government had invited Gordon to join the project "World Class University".



Dr Attila Mozer (ACES) spent one week in October at the National Metal and Materials Technology Center (MTEC) in Bangkok

Singapore

Dr Atilla Mozer (ACES) visited the A*Star Institute of Materials Research and Engineering (IMRE) in Singapore on 12-13 March, and attended the IMRE-ICOS Photovoltaic Workshop. He gave a lecture on "Transient Optical and Electrical Probes: Overview of Charge Transport and Lifetime Measurements at the Intelligent Polymer Research Institute". Dr Jenny Pringle (ACES) also presented a lecture entitled "PEDOT Electrocatalysts for Dye-Sensitised Solar Cells" at the IMRE-ICOS workshop.

Dr Udo Bach (ACES) visited Bosch in Singapore on 18 September 2009 where he had discussions about involvement of Bosch as commercial partner for ASI and VSA applications. Udo gave a presentation on behalf of the Victorian organic solar cell consortium.

Switzerland

Prof Leone Spiccia (ACES) visited a number of research groups during July including Prof Graetzel (EPFL).

Naomi Lewcenko (ACES) attended the European Materials Research Society Conference in Strasbourg from June 8 - 12 and also visited Prof Graetzel at EPFL in Lausanne, Switzerland.

Dr Udo Bach (ACES) visited Prof Michael Graetzel at the Swiss Federal Institute of Technology, Switzerland on 4 September. He also visited Prof J. Moser at the Swiss Federal Institute of Technology, Switzerland to discuss a potential collaboration on laser spectroscopy on 7 September.

Thailand

Dr Atilla Mozer (ACES) spent one week in October at the National Metal and Materials Technology Center (MTEC) in Bangkok. Attila is a partner investigator on a collaborative project funded by a Thai Government, MTEC Director's Initiative

grant, which is focused on developing advanced organic electronic devices. He contributes to the grant by using advanced spectroscopy techniques to characterise solar cell materials.

The main objective of this first visit was to overview solar cell activities at MTEC focused on inverted inorganic / organic hybrid solar cells. He then toured the most prestigious research institutes in Bangkok: MTEC, NANOTECH, NECTEC - all part of NSTDA (National Science and Technology Development Centre).

United Kingdom

To follow up on her sabbatical in Warwick in 2008, Prof Maria Forsyth (ACES) visited Warwick University and the University of Birmingham. PhD student Paul Bayley (ACES) spent from March to May working with colleagues at the University of Warwick and University of Leicester, whilst Dr Patrick Howlett (ACES) visited the University of Birmingham in May. Whilst in the United Kingdom, Dr Patrick Howlett (ACES) also attended the Conference on the Corrosion Chemistry in Pits, Crevices and Cracks at Manchester College in Oxford.

Professor Doug MacFarlane (ACES) visited the University of Surrey, Department of Chemistry in October.

USA

In January, Dr Pawel Wagner (ACES) visited the laboratories of Profs Marder, Kippelen and Brédas in the Centre for Organic Photonics and Electronics and the School of Chemistry and Biochemistry at Georgia University of Technology, where he presented a seminar entitled "New materials for organic solar cells".

Dr Pawel Wagner also visited Prof George Malliaras' laboratories at Cornell University, meeting Dr Lee-Fun Lim. Discussions took place about how the superb CNS

semiconductor device fabrication and characterisation facilities could be utilised in conjunction with the ACES conducting polymer development program. Dr. Lim provided a batch of specially designed ITO-coated glass plates for electronic devices to test back in Wollongong.

In March, Dr Scott McGovern attended the SPIE Smart Materials and Structures Conference, San Diego USA, March 2009, where he gave an invited talk "Organic bionics" on behalf of Professor Gordon Wallace. Scott also accepted the SPIE Smart Structures and Materials Lifetime Achievement Award on behalf of Prof Gordon Wallace.

Links with the University of Texas at Dallas were expanded during 2009. In May, Joselito Razal (ACES) attended the San Francisco MRS Conference where he presented a talk on Nanostructure-Mediated Skeletal Muscle Regeneration Using Multiwall Carbon Nanotubes and Polypyrrole Platforms. He also visited the University of Texas at Dallas (UTD), where he learned the technical skills of spinning carbon nanotube (CNT) sheets and yarns, and UTD provided open-access to samples of spinnable CNT forests. Joe also visited University of Texas at Arlington, to further collaborative discussions.

Mr. Suriya Ounnunkad, an ACES PhD student, gave an oral presentation at the world's largest annual nanotechnology meeting, NSTI Nanotech Conference & Expo 2009 in May, at Houston, Texas. His talk "A novel carbon nanotube-biomedical polymer composite platform for bioelectrochemical applications" highlighted his research into carbon nanotube nanocomposite materials. Suriya also visited Prof. Thomas Randall Lee at the University of Houston.

Dr Philip Whitten (ACES) continued to develop on an existing collaboration with Prof Ric Kaner at UCLA with a visit for

4 weeks in June after receiving an UIC International Links Grant Scheme Award from UOW. Whilst at UCLA, he continued his collaborative research in the area of self-assembled arrays of conducting polymer nanofibres and also presented a seminar to Qebing Pei's group at UCLA. Phil's visit to UCLA was followed up with a visit to ACES by Veronica Strong from Ric Kaner's lab in August, also courtesy of the International Linkage Grant Scheme Award.

Dr Whitten also attended two Gordon Research Conferences for Polymers presenting a poster on "Flash Welding of Polyaniline Nanofiber Mats and Their Actuation".

Prof Doug MacFarlane (ACES) visited the University North Carolina, Centre for Bio Engineering in July for collaborative research discussions.

Dr Attila Mozer (ACES) visited our ICOS solar cell consortium partners at Georgiatech (Prof. Seth Marder, Prof J.-L. Bredas, Prof. Ken Sandhage and Prof. Bernard Kippelen) and discussed collaboration between the parties. A two year collaboration agreement with leading organic solar cell company Konarka

Technologies Inc. was also signed, as a result of which a post-doctoral position will be funded to perform advanced laser spectroscopy investigations, in Wollongong, on Konarka solar cell materials.

Prof Leone Spiccia (ACES) delivered an invited talk at the SPIE conference on Optics and Photonics (San Diego) in August and also visited the research team of Prof Casey (UC Davis).

Dr Udo Bach (ACES/Monash) visited Prof C. Drain at the City University of New York USA on 15 September, holding discussions about collaboration on dye synthesis.

ACES hosted Assoc Prof Mario Romero-Ortega (University of Texas at Arlington) during February where he was an invited speaker at the February international symposia talking about described his most recent work on the use of nerve growth factors to guide sensory nerves to specific target areas. Discussions were also held about a collaborative project on nerve segregation using a 3D implantable nerve conduit and planning the next stage of preliminary experiments.

Further collaborative links were developed with Prof Paul Calvert, from the Department of Materials and Textiles at Massachusetts Institute of Technology, Dartmouth. An ARC Linkage International Award for Prof Calvert has allowed Paul to be in ACES to commence research on inkjet printing bio-functional materials.

Inkjet printing technology offers a way to create three-dimensional biological structures for studying cell interactions and artificial organs. Paul is assisting the ACES team to develop new machinery to allow the printing of active materials such as drugs, biopolymers and electronic conductors generating systems where electronics and cells can 'communicate'. This should ultimately feed into existing devices such as pacemakers and implantable insulin pumps, and future goals such as better nerve-driven artificial arms and electronic sight.

PhD student, James Vincent Scicolone, from New Jersey Institute of Technology spent 3 months in ACES from September, investigating with Dr Simon Moulton, the use of electrospraying and spray drying to form nanoparticles that contain drugs for controlled release.



Collaborative links were developed with Prof Paul Calvert (ARC Professional Linkage Fellow).

Invited International Presentations

In 2009, 39 invitations were received by ACES researchers to address international conferences.

January 2009

Dr Udo Bach participated in a podium discussion by Australian Consulate and DVC international (Monash) to Water and Energy Forum Conference called (Australia Week) in LA on 14 January.

Dr Udo Bach gave an invited talk to Nano fabrication group called (DNA – directed nano fabrication) on 21 January, at the Molecular Foundry (Lawrence Berkeley National Labs).

March 2009

Dr Udo Bach gave an invited Presentation on (Dye-Sensitized Solar cells – Towards tandem solar cells) to COPE researchers: Towards Tandem DSC's in Atlanta on 2 March.

Dr Scott McGovern attended the SPIE Smart Materials and Structures Conference, San Diego USA, March, where he gave an invited talk "Organic bionics" for **Professor Gordon Wallace**.

April 2009

Prof Gordon Wallace gave an invited lecture "Nanostructured Organic Electrodes" at the 60th Annual meeting of the International Society of Electrochemistry (ISE2009_Beijing).

Prof David Officer presented at the 3rd International Conference on the Industrialisation of DSC (DSC-IC 2009), Nara in Japan, 22-24 April. He invited talk was on "Porphyrin-sensitised Titanium Dioxide Solar Cells".

May 2009

Prof Maria Forsyth was invited to give a presentation on 'Coatings and Cathodic Protection - Corrosion mitigation in the Field' at the 17th Joint technical Meeting in Milan in May.

June 2009

Prof Maria Forsyth was an invited speaker at the 3rd Congress on Ionic Liquids (COIL-3), Cairns, June. Her talk was 'NMR Transport Measurements in Ionic liquids'.

Prof Doug MacFarlane gave the Chairman's Opening Remarks at the 3rd Congress on Ionic Liquids (COIL-3), Cairns, June.

Prof David Officer was invited to present at 'Nanophotonics Down Under 2009: Devices and Applications', held in Melbourne from 21 - 24 June. David's talk was "Towards Artificial Photosynthesis: Light Harvesting with Nanostructured Porphyrins".

Prof David Officer addressed the 3rd Congress on Ionic Liquids (COIL-3) at Cairns, Australia on "Organic Dye-sensitised Solar Cells: The Effect of Ionic Liquid Electrolytes".

Professor Gordon Wallace addressed the 3rd Congress on Ionic Liquids (COIL-3) at Cairns, Australia on "Ionic Liquids: The Elixir of Life for Organic Conducting Polymer Based Electrochemical Devices".

July 2009

Prof Maria Forsyth participated and chaired a session on Intergranular Corrosion at the Corrosion Chemistry in Pits, crevices and Cracks, Manchester College, Oxford 16- 20 July.

Prof Doug MacFarlane gave an invited talk "Plastic Crystal proton Conductors for Fuel Cells" at the Solid State Ionics 17 in Toronto July.

Prof Doug MacFarlane gave an invited talk "ionic liquids" on a Webinar at Cytec's Welland plant, Canada 6 July.

August 2009

Prof YiBing Cheng gave an invited talk at the 2nd Photonics and OptoElectronics Meetings, Wuhan, China 8-10 August.

Dr Jenny Pringle attended the 42nd IUPAC meeting in Glasgow, Scotland from 2-9 August, giving an oral presentation on "Synthesis of Conducting Polymers in Ionic Liquids for Photovoltaic Applications."

Dr Jun Chen gave an invited talk at the ISE Annual Conference in Beijing (17-22 August).

Dr Attila Mozer gave an invited address "Efficient photo-induced charge injection in Zn-Zn porphyrin dimer-sensitised TiO₂ solar cells: towards 3-dimensional light harvesting" at the SPIE conference in San Diego.

Prof Leone Spiccia attended and delivered an invited talk at the SPIE conference on Optics and Photonics, San Diego.

Dr Udo Bach participated to the eMRS - Symposium A (Dye-sensitized Solar Cells) in Strasbourg on 6 August.

Prof Gordon Wallace was an invited keynote speaker at the Royal Chemical Society 42nd IUPAC Congress: Chemistry Solutions 2-7 August, Glasgow, United Kingdom. The topic of Gordon's keynote address was "Nanostructured Organic Electrodes: the Impact on Medical Bionics" and the address was delivered by **Assoc Prof Stephen Ralph**.

September 2009

Prof Doug MacFarlane gave the plenary lecture at the Opening of the Centre for Molecular Systems Science at the University

of Kyushu, Global Centre of Excellence September 2009: "Ionic Liquids Applications in the Chemical- and Bio- Sciences".

Prof Graeme Clark gave the opening address for Virtual Conference organised by The Ear Foundation, Nottingham on 29 September.

Dr Michael Higgins gave an invited talk at the International Symposium on Functional Nanomaterials, on "Dynamic Polymer Interfaces for Controlling Protein and Cellular Interactions" in Ireland, September.

Prof YiBing Cheng gave an invited talk at the 3rd GCOE International Symposium: Catalysis as the basis for the innovation in materials science, Sapporo, Japan, 14-15 September.

Prof David Officer addressed the audience at the International Conference Stuttgart Nanodays'09, held 14-15 September on "Nanostructured Carbon Electrodes".

October 2009

Prof Maria Forsyth was an invited speaker, 216th ECS Meeting with Euro CVD 17 and SOFC-XI at the Centre of Electrochemical Surface Technology (CEST) in Vienna, 4 – 9 October . Her talk was on 'Insights into the nature of Ionic Liquid surface film formation on reactive metals'.

Dr Patrick Howlett presented his work on 'Novel Electro-materials and Electro-interphases: from Energy to Sustainable Infrastructure' at the 216th ECS Meeting with EuroCVD 17 and SOFC-XI: Vienna, Austria. Austria Centre Vienna, October 4 - 9.

Maria and Patrick were also Invited Panel Members at the Round Table: The Future of Ionic Liquids in Electrochemical Surface Technology, CEST, 9 Oct, Wiener Neustadt, Austria. (Ionic Liquids, Surface Interactions & Applications).

Prof Doug MacFarlane gave the Plenary Lecture "Polymerisation and Device Applications of Conducting Polymers in Ionic Liquids" at the International Symposium on Ionic Liquids and Polymers, Washington DC, in October .

Prof Doug MacFarlane gave an invited talk "Plastic Crystal proton Conductors for Fuel Cells" at the 1st Latin American Chemical Congress, Havana, in October .

Prof Doug MacFarlane presented an invited talk at the 3rd International Conference on Electroactive Polymers in Jaipur in October.

Prof Leon Kane-Maguire gave an invited presentation "Multifunctional Materials for Advanced Monitoring Systems" at the European Commission - Australian Scientists Workshop, Brussels, Belgium, 13 October.

Prof David Officer gave an invited seminar at the Korea-Australia International Collaboration Seminar at the Kangwon Fine Chemicals Centre, Kangwon, Korea on 27 October. His seminar was on "Porphyrin-sensitised Titanium Dioxide Solar Cells".

Prof David Officer gave his invited address "Light Harvesting with Nanostructured Porphyrins: Towards Artificial Photosynthesis" at the 104th National Korean Chemical Society Meeting, held at the Daejeon Convention Center, Daejeon, Korea, 29-30 October.

Prof Gordon Wallace gave his invited address "Organic Conductors for Regenerative Medical Bionics" at the 104th National Korean Chemical Society Meeting, held at the Daejeon Convention Center, Daejeon, Korea, 29-30 October.

November 2009

Prof Doug MacFarlane gave the Plenary Lecture "Ionic Liquids and Global Sustainability" at the International Symposium on Green and Sustainable Chemistry, Tottori, Japan, November.

Prof Doug MacFarlane gave the Plenary Lecture "Advanced Applications of Ionic Liquids in Chemical Processing, Electrochemical Devices and Biosciences" at the Regional Conference on Ionic Liquids, Kuala Lumpur November.

Prof YiBing Cheng gave an invited presentation on "Synthesis and Application of Submicron-sized Mesoporous TiO₂ Spheres for Dye Sensitized Solar Cells" at the International Symposium on Advanced Ceramics and Technology for Sustainable Energy Applications (ACTSEA-2009), Taipei, Taiwan, 1-4 November.

ACES National Linkages

ACES participates in a number of active national research collaborations, some of which are outlined below. During 2009, ACES produced 98 refereed publications, with 36 of these involving collaborators external to ACES.

ACES currently enjoys an important national linkage, with Professor Rose Amal's (Assoc. Director ARC Centre of Excellence for Functional Nanomaterials) group, 'Particles and Catalysis Research Group' at **University of NSW**, in the area of characterisation of metal oxide nanostructure for solar cells application, where two new projects were initiated in 2009. One-step flame-made TiO_2 particles have been investigated for use in dye-sensitised solar cells. A second study into the effect of rutile to anatase fraction on charge transport and recombination has been carried out. Investigations were also carried out into the application of aligned TiO_2 nanotubes for use in solar cells. To date a maximum efficiency of around 3% has been achieved. Initial studies into the use of WO_3 nanostructures for use dye-sensitised solar cells are underway.

Studies continued on the porphyrin-based organic solar cell collaboration between Prof Paul Dastoor, in the Centre for Organic Electronics (CoE) at the **University of Newcastle**, and Prof David Officer (ACES). Two visits were made to the CoE by post-doctoral researcher Dr Lynn Dennany to investigate the use of ruthenium porphyrins, developed in an ARC Discovery project, as sensitisers in polymer solar cells. Further work will continue in this area in 2010 following the promising results obtained.

ACES PhD student Benjamin Müller has been collaborating with Dr Joselito Quirino and Prof Pavel Nesterenko in the group of Prof Paul Haddad at the Australian Centre for Research on Separation Science, **University of Tasmania** to work on Capillary Zone Electrophoresis (CZE) and Open Tubular Capillary Electrochromatography (OT-CEC) of graphene oxide and chemically converted graphene. In 2009 Ben has made 2 week long visits to Tasmania. CZE allowed us to separate graphene oxide (GO) and

chemically converted graphene (CCG) dispersions depending on their sheet size and on their charge carried.

ACES/ISEM has collaborated and hosted numerous national visitors in 2009. As a result of the collaborations two papers are in preparation with: (i) Dr. Young-Hee Cho from the **University of Queensland** who visited ACES 12-13 November, and (ii) Dr. Alexey Glushenkov, from the **Australian National University** in Canberra who visited 22-24 July.

ACES has established a collaboration with Margaret Morris (**University of NSW**) and Terry O'Brien (**University of Melbourne**) to design and synthesise polymer micro- and nano-spheres for the delivery of the anti-epilepsy neuropeptide (NPY). The polymers prepared at ACES are to be implanted into animals at University of Melbourne.

The development of conducting spheres for drug delivery is a collaboration with Frank Caruso's group at the **University of Melbourne**. Frank's group have developed a layer-by-layer method where by oppositely charged polymers are sequentially deposited onto SiO_2 spheres templates, and ACES are



Ben Mueller (front) with his collaborators at University of Tasmania.

designing and assessing the introduction of conducting layers into this process. Dr Simon Moulton spent a week with Frank's group in 2009 as part of this collaboration.

Dr Michael Higgins (ACES) is collaborating with Prof. Hans Griesser, at the Ian Wark Research Institute, **University of South Australia**, on "Nanoscale dynamics and protein surface interactions of thermoreponsive polymer coatings". This collaboration has involved 3 visits to ACES; two by Hans and a visit by his PhD student Martin Cole, where they used the ACES AFM facilities for characterisation studies. A publication is currently in preparation.

The collaboration with Prof Alan Bond's group from **Monash University** strengthened with two visits to his laboratory by PhD student Mr Suriya Ounnunkad to work on Fourier Transformed AC Voltammetry, a new electrochemistry technique revolutionised by the Bond laboratory. Using the technique to study carbon nanotube composite nanostructured electrodes, interesting results obtained from the studies have lead to two publications soon to be submitted. Ongoing research from these initial studies is planned for 2010 and beyond.

Prof Doug Mac Farlane has collaborations with Dr Anita Hill **CSIRO Manufacturing and Materials Technology** and Dr Mike Horne and Dr Theo Rodopoulos from **CSIRO Minerals**.

In addition, every year ACES hosts numerous visitors - from international, national and enduser groups. For a complete list of visitors to ACES in 2009 see appendix 1.

Outreach 2009

In 2009 ACES was involved in many outreach activities, which are summarised below:

- (i) ACES in the media
- (ii) ACES community engagement activities
- (iii) ACES 'Hands-On'
- (iv) ACES public communications/ presentations/competitions
- (v) ACES involvement in other community activities

(i) ACES in the Media

ACES formalised a targeted Communications Strategy and Media Relations Strategy aimed at increased awareness, understanding and support among various stakeholders and the community of the outcomes and benefits of the scientific research credentials of ACES. This included the creation of a Communications & Media Officer Position dedicated to these activities.

As a result, ACES featured more prominently in the media in 2009. There were a total of 101 media interest stories published (appendix 2); with 41 articles in print, 34 articles online/web, 16 radio interviews and 10 TV appearances.

As well as generating substantial interest in the media, new initiatives in the area of social media and networking were started in September, via the University of Wollongong's Research Office UOW Facebook and Twitter sites (to date UOW has 363 Facebook fans and 282 Twitter followers). Since September 12 stories about ACES/IPRI were posted on Facebook and 29 messages were tweeted concerning ACES/IPRI.

In addition, media demonstrations and community lab tours were held; and an events calendar developed for staff and

students across the nodes to keep them updated on training, education and other events among the group.

Several of those outreach activities are highlighted below.

21 January 2009

Story in the Diamond Valley Leader on how scientists are working with a team at ACES/IPRI to trial the use of "carbon nanotubes" to connect cochlear implants with the human brain.

27 January 2009

Follow-up Drive Time (ABC radio) report about a new research initiative, funded by a \$100 000 grant from the NSW Department of Science and Medical research, in which ACES/IPRI will collaborate with Korean nanotechnology researchers to develop new materials for batteries. This research will have a major impact on devices such as mobile phones and digital cameras.

10 March 2009

The *Illawarra Mercury* followed up on the opening of the Australian Institute for Innovative Materials, including an overview of research at IPRI and profiles of two PhD students, Brianna Thompson and Peter Sherrell, in its story "Minister launches cutting-edge campus at Wollongong". *ABC Illawarra Radio* provided a report on the opening during its Morning Show with Steve Parsons, including airing an interview with Kim Carr, Minister for Innovation, Industry, Science and Research. "*Minister opens AIIM building and praises collaborative partnerships*", was written by Nick Hartgerink from the UOW media unit.

18 March 2009

The Korean *DaeJeonToday* Newspaper ran a news story on Prof Gordon Wallace's visit to Korea in March, during which he attended

a ceremony for the "World Class University" project where he was presented with a letter of appointment.

18 March 2009

Professor Doug MacFarlane (ACES/Monash) was interviewed about the development in fuel cell technology using Gore-Tex that he and researchers at Monash University have been exploring. The interview appeared in the March 2009 edition of *Mobile Tex*. *Mobile Tex*, which features news and information on the global transport textiles industry, including the automotive, aerospace, rail and marine sectors.

6 April 2009

A radio interview with Prof Graeme Clark, first broadcast on ABC radio's Conversation Hour program, was repeated on Monday 6 April.

9 April 2009

A *Perspectives* article published in *Science* on 9 April, entitled "Electrode-Cellular Interface" was contributed by Prof Gordon Wallace; Prof Graeme Clark and Dr Simon Moulton. "A 'stacked' bionic materials store promises a medical revolution", was written by Bernie Goldie, UOW media unit.

15, 18 April 2009

After a landmark case, which saw a grandmother being posthumously awarded damages in an asbestos case, there has been discussion in the media about the possible dangers of nanotechnology. Prof Gordon Wallace was asked to comment on the new call for stricter regulations on nanotechnology. Gordon said he supported discussion over stricter regulations on the importing, manufacturing, supplying and selling nanotechnology materials, as well as labels on all products that contain nanoparticles, called by the ACTU. He also would welcome further study into

the potential health risks associated with nanotechnology, and that staff doing research in the field use the same safety standards that apply to all new chemistry research. The story was reported in the *Illawarra Mercury* by journalist Courtney Trenwith 'UOW professor welcomes nanotech study'.

23 April 2009

The *Catalyst* Program on ABC TV featured a story on solar prints which featured the research being undertaken by Dr Udo Bach, who is a Research Fellow with ACES at Monash University. The team of researchers including Dr Udo Bach and Prof Yi-Bing Cheng, have developed a solar cell which is thin, flexible and can be produced on a mass-scale using the same technology used to print polymer banknotes.

29 April 2009

The Higher Education liftout in *The Australian* newspaper profiled ACES Executive Director Professor Gordon Wallace talking about his work in the fields of bionics and polymers. The article titled "Polymers Rescue Bionic Man From Fantasy World" by Jane McCredie also featured a photo of Gordon outside the AllIM Facility in Wollongong.

30 May 2009

"Wollongong uni nerve centre for spinal repairs" - Angela Thompson's story in the *Illawarra Mercury* describes how researchers at ACES/IPRI have claimed a seat at the cutting edge of medical bionics, taking a 'giant step' towards repairing spinal injuries.

1 August 2009

The Illawarra Mercury ran a special 16-page feature celebrating the first year of operation of the Innovation Campus, administrative home for ACES. The feature included messages of support from

UOW Vice-Chancellor Professor Gerard Sutton and Minister for the Illawarra David Campbell as well as articles on the cutting edge research being undertaken at ACES/IPRI including the partnership with the Wollongong Science Centre and the new iDome exhibition.

11 August 2009

The IQ Education Supplement in the *Illawarra Mercury* featured an article previewing Prof Graeme Clark's public lecture. The article included an interview with Prof Clark who spoke highly about the research being currently undertaken at ACES and the importance of initiatives such as the 'Bionics for 2020' High School Competition, which provide vital encouragement for young minds. The lecture was also promoted via ABC Illawarra Radio, i98FM and Wave FM radio and the *Lake Times* Newspaper.

The *Illawarra Mercury* also featured an article on the 'Bionics' Competition, including an interview with UOW Dean of Science and ACES Chief Investigator Prof Will Price who said he was delighted with the quality of the entries received from schools, including a number from outside the local area.

10 September 2009

Irish Times, ran a news story on "A Robot Fish Called WANDA", a collaborative research project between ACES and DCU.

14 September 2009

Story in *Illawarra Mercury* titled "Two researchers within ACES have been named as recipients of ARC (Australian Research Council) Future Fellowships".

1 October 2009

On-line and in *The Illawarra Mercury*, an article on visiting Professorial Linkage Fellow Prof Paul Calvert, a world-renowned materials scientist from the University

of Massachusetts Dartmouth in the US, currently carrying out collaborative research at ACES/IPRI.

27 October 2009

The University of Wollongong's Community Connections Feature which appeared in the *Illawarra Mercury* and *Wollongong Advertiser* featured an article on IPRI community lab tours and a profile on ACES/IPRI PhD student Cameron Ferris.

8 December 2009

ACES/IPRI PhD student, Matthew Griffith, has been named as one of 20 postgraduate students in Australia to receive a \$63,500 Prime Minister's Australia Asia Endeavour Award. Story in *Illawarra Mercury*.

21 December 2009

Prof Gordon Wallace interviewed about current research in the area of medical bionics, including comments on the bionic eye design for the future.

(ii) ACES Community Engagement Activities

March 2009

ACES/IPRI moved into their new facility at the Innovation Campus, which was opened officially in March by Kim Carr the Federal Minister for Innovation, Industry, Science and Research. Local dignitaries and University members were given the opportunity to participate in a 45 minute tour of the laboratories. Since the opening, the Illawarra community have shown a great interest in finding out 'what happens in those buildings on the Innovation Campus'. Consequently, IPRI has opened its doors to the public to showcase its work.

29 March 2009

Assoc. Prof. Robert Kapsa (ACES) presented his work on 'Development of Advanced Polymer Systems for Regenerative Bionics Applications: *Molecular Chemistry Meets the Molecular*

Biology of the Cell: Building Regenerative Systems for Muscle and Nerve' at the Bernard O'Brien Institute for Microsurgery, Melbourne.

April 2009

Two upcoming artists in residence within the School of Art & Design, Faculty of Creative Arts at UOW, Janet Burchill and Jenifer McCamley, along with Jacky Redgate Visual Arts Coordinator and Derek Kreckler Senior Lecturer, were hosted at ACES for an afternoon. They were interested in the ascetics of the electromaterial research, especially energy conversion and electronic textiles. They were also shown the iDome interactive display in the Science centre.

5 April 2009

Assoc Prof Robert Kapsa (ACES) gave the Lion's Australia: Step Ahead Australia Spinal Cord Fellowship Presentation at the Melbourne Exhibition Centre. His talk, "Spinal Cord Injury: New Ways of Treating an Old Problem," was keenly listened to by the 250 seniors of the Lions Club executive and a number of individuals affected by spinal cord injury.

29 April 2009

The Australasian Gene Therapy Society Conference was held with around 450 registrants. ACES sponsored the keynote speaker Prof Jeffrey Chamberlain to talk about his work on 'Adeno-Associated Virus mediated gene transfer as a therapy for Duchenne Muscular Dystrophy'. Assoc Prof Rob Kapsa (ACES) presented a talk and two posters.

25 May 2009

ACES played a large role in the Illawarra Innovation Showcase which is part of the National Innovation Festival, as follows:

- ▶ Community Tours of the IPRI/AIIM Building
- ▶ Launch of the **"Bionics for 2020"** high school competition by Prof. Will Price
- ▶ Presence at the Illawarra Innovation Showcase Expo
- ▶ Involvement in the Seminar Presentation Series (Prof. Gordon Wallace spoke on organic bionics)



ACES/IPRI moved into their new facility at the Innovation Campus, which was opened officially in March by Kim Carr the Federal Minister for Innovation, Industry, Science and Research.



- Innovation Week Lecture, by Paul Bourke, was co-sponsored by ACES. Paul talked about visualisation techniques for science, including the iDome.

The involvement of ACES in the showcase was reported on WIN TV news, ABC Illawarra Radio, the Illawarra Mercury article on *"Science Centre drawcards just about out of this world"* and the Illawarra Mercury and the University of Wollongong media unit article *"iC opens its doors for Innovation Week"*.

7 July 2009

ACES hosted 8 undergraduate students undertaking the Advanced Science program at the University of Western Sydney. They were given an overview of ACES activities followed by a half day laboratory tour. After the tour the students were effusive in their thanks and Dr Robyn Crumbie, the subject coordinator, wrote: "I personally found the visit very worthwhile and impressive".

29 July 2009

Significant inroads into the development of the latest materials for "smarter" medical bionic devices were announced at a special demonstration held at ACES. The *Illawarra*

Mercury and *WIN Television* reported on and aired the demonstration, and Prof Gordon Wallace was also interviewed on ABC Radio.

In addition to the demonstration, a 30 minute lab tour for local businesses and science teachers from local high schools was held. Teachers also previewed the new animated DVD developed by the Centre called "Nanostructures for Electromaterial". This educational outreach DVD has since been distributed to high schools throughout the country and placed on the ACES, IPRI and UOW websites.

19 October 2009

A focus group was held in Wollongong on the subject of bionics. This was a collaborative activity between the Department of Innovation, Industry, Science and Research and ACES. The focus group was one in a series, where the aim is to gain a better understanding of the public's knowledge, concerns and aspirations towards biotechnology and nanotechnology (in particular, applications of these technologies). Prof Susan Dodds facilitated the discussion. Prof Gordon Wallace

attended the focus group as an expert in bionics, to engage in the discussion and answer any questions.

December 2009

On 8 December, ACES PhD student Cameron Ferris presented a lecture on his journey towards his PhD for 30 Careers Advisors from the Illawarra. His talk, "Cells, gels and nanotechnology" highlighted Cameron's experiences of the nanotechnology undergraduate degree at UOW, the research he is undertaking for his PhD, and a general background about the scope of the research being done here at ACES.

ACES also hosted 20 Careers Advisors from High Schools in the Sutherland Shire on 10 December. Cameron Ferris again gave a short presentation. Each group (4) was then aligned with other ACES PhD students and given a tour of the laboratories, where the students showcased their research. Feedback was very positive.

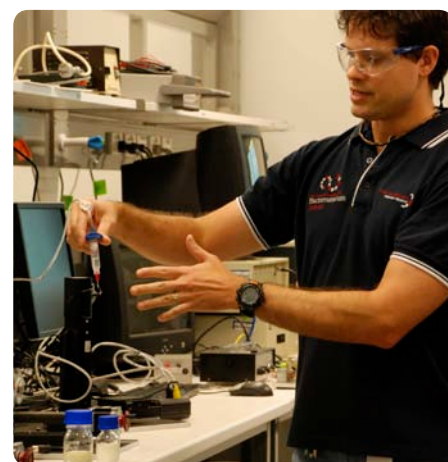
On December 17, IPRI hosted a community tour of the laboratories for interested members of the public.



Prof Will Price launching "Bionics for 2020" high school competition



ACES hosted 8 undergraduate students undertaking the Advanced Science program at the University of Western Sydney



(ii) ACES Hands-On

ACES/St Vincents researchers delivered a Masterclass for the University of Melbourne International Advanced Medical Science class. This class was made up of 35 second year medical students from Universitas Indonesia. The lecture covered potential therapies for the most lethal progressive childhood disorder, Duchenne Muscular Dystrophy, which affects 1 in 3,500 new-born male children. The 35 students, along with a further ten, second year medical students from the University of Melbourne were also provided with a Laboratory Skills workshop, given by ACES/St Vincents researchers, that took place during the periods, 20-31 July and 10-21 August. During the laboratory workshop the students received training in basic biological laboratory skills required for their Advanced Medical Science year.

A significant challenge for the Centre is to recruit top quality postgraduate candidates. As a first step in addressing this challenge, ACES gave two keen high school students interested in cutting edge science and research the opportunity to have hands-on experience.

Year 12 Illawarra Grammer School (TIGS) student Vaughan Patterson gave up part of his school holidays to get two days hands-on experience with nanomaterials. He produced a magnetic liquid called 'ferrofluid', a material originally laboriously produced in the 1960's by NASA, but the ferrofluid produced by Vaughan, using clever chemistry makes these nanoparticles within 2-3 hours. When put near a magnet, the ferrofluid shows amazing transitions, such as forming spikes, as pictured.

(iii) Public Communications/ Presentations/ Competitions

12 May 2009

On 12 May, *Future Materials* arranged a Sydney Executive series forum entitled "Enabling Technologies – Intelligent Materials" at which Prof Gordon Wallace (ACES) and Phil Aitchison (CAP-XX) were guest speakers, showcasing the success of their organisations utilising novel technologies.

22 May 2009

Prof Graeme Clark delivered the The Libby Harricks Memorial Oration 2009 in Sydney, giving an address entitled "The Bionic Ear: from an idea to reality". The aim of the Libby Harricks Memorial Oration is to create greater public awareness of hearing problems and to highlight the work done on behalf of the Deaf and Hearing Impaired community by voluntary groups throughout Australia.



Vaughan Patterson (centre) with a magnetic liquid he produced called 'ferrofluid' (inset)



18-19 June 2009

Prof Gordon Wallace presented a lecture entitled "Taking the speed humps out of the biofunctional materials highway" at the 3rd Annual 'Excitable Cells' Meeting, at the Melbourne Museum. The meeting linked associates from neuroscience, laboratory to bedside, as well as engaging other disciplines such as engineering, biochemistry and biomaterials science. Dr Michael Higgins and Dr Simon Moulton also gave talks about their research carried out in ACES.

9 July 2009

ACES Communications Officer Leanne Crouch attended the National Nanotechnology Communications Meeting in Canberra, which was hosted by Department of Innovation, Industry, Science and Research. The meeting involved presentations by various research and industry representatives as well as discussions over a national framework for communicating nanotechnology in the media and within the broader community.

Some of the key outcomes of the meeting included an agreement to undertake forums to educate the media on the science of nanotechnology, as well as forums to educate key scientists on how to work

with the media; the provision of a weekly news summary on nanotechnology issues to participants who request it (ACES has subscribed to this service) and co-operate with other agencies on joint community engagement activities.

28 July 2009

Prof David Officer (ACES) participated in the Green Jobs Illawarra Renewable Energy Forum at Rydges Hotel in Wollongong, where he presented an invited lecture on solar energy entitled "Renewable Energy: Powering Australia and the Planet".

19 August 2009

A growing partnership between IPRI and the Wollongong Science Centre & Planetarium is providing a number of opportunities to engage communities and schools in research being undertaken on their doorstep.

A new exhibition was launched during National Science Week. The 'iDome' allows people to get a 180-degree view inside the IPRI laboratories, including a guided tour of the labs by senior researcher Dr Simon Moulton and demonstrations and animations of the research being carried out. There are plans to install a live video feed into

the exhibition so that people can watch scientists' conducting this amazing research as it happens.

The partnership also led the sponsorship of a free Public Lecture, by Bionic Ear pioneer and ACES Chief Investigator, Professor Graeme Clark. Graeme's lecture, titled "Big thinking, small technologies", took the audience through some of the implications of nano-bio-technology, including how it may help with spinal cord repair, drug delivery and the development of a visual prosthesis – the bionic eye - and his collaborative research with IPRI and the University of Wollongong.

Sponsored by ACES, UOW's Faculty of Science, Wollongong Science Centre and supported by RACI, the lecture was attended by more than 120 people including community members, local high school students and science teachers, University staff and students and recipients of cochlear implants and their relatives and resulted in positive feedback. The event also gained widespread media publicity in the region. In particular, WIN TV News reported on the lecture, including interviews with Prof Clark and the mother of four-month old Felix Williams, who was due to receive bilateral cochlear implants within the next month.



(L to R): Dr Simon Moulton, Professor Mark Cook, Professor Gordon Wallace and Dr Michael Higgins at 'excitable cells' workshop in Melbourne.



Prof Graeme Clark with Joanne Williams and four-month old Felix Williams, who is due to receive bilateral cochlear implants in September 2009.

20 August 2009

Prof Graeme Clark was invited to attend a parliamentary symposium, hosted by Dr Brendan Nelson, in Canberra, on infant and early childhood deafness.

27 August 2009

Dr Simon Moulton (ACES) presented a lecture, "The role of Nanotechnology in Bionic Research", to the Southern Highlands & Tablelands Regional Group of Engineers Australia- Sydney Division.

7 September 2009

Dr Simon Moulton described the ACES bionics research in a lecture, "Latest Research in Medical Bionics" to the audience of the University of the Third Age (U3A). U3A consists of retired people, who appreciate the stimulation and enjoyment of learning together.

22 September 2009

Prof Graeme Clark gave a lecture on the "Issues in Nanotechnology", to 4th year students at La Trobe University.

2 October 2009

At the October Wollongong Innovation Campus Networking Function, Prof David Officer gave a short presentation on the

current and future Australian Institute of Innovative Materials research facilities and associated ACES research program.

3 November 2009

Maria Forsyth (ACES) was the key note speaker at Deakin University's Inaugural ITRI annual symposium in Geelong. Her talk was about "Novel Electro-materials and Electro-interphases: from Energy to Sustainable Infrastructure".

Public Lecture Series: Campus to Corporation to Customer Lecture Series (C2C2C)

ACES initiated a lecture series that ran throughout 2009 entitled 'Campus to Corporation to Customer' (C2C2C). This free series of lectures featured Australia's leading venture capitalists, financial and legal minds and entrepreneurs providing personal insights and experiences into the opportunities, risks and rewards associated with commercialising innovation. This series opened the minds of ACES researchers to the highs and lows when striving for commercialisation of their research.

The inaugural lecture on 25 June featured Roger Buckeridge from Allen & Buckeridge. The lecture focused on the challenges associated with migrating innovation into the marketplace; the pitfalls, the risks and rewards, and the temperament required to minimise the risk of failure and maximise the potential for success.

On 4 September, Lindley Edwards, CEO Venture Bank, gave the second lecture. She is a specialist adviser in merger, acquisition, divestments, fund raising, strategic consulting and licensing for growth public and private companies.

The third presentation on 1 October was by intellectual law specialist Noric Dilanchian, the Managing Partner of Dilanchian Lawyers & Consultants in Sydney. Noric talked about innovation and the timing of when it was best to engage 'the team' to plan the way forward.

Victor Bivell, Editor and Publisher with Eco Investor Magazine, provided an insightful presentation on 11 November titled 'The Whole of Commercialisation Approach to Innovation'. In the 15 years Victor spent as a venture capital editor, one of the sayings about commercialisation he came across that is pertinent to commercialisation is that "what ever you may think it is going to take, double the money and triple the time".



Lindley Edwards, CEO Venture Bank



Intellectual law specialist Noric Dilanchian



Victor Bivell, Editor and Publisher with Eco Investor Magazine

(iv) ACES involved in community engagements

Funds for Heart Foundation

ACES staff took out the 'iC Treadmill Challenge' 2009, an Innovation Campus Health initiative in conjunction with the National Heart Foundation's National Heart Week. Members of the team decked out in red, ran their way to victory during the five hour Challenge and raised funds for the Heart Foundation.

Jeans for Genes

The team at ACES donned their jeans and donated money for the annual Jeans for Genes Day on 17 August, raising money for the Children's Medical Research Institute and to support research by scientists

into areas like cancer research, cell transformation, cell signalling, embryology and gene therapy.

Team supports 'Sizzle for a Cause'

ACES staff and students supported the 'SIZZLE FOR A CAUSE' fundraising event held at the Innovation Campus in Wollongong on 25 September. The team helped to help raise money and awareness for the Prostate Cancer Foundation.

U-MO-W team show support for men's health

Students and researchers at ACES/IPRI raised \$570 for Movember's men's health partners – The Prostate Cancer Foundation of Australia and Beyond Blue – the national depression initiative.



ACES staff taking the 'iC Treadmill Challenge' 2009

Prizes and Awards

March 2009

1. In March, Prof Graeme Clark (ACES), presented the inaugural **Bill Wheeler Scholarship to Tom Higgins**, who was undertaking the final honours year of a degree in nanotechnology. The scholarship supports research on any aspect of nanobionics carried out by Honours degree students in science or engineering at the University of Wollongong.

Bill Wheeler was a very community-minded person who devoted time to the Rotary Club of Kiama and to disadvantaged children. He took a special interest in the further development of the cochlea implant for deafness and the new research at ACES on spinal cord repair.

2. **Prof Gordon Wallace** was honoured with the Lifetime Achievement Award for 2009 by the International Society for Optical Engineering. Announcement of the award was made at the annual SPIE Smart Structures and Materials/Non-destructive Evaluation Symposium, held in San Diego, USA.

3. **Prof Graeme Clark was presented an Honorary Doctorate by Zaragoza University.** The University of Zaragoza

is the only public university in the historic region of Aragón, Spain. Founded in 1542, it is one of the oldest universities in the world with over 40,000 students in its 22 faculties and ranks among the top public universities in Europe.

4. **Scots College names building after Prof Clark.** The Graeme Clarke Centre (Science, PDHPE and Mathematics) at Scots College has been named after Prof Graeme Clark (ACES). Scots College is an independent day and boarding school for boys, located in Bellevue Hill, Sydney.

27 April 2009

Shulei Chou, a PhD student in ACES, has been awarded a highly-competitive Electrochemical Society (ECS) summer fellowship to study at Canada's Dalhousie University. He will receive a US\$5,000 award and will spend from June with his summer fellowship host, Prof Jeff Dahn. ECS is a very large society covering many disciplines in chemistry, materials, engineering and solid state science. ECS has a world-wide membership, including most universities in North America, many

from Asia, Europe, South America and Australia. The ECS awards are given to only five candidates each year.

May 2009

1. **Dr Joselito Razal** (ACES), received an ARC Early Career Researchers Award, and was one of only six Australian Postdoctoral Fellowship holders in the country selected by the Australian Research Council to participate in a special event held recently at Canberra's *Science at the Shine Dome*. This is an annual three-day event held in Canberra (May 6-8) by the Australian Academy of Science. It provides a unique opportunity for young scientists to hear about the research findings of colleagues across a wide range of disciplines and to mix with Academy Fellows and symposium speakers, as well as their peers and participate in career development workshops.

Joe's APD for 2009 -2011 (DP DP0987503, \$235.8k) was on **Wet-Spinning Novel Multi-Functional Bio-Synthetic Platforms**. The project will deliver new advanced materials for novel biomedical devices such as nanostructured electrodes and tunable drug delivery



Prof Gordon Wallace (left) and Prof Graeme Clark, pictured with Tom Higgins the inaugural Bill Wheeler Scholarship recipient.



Summer Fellowship Award winner Shulei Chou (foreground) pictured with his PhD supervisors (from left) Prof Hua Kun Liu, Prof Shi Xue Dou and Dr Jiazhaio Wang.

systems. It will also develop a very versatile and low-cost technology that is well-suited for overcoming some of the current limitations in exploiting nanomaterials in nanoscience and biomedical industries.

2. UOW Cares Program won the category of Outreach and Community Relations category in the 2008 Association of Commonwealth Universities PR, Marketing and Communications Awards, 15 May. ACES communications and media officer, **Leanne Crouch**, was recognised for her contribution and passion for this novel program.

11 June 2009

Congratulations to **Prof Gordon Wallace and Geoff Spinks** (ACES) who were part of the winning team in this year's annual Trailblazer competition organised by the University of Wollongong. This competition rewards innovative ideas and early-stage research which have the potential to benefit the community, industry or business.

Along with Dr Bridget Munro and Prof Julie Steele from Health and Behavioural Sciences, they won the open section for their project titled "Controlling lymphoedema in an intelligent fashion – lymphoedema

support device for breast cancer patients". Lymphoedema is a substantial problem suffered post-operatively by breast cancer patients. Insufficient lymph flow can lead to swelling of the arm, disfigurement, pain and reduced function. The UOW researchers devised a wearable sleeve that can provide enhanced lymph flow.

Congratulations also goes to ACES researcher **Dr Grant Mathieson** (ACES) who was named runner up in the same category for his project "The Flexalex Cistern." **Dr Philip Whitten** (ACES) was also selected as a finalist in the competition for his entry titled "Novel hydrogel production".

19 June 2009

ACES staff recognised at the University of Wollongong's Staff Awards for Excellence

Research Excellence for Emerging Researcher Award: Recipient **Dr Simon Moulton**. This Award is in recognition of Simon's strong research track record, both nationally and internationally, as well as his leadership role in the Bionics Program within ACES. Simon is also highly respected

both for his ability to grasp challenging multidisciplinary issues, serving as an excellent mentor for younger researchers.

Research Excellence for Senior Researchers Award : Highly Commended **Prof Geoffrey Spinks**. Geoff is one of Australia's pre-eminent materials engineers and has made exceptional research contributions to materials science. Geoff has been the driving force in ACES widely acclaimed actuator (or "artificial muscle") research, which is being successfully applied in areas such as the Cochlear bionic ear implant, an electronic Braille screen, rehabilitation garments and robotics.

Vice Chancellor's Award for Excellence in Community Engagement Highly commended was 'The Welcome to Wollongong Team' of which ACES communications and media officer **Leanne Crouch** was a member. The team were recognised for facilitating better interactions and relationships between international students and the Illawarra Community. Activities conducted as part of the Welcome to Wollongong initiative included a formal civic festival, a mini



Dr Joselito Razal (centre) is pictured at the *Science at the Shine Dome* 2009 with the President of the Australian Academy of Science, Prof Kurt Lambeck, and the CEO of the Australian Research Council, Prof Margaret Sheil.



Pictured at the Trailblazer awards announcement with Professor Judy Raper (Deputy Vice-Chancellor of Research) are the winners.

international festival as well as developing and maintaining a website www.w2w.uow.edu.au.

8 July 2009

Congratulations to **Javad Foroughi**, a PhD student in ACES, who was announced as one of only three young scientists selected to represent Australia at the Asia Nanotech Camp (ANC 2009) held in Taiwan from 28 September to 12 October. Initiated by the Asia Nano Forum, the Asia Nanotech Camps foster young nanotechnology leaders in Asia, and provide a platform for young researchers to communicate and learn from each other.

Congratulations also go to ACES PhD student, **Dillip Kumar Panda**, who was selected to attend the "Chemistry and Physics of Materials for Energetics. This announcement allows Dillip to attend A European School in Materials Science" at the University of Milano-Bicocca in Milano, Italy from 14-19 September. This school will be focused on renewable sources and new materials.

13 July 2009

Success for ACES researcher **Dr Anita Quigley**, who has received the highest recognition at the annual "Research Week" activity hosted by St Vincent's Hospital, Melbourne, which showcases activities occurring within the SVHM Campus. Anita was awarded the Senior Investigator Award in the Scientific Research Category and her abstract, describing the work recently published in *Advanced Materials* on electrical neurostimulation: "Hybrid Biodegradable-Conductive Polymer Platforms for Stimulation of Neural Growth", was selected as the 'Outstanding Abstract' by a panel of senior scientists. Congratulations to Anita and her co-workers of this work from ACES, Joe Razal, Brianna Thompson, Simon Moulton, Magda Kita and Lizzie Kennedy.

15 July 2009

A team involving researchers from ACES has had its paper awarded the Best Conference Paper Prize at the 6th International conference on Informatics in Control, Automation and Robotics held in Milan, Italy. The paper beat out 129 papers to win the title. Congratulations to all those

involved. In addition to being published in the fully refereed conference proceedings, the paper titled 'FROM BENDING TO LINEAR MOVEMENT: A Linear Actuation Mechanism Based on Conducting Polymer Actuators', authored by **Elise Burriss, Gursel Alici, Geoff Spinks, and Scott McGovern**, will appear in a selected papers book to be published by Springer-Verlag.

8 September 2009

Prof Graeme Clark was awarded the Otto Schmitt Award for exceptional contributions to advancements in medical and biological engineering at the opening session of the World Congress on Medical Physics and Biomedical Engineering in Munich, Germany. The award, regarded as one of the world's major scientific prizes, is made every three years by the International Federation for Medical and Biological Engineering which represents research organisations from more than 50 countries.

The award was presented to Prof Clark at the opening session of the World Congress. In his acceptance speech 'The Multi-channel Cochlear Implant- Past, Present and Future', Prof Clark highlighted how the success of the bionic



UOW Vice-Chancellor Gerard Sutton with Research Excellence for Emerging Researcher Award recipient Dr Simon Moulton



UOW Vice-Chancellor Gerard Sutton with Research Excellence for Senior Researchers Award (Highly Commended) recipient Prof Geoffrey Spinks

ear resulted from multi-institutional and wide-ranging interdisciplinary research – in neurophysiology, neurobiology, biophysics, bioengineering, electrical engineering, surgery, psychophysics, speech science, and audiology. He believes the trinity of early diagnosis, hearing aids or cochlear implants, and auditory verbal education will help many more children to achieve their true potential.

September 2009

Professor Maria Forsyth (ACES) received a Vice-Chancellor's Award for Postgraduate Supervision 2009 Commendation from Monash University. The award recognises staff who have demonstrated not only commitment to teaching or research student supervision, but, also innovative and exciting approaches that serve as a model for how research and education can be brought together.

October 2009

A discovery grant (DP 1092610 \$240.5k, APD) was awarded to Dr Orawan Winther-Jensen (ACES) for funding 2010-2012. Her work will centre on **photo-enhanced water oxidation using novel structures and conjugated polymers**. The proposed solar water splitting cell will facilitate an efficient, low-cost and renewable production of hydrogen. Hydrogen is considered to be the ultimate fuel since only water is produced as a product of combustion.

26 November 2009

Matthew Griffith, a PhD student in ACES/IPRI was named as one of 20 postgraduate students in Australia to receive a \$63,500 Australia Asia Endeavour Award. This prestigious Prime Minister's award provides scholarships for the "best and brightest" university students from Australia and Asia to undertake international research in China, India, Indonesia, Japan, Malaysia, Singapore, Republic of Korea, Taiwan, Thailand, or

Vietnam. It is hoped that the awards will build a new generation of leaders with strong ties to Australia and to our region.

Matt will be using the opportunity to develop his research in nanotechnology applied in solar energy at IPRI at his host university in Japan, ShinShu University.

Recipient of an Australia Asia Endeavour Award, Matthew Griffith (centre), is pictured with some of the colleagues from ShinShu University in Japan who will host him so he can develop his research further.

December 2009

To cap off a great year, ACES/IPRI Honors student, **Tom Higgins**, who was this year awarded the inaugural Bill Wheeler Scholarship to support research on nanobionics, was awarded the University of Wollongong University Medal. The medal is awarded for achieving the best academic record in Science in 2009.



Dr Chryssie Heine, Prof Graeme Clark, Rebecca French, and Dr Tony Paolini were delighted to hear of Prof. Clarke's award.



Matthew Griffith received a \$63,500 Australia Asia Endeavour Award



Tom Higgins, the inaugural Bill Wheeler scholarship holder, was awarded the Wollongong University Medal for achieving the best academic record in Science in 2009.

Industry/ End-User Liasion

Key Achievements in 2009

- ▶ Development of the ACES Strategic Plan
- ▶ Establishment of a Director of Commercial Development position
- ▶ Development of a suite of ACES technology brochures
- ▶ Recruitment of a new Chief Operating Officer
- ▶ Creation of a Communications Officer position
- ▶ Redevelopment of the ACES website
- ▶ Development of standard IP management contracts and promotions at UOW for roll-out to other ACES partners in 2010.
- ▶ Funding for the AIIM-PD Facility at UOW.
- ▶ Extended funding for the ANFFL facility at UOW.

ACES Strategic Plan

In mid-2009, a consultant (Perceptic Pty Ltd) was engaged to develop a detailed 3 to 5 year Strategic Plan for ACES, concentrating on fundamental research, commercial research, intellectual property development and management, and commercialisation directions. A plan has been provided for consideration.

The key recommendations of the Strategic Plan will be evaluated by the ACES Executive Committee in early 2010 and

recommendations approved by the Centre Executive will be implemented in 2011.

It is anticipated that implementation will commence with the participation of the key service provider within Perceptic, Mr Chris Gilbey, the Director of Commercial Research and a new role of Business Development Manager.

Establishment of the Director of Commercial Development

In early 2009, two attempts were made to identify a suitable Director of Commercial Development, with advertisements placed in commercial media. Only one applicant was found to have the suitable skills, experience and cultural fit, but unfortunately, pulled out of the process after they had been offered the position. It was then decided that full-time employment of the Director of Commercial Development would be unwise in 2009, given that the Strategic Plan was being developed. It is anticipated that the position will be re-advertised in 2010 so that the key recommendations of the Strategic Plan can be implemented. In addition, NSW State Government funding is currently being sought through the NSW Science Leveraging Fund to support this position.

In the interim, UOW has seconded its Director of Commercial Research/ Executive Officer of Research Development, Dr Troy Coyle, to the role. Key outcomes to date from this secondment include:

- ▶ development of a suite of one-page technology promotion brochures
- ▶ input to the development of the Strategic Plan
- ▶ Development of the IPRI Patent and Patent Application Portfolio, which will be rolled out to other parties in 2010
- ▶ Development of IP management processes and contracts for Visiting Fellows, Visiting Students and Collaborators, which can be rolled out to other parties in 2010
- ▶ Development of standard templates for ACES confidentiality agreements (particularly useful for students involved in ACES presentations) and commercial research subcontracting (to allow UOW to be the lead in negotiations with industry and then subcontract the ACES parties). These documents have been circulated to the other parties and are currently being negotiated. As ACES is not its own entity, all members have to sign individual agreements, so acceptance of a template will speed this process up.
- ▶ Negotiation of two IP licences (still in process), three Collaboration Agreements, five Confidentiality Agreements, one ARC Linkage Agreement and five Fellow Agreements.

Development of a suite of ACES technology brochures

Recognising that there were a range of technologies evolving that require commercial investment and proof-of-concept funding, technology fliers have been developed for the following technologies:

- ▶ Graphene
- ▶ Self- Powered Sensing and Delivery Devices
- ▶ Novel Nano-Carbon Electrodes
- ▶ Printing of Functional Electromaterials
- ▶ Fabrication of Novel Nano-Materials

This initial suite will be built upon in 2010 and already drafts exist for Precious Metal Recovery, Batteries and Solar Cells.

Recruitment of a new Chief Operating Officer

In November 2009, the ACES Chief Operating Officer, Dr Chee Too, retired. Dr Toni Campbell has been appointed as his replacement in this role. Toni has a PhD in Chemistry (2000) from IPRI at the University of Wollongong and has worked as a research fellow in ACES/IPRI since 2001. As Toni progressed through her post doctoral years she participated in developing projects with collaborators as well as designing and completing or supervising the experimental work. A significant number of the projects have involved participation with external collaborators, both national and international.

The focus of her time within IPRI was not restricted to research. For the past 6-7 years she had a principal coordination role in relation to core communications within IPRI and ACES. Toni was the Technical Director of Communications within ACES and advised the Communications Officer on any technical aspects of the research that needed to be presented in the public arena.

Development of the Communications Officer position

The Communications Officer position was developed in January 2009 with the core aim of maintaining communication strategies for ACES in order to raise the profile of the Centre and showcase the ground-breaking research being undertaken. The role includes communicating with end-users and other target audiences, developing promotional material, maintaining the ACES website and quarterly e-newsletter and generating media opportunities.

The ACES Communication Strategy 2009-2012 was developed and implemented mid-year, identifying End-Users as one of five target audience groups along with objectives, strategies and communications tools designed to keep end-users informed, updated and engaged, as well as attract potential partners for collaborative activities and commercial opportunities that will benefit the Centre. Tools included face-to-face meetings, website, brochures, flyers,

newsletters, invitations to presentations and key Centre events and tours of the laboratories. To make it easier for members of ACES, a data collection sheet was developed and distributed.

Feedback on the format and content of the newsletter was sought from the ACES End-Users Committee. It was clear there needed to be a change made to the format, content and distribution of the e-newsletter, including focusing on a particular theme for each edition; simplifying the email version of the newsletter into key points and links to the website, and growing the distribution list.

The ACES Media Strategy implemented during the year resulted in substantial media attention. This included articles in international newspapers, national television reports including the Catalyst Program, Channel 9 National News and SBS National News, national radio segments and website mentions.

In addition, the Communications Office was appointed to the ACES Education & Communications Committee, which initiated several outreach activities during 2009 including targeted communications and visits planned for regional high schools, a new "Bionics for 2020" Competition for high school students, involvement in National Science Week and the National Innovation Showcase and the launch of an interactive exhibition.

Redevelopment of the ACES website

A 'Marketing Communications' Plan was developed as part of the overall ACES Strategic Plan. This Plan takes into consideration current issues faced by ACES including conquering the tyranny of distance between the different ACES nodes; presenting ACES as an authoritative source; building a sales funnel of end-users; qualifying leads; driving tactical public relations activities; and presenting a central brand identity - by leveraging the value of the internet.

ACES will need to enable communication to take place in a way that mirrors the way that individuals are now using the web. It will need to effectively communicate through social networks and use tools that are being used by the future target stakeholders. The market is not the ACES peer group of scientists but includes businessmen, journalists, investors, public servants and students.

Development of standard IP management contracts and promotions at UOW for roll-out to other ACES partners in 2010.

The Director of Commercial Development has conducted an audit of IPRI Intellectual property and developed a promotional brochure outlining all available patents and patent applications of potential interest to end-users (Appendix 3). In 2010, a similar review will be undertaken of the other partners. These documents are intended to be publicly available and so are written in a way that protects confidential information, while still allowing anticipated partners to review the IP.

A suite of template agreements has been developed for Visiting Fellows and Visiting Students with varying scenarios based on who owns the IP that they develop initially (the Fellow/Student or their Employer/Institute). These will be provided to other partners for use in their own institutions.

Finally, a standard confidentiality and sub-contracting agreement has been developed to ensure smooth negotiations for projects where all partners must sign off on contracts. It is intended that these also become attachments to the new Centre Agreement.

Funding for the AIIM-P&D Facility at UOW

In 2009, funding was obtained via the Education Investment Fund to develop the \$50 million "Australian Institute for Innovative Materials (AIIM) -- Processing and Devices" Facility (AIIM P&D). This new building will be developed alongside the existing Australian Institute for Innovative Materials (AIIM Building) at UOW's Innovation Campus. This facility will significantly assist ACES IP to progress to commercial development. Already, UOW has hosted several forums and meetings with various end-users, including a specific forum with Korean partners. The concept of the new AIIM P&D facility is that it will enable projects to extend through proof-of-concept and device development stage and partners could either invest through secondment of people to the facility, funding research projects or jointly developing specialised materials processing capabilities.

Management Arrangements

The Governance/Organisation Chart for ACES is shown below (Chart 1).

The Centre Executive (Table 1) met 8 times in 2009 to review the progress of the Centre as well as the procedures used to facilitate the dissemination of research findings and to maximise the use of skills within the Centre and externally.

The International Advisory Board (IAB) (Table 1) met on 4 February 2009. The board provided valuable advice on scientific and commercial opportunities relevant to the Centre, as well as monitoring the Centre's progress. Members of the IAB also provided regular comment and guidance to the Director.

The End-Users Committee (EUC) (Table 1) provided advice on strategies used to engage End-Users and identified new collaborative opportunities. Anita Hill (CSIRO) joined the EUC in 2009. The EUC met twice in 2009.

The Education Committee (Table 1) initiates and implements strategies to attract and engage high calibre research students. Chaired by Professor Will Price, it met regularly during 2009.

Director Commercial Development (Table 1): In 2009 UOW has seconded its Director of Commercial Research/ Executive Officer of Research Development, Dr Troy Coyle, to the role.

Staff of ACES: A list of current staff and affiliations are provided in Appendix 4.

ACES Students: In 2009, 9 new PhD students were recruited to the centre, with 6 PhD completions. A complete list of students and graduates is provided in Appendix 5.

The Intellectual Property Register is provided in Appendix 3.



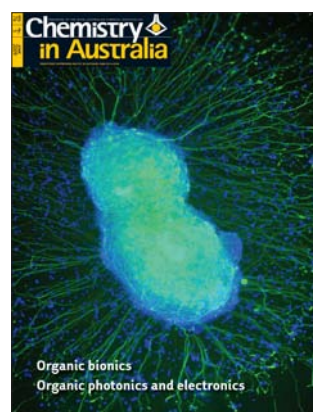
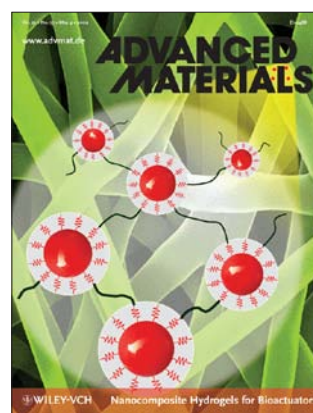
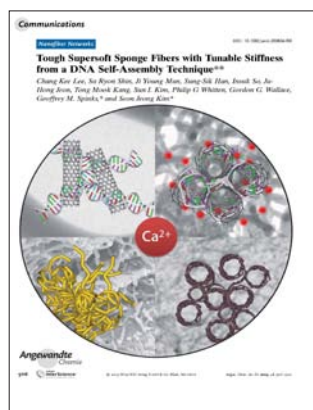
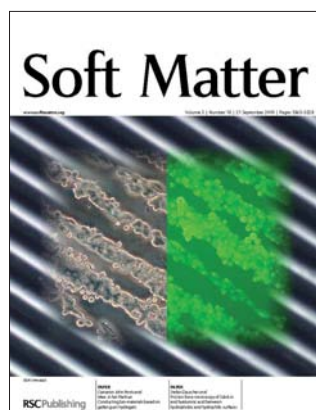
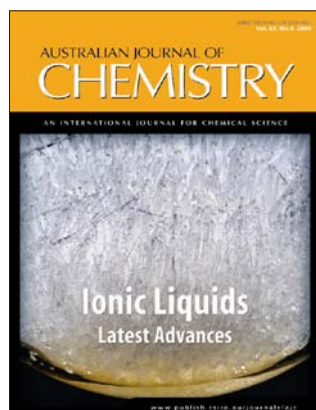
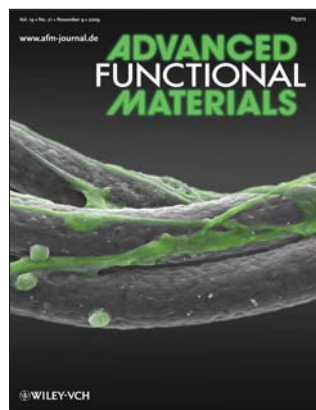
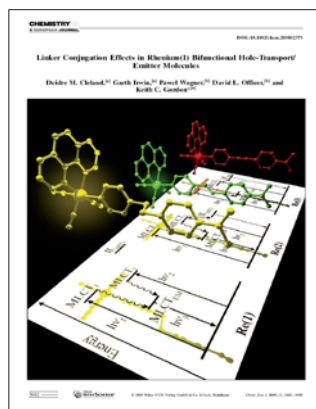
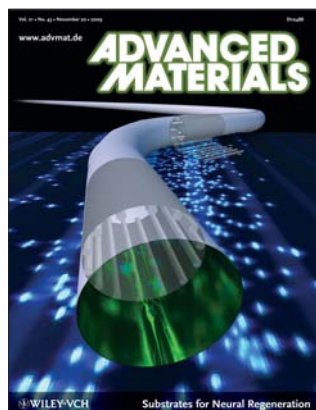
Chart 1. ACES Governance/Organisation Chart

Table 1: Members of ACES Management		
Centre Executive	International Advisory Board	End-Users Committee
Executive Director: Prof. G. Wallace	Dr (Dame) Bridget Ogilvie (Chair, AC, DBE, FAA, FRS, FMedSci)	G. Smith (Chair, SciVentures)
Associate Director: Prof. M. Forsyth	Prof. R. Baughman (University of Texas at Dallas)	P. Aitchison (Cap-XX)
Selected Senior Researchers: Prof. L. Kane-Maguire Prof. D. MacFarlane Prof. G. Clark Prof. D. Officer A/Prof. R. Kapsa Prof. G. Spinks Prof. S. Dodds	Prof. R. Kaner (University of California)	E. Evans (BlueScope Steel)
Chief Operating Officer: A/Prof. C. Too (Jan - Sept) Dr T. Campbell (Oct - Dec)	Prof. K. Kaneto (Kyushu Institute of Technology, Japan)	A. Hill (CSIRO)
Business Development Officer: Director Commercial Development Dr Troy Coyle (UOW)	Prof. Thomas W.H. Kay (St Vincent's Hospital, Melb.)	P. Murphy (IWRI, UNISA)
Communications Officer: Leanne Crouch	Dr. A. Khan (Monash University)	J. Nicholson (Visiocorp)
Education Director: Prof. W. Price	Dr. A. Mau (CSIRO)	J. Patrick (Cochlear)
Early Career Researchers Representative: Dr A. Mozer	Prof. N. Ogata (Chitose Institute of Science and Technology, Japan)	R. Shaw (Rio Tinto)
	Prof. J. Raper (DVC Research, UOW)	T. Truong (DSTO)
	Prof. S. Roth (Max Planck Institute, Stuttgart)	
	Dr. I. Sare (DSTO)	Education Committee
	Dr. G. Smith (SciVentures)	Prof. W. Price (Chair)
		Dr T. Campbell (UOW)
		Ms. L. Crouch (UOW)
		Dr A. Minett (UOW)
		Dr J. Pringle (Monash)
		Ms S. Shekibi (Monash)

2009 ACES Publications

The target for 2009 was 50 publications with 50% of journal articles in journals with an impact factor greater than 2. The Centre has exceeded this target, publishing 98 refereed publications. Of the 98 journal articles 68 (69%) were published in journals with an impact factor greater than 2 and 37 (38%) in journals with an impact factor greater than 4.

In addition ACES research has graced the covers of 11 journals in 2009.



Book Chapters

Conjugated Polymer Actuators: Fundamentals Spinks, G.M., Alici, G., McGovern, S., Xi, B., Wallace, G.G. Biomedical Applications of Electroactive Polymer Actuators Edited by Federico Carpi, Elisabeth Smela, Wiley, Great Britain (2009), 195-228.

Actuated Pins for Braille Displays Spinks, G.M., Wallace, G.G. Biomedical Applications of Electroactive Polymer Actuators Edited by Federico Carpi, Elisabeth Smela, Wiley, Great Britain (2009), 265-278.

Journals

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Performance Indicators

The Key Result Areas and Performance Measures Schedule for the Centre are given below. In general the performance of the Centre has exceeded our targets. In particular, there were 98 refereed publications of which 68 (69%) had an impact factor greater than 2 (37 had an impact factor greater than 4), 9 postgraduate students were recruited, 6 postgraduate completions, 4 international workshops, 4 ACES in house workshops, 6 national workshops, 39 invitations to present at international conferences, 54 visits to leading international laboratories, 101 media interest stories published, 92 international visitors, 2 patents lodged, and 8 new organisations recruited to collaborate with the Centre.

Key Result Areas and Performance Measures

Key Result Area: Research findings			
Performance Measure	Target	2008 Outcome	2009 Outcome
Quality of publications	At least 50% of journal articles in journals with impact factor >2	Impact factor >2: 74 (79%) Impact factor >4: 34 (36%)	Impact factor >2: 68 (69%) Impact factor >4: 37 (38%)
Number of publications	2006 - 30 2007 - 35 2008 - 40 2009 - 45 2010 - 50	93	98
Number of provisional patents lodged	2 per annum	4	2
Invitations to address and participate in international conferences	6 per annum	39	39
Invitations to visit leading international laboratories	6 per annum	60	54
Number and nature of commentaries about the Centre's achievements	Print, radio, TV media, 1 per annum	30 print, 807 website, 28 radio, and 12 TV	101 media interest stories published: 41 articles in print, 34 articles online/web, 16 radio interviews and 10 TV appearances.
Key Result Area: International, national and regional links and networks			
Performance Measure	Target	2008 Outcome	2009 Outcome
Number of international visitors	4 per annum	93	92
Number of national and international workshops	1 per annum	4	ACES hosted or co-hosted: 4 international workshops; 4 in house workshops; 6 national workshops.
Number of visits to overseas laboratories	6 per annum	60	54

Key Result Area: Research training and professional education			
Performance Measure	Target	2008 Outcome	2009 Outcome
Number of postgraduates recruited	20 over 5 years	13	9
Number of postgraduate completions	4 per annum	8	6
Number of Honours students	-	7	2
			8
Number of professional courses	1 per annum	4	First aid course, Hydrofluoric Acid Safety Training, Graduate Certificate in Business Administration, EDS analysis, High Resolution SEM, Research Information System (RIS) training, OH&S Representatives, Managers and Supervisors Training course (5 days); Future Research Leadership course (2 year course)
			32
			2 : First aid course
			1 : Hydrofluoric Acid Safety Training
			1 : Graduate Certificate in Business Admin
			1 : EDS analysis
		3	1 : High Resolution SEM
Participation in professional courses	-		2 : OH&S Representatives, Managers and Supervisors Training course
			1 : Future Research Leadership course
			23 : Research Information System (RIS) training
Number and level of undergraduate and high school courses	Undergraduate: 1 per annum. Honours: 1 per annum from 2007. Schools: 1 per annum.	University of Wollongong's Bachelor of Nanotechnology	Undergraduate course: 1 University of Wollongong's Bachelor of Nanotechnology Honours students: 2 School/public: iDome exhibit launched at Wollongong Science Centre; Bionics 2020 competition for schools.
Key Result Area: End-user links			
Performance Measure	Target	2008 Outcome	2009 Outcome
Number & nature of commercialisation activities: Licences, assignments or options.	1 per annum		1 licence
			12
Number of government, industry and business briefings	2 per annum	1	2 forums (Korean, National); 1 Govt briefing Innovation, Industry and Regional Development (DIIRD, Victoria) for a submission to their Victoria's Science Agenda (VSA) Program; 9 industry briefings: Cochlear Ltd Sydney, Bosch, Konarka Technologies, Sekisui (Japan), KITE, Aqua Diagnostics, ANFFL, Millipore, Chemicon Australia. 35
			enduser groups hosted at ACES in 2009 participating in research discussions (see visitor list appendix 1)

Number of Centre associates trained/ing in technology transfer and commercialisation	2 per annum	6	<p>50 staff/student attended (i) IP protection and commercialisation workshop (ii) C2C2C lecture series (x 4 lectures)</p> <p>1 staff/1 student attended Unique Quest Commercialisation training scheme 2-3 April;</p> <p>2 PhD students completed Graduate Certificate in Commercialising Research</p> <p>Total of 18 events (PLUS 41 articles in print, 34 articles online/web, 16 radio interviews and 10 TV appearances). Official opening AIM building Innovation Campus; presented at the Bernard O'Brien Institute for Microsurgery, Melbourne; hosted 2 artists in residence School of Art & Design, UOW; Lion's Australia; Step Ahead Australia Spinal Cord Fellowship Presentation at the Melbourne Exhibition Centre; ACES/IPRI large role in the Illawarra Innovation Showcase which is part of the National Innovation Festival: Community Tours of the ACES/IPRI; Launch of the "Bionics for 2020" high school competition; presence at the Illawarra Innovation Showcase Expo; presented in the Expo public Seminar Presentation Series; iDome in the Innovation Week Public Lecture; hosted 8 undergraduate students undertaking the Advanced Science program at the University of Western Sydney; DVD launch, lab demo & lab tour for local businesses and science teachers from local high schools; DIIRD focus group facilitated by ACES on subject of bionics;</p> <p>hosted 50 Careers Advisors from High Schools Illawarra and Sutherland shires; Masterclass for the University of Melbourne International Advanced Medical Science class (35 Universitas Indonesia, 10 Uni Melb students); hosted 2 Illawarra Grammar School (TIGS) students for 2 days; presented at Future Materials forum (a research institution-based network); delivered The Libby Harricks Memorial Oration 2009; presented at the Green Jobs Illawarra Renewable Energy Forum; presented public lecture Science week, official launch iDome; presented to the Southern Highlands & Tablelands Regional Group of Engineers Australia- Sydney Division; presented to University of the Third Age (U3A); presented to October Wollongong Innovation Campus Networking Function.</p>
Number and nature of Public Awareness programs	1 per annum		<p>Total of 11:</p> <p>2 Inner Wheel Rotary,</p> <p>2 Lions, UOW Research Strength Showcase Series, NSW Government Inquiry into Nanotechnology in NSW, Inaugural ARC Graeme Clark Research Outcomes Forum, Public Plenary lecture at inaugural Asia-Pacific Symposium on Nano bionics, Opening of UOW Innovation Campus, UOW showcase of Innovation Campus at the Illawarra Business Chamber's September Business After Hours function, ABC TV Catalyst program.</p>

Organisational support									
Annual cash contributions from Collaborating Institutions/Organisations	UOW	UOW	UOW	UOW	UOW	UOW	UOW	UOW	UOW
	\$712.6K indicative p.a.	\$310,000	\$437,161	\$746,986	\$882,395	\$729,154	Monash	Monash	Monash
	Monash	Monash	Monash	Monash	Monash	Monash	Monash	Monash	Monash
	\$257K indicative p.a.	\$5,000	\$258,000	\$278,430	\$278,412	\$287,000	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development
	BEI	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development
Annual in-kind contributions from Collaborating Institutions/Organisations	\$0	\$48,984	\$48,984	\$48,984	\$48,984	\$48,984	\$48,984	\$48,984	\$48,984
	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM
	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development
	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007	\$48,984 p.a. until 2007
Annual in-kind contributions from Collaborating Institutions/Organisations	Years 1 to 5:	UOW	UOW	UOW	UOW	UOW	UOW	UOW	UOW
	UOW	\$3,835,129	\$526,718	\$692,111	\$724,689	\$755,084	\$782,616	Monash	Monash
	Monash	\$1,093,753	Monash	Monash	Monash	Monash	Monash	Monash	Monash
	\$1,120,223	\$1,146,511	\$252,878	\$461,566	\$489,260	\$826,106	\$876,137	BEI	BEI
	\$1,173,048	BEI	\$62,005	BEI	BEI	BEI	BEI	BEI	BEI
Annual in-kind contributions from Collaborating Institutions/Organisations	Monash	\$569,424	\$557,804	\$505,737	\$486,424	\$486,424	\$255,212	SVHM	SVHM
	\$683,869	\$598,411	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM
	\$613,051	\$627,791	\$618,198	\$539,024	\$549,707	\$549,707	\$475,968	\$475,968	\$475,968
	BEI	BEI	BEI	BEI	BEI	BEI	BEI	BEI	BEI
	\$596,751	\$487,451	\$596,751	\$487,451	\$596,751	\$487,451	\$596,751	\$487,451	\$596,751
Annual in-kind contributions from Collaborating Institutions/Organisations	\$612,739	\$539,391	\$612,739	\$539,391	\$612,739	\$539,391	\$612,739	\$539,391	\$612,739
	\$567,477	\$567,477	\$567,477	\$567,477	\$567,477	\$567,477	\$567,477	\$567,477	\$567,477
	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM	SVHM
	\$553,812	\$570,426	\$553,812	\$570,426	\$553,812	\$570,426	\$553,812	\$570,426	\$553,812
	\$687,539	\$482,138	\$687,539	\$482,138	\$687,539	\$482,138	\$687,539	\$482,138	\$687,539
Annual in-kind contributions from Collaborating Institutions/Organisations	\$498,612	\$498,612	\$498,612	\$498,612	\$498,612	\$498,612	\$498,612	\$498,612	\$498,612
	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development	NSW Dept of State & Regional Development
	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years	3 over 5 years
	Number of new Organisations recruited to or involved in the Centre	7 recruited: Cap-XX, Schefenacker, CRC Polymers, DLG Battery (Shanghai) Ltd, Guangzhou Delong Energy Tech Ltd (China), CSIRO cluster, DSTO.	7 recruited: Cap-XX, Schefenacker, CRC Polymers, DLG Battery (Shanghai) Ltd, Guangzhou Delong Energy Tech Ltd (China), CSIRO cluster, DSTO.	7 recruited: Bionic Technologies Australia, Australian Pipeline Industry Association, Organic Solar Cell Research, DSTO, CSIRO-Minerals, BlueScope Steel, The Hearing CRC.	5 recruited: CSIRO-Energy Technology, The University of Melbourne, La Trobe University, Shinshu University (Japan), Kangnung University (Korea).	5 recruited: CSIRO-Energy Technology, The University of Melbourne, La Trobe University, Shinshu University (Japan), Kangnung University (Korea).	5 recruited: CSIRO-Energy Technology, The University of Melbourne, La Trobe University, Shinshu University (Japan), Kangnung University (Korea).	5 recruited: CSIRO-Energy Technology, The University of Melbourne, La Trobe University, Shinshu University (Japan), Kangnung University (Korea).	5 recruited: CSIRO-Energy Technology, The University of Melbourne, La Trobe University, Shinshu University (Japan), Kangnung University (Korea).
Level and quality of infrastructure provided to the Centre	Level and quality of infrastructure provided to the Centre	High	High	High	High	High	High	High	High
	Annual cash contributions from other Organisations	-	-	-	-	-	-	-	-
	Annual in-kind contributions from other Organisations	-	-	-	-	-	-	-	-
	Annual in-kind contributions from other Organisations	-	-	-	-	-	-	-	-
	Annual in-kind contributions from other Organisations	-	-	-	-	-	-	-	-

Governance				
Breadth and experience of the members of the Advisory Board	Extensive	Considerable	11 Board members	12 Board members
Frequency and effectiveness of Advisory Board meetings	1 per annum. Minutes will be provided.		1 meeting held.	1 meeting held.
Quality of the Centre strategic plan	Evaluated by IAB			See IAB report
Effectiveness of arrangements to manage Centre nodes	Centre Exec to meet 4 times per annum		6 meetings held	7 meetings held
The adequacy of the Centre's Key Performance Measures	Evaluated by IAB		See IAB report	See IAB report
National benefit				
Measures of expansion of Australia's capability in the priority area(s)	International Visitors : 20 International Exchange Visits : 10. International Joint Publications : 10.		International Visitors : 73 International Exchange Visits : 3. International Joint Publications : 15.	International Visitors : 92 International Joint Publications : 40
Case studies of economic, social, cultural environmental or other benefits	1			1. 'Bionics' focus group facilitated by Susan Dodds (ACES) and Gordon Wallace (ACES) 'expert' to answer questions (event was a collaborative activity DIISR and ACES). Aim was was to gain a better understanding of the publics' knowledge, concerns and aspirations towards biotechnology and nanotechnology (in particular, applications of these technologies). 2. Gordon Wallace contributed to The Australian Academy of Science "Nanotechnology in Australia: trends, applications and collaborative opportunities" report, published Dec 2009.

- The ARC recommends that a sum of money of the order of 5% of the annual ARC Centre funding should be spent each year on Centre community awareness programs, possibly including:
- ▲ professional and technical training;
 - ▲ primary and secondary school awareness;
 - ▲ "front-office" service for, and interaction with, Australians end-users; and
 - ▲ workshops, international visitor programs and other networking activities that engage cognate Australian researchers who might not be formally associated with the Centre.

Activity Report 2009

Research programs

The core experimental activities of ACES in 2009 were focused on the Year 4 and year 5 milestones and summaries of these activities are given below. Activity reports from previous years are available on request or can be found in the Annual Reports for 2007 and 2008.

P1 Electromaterials

P1-1 Synthesis and Processing

MILESTONE 5

Supply of new materials to P2 –P4

The key material types that continue to be supplied to other ACES programs are porphyrins for solar cell dyes and electrocatalysts (P2); functionalised thiophene and terthiophene monomers and polymers for batteries, capacitors, electrochromic devices (P3) and bionics

(P4); and graphenes for solar cells (P2), batteries (P3), capacitors (P3) and bionics (P4).

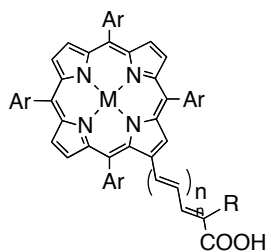
P2 – Energy Conversion: An increasingly large range of porphyrins **1-3** continue to be made for use in solar cells. In addition, bisEDOT and graphene papers were supplied for use in solid state dye-sensitised solar cells (DSSCs). A number of cobalt porphyrins of the type **2** and **3** have also been supplied and investigated for use as electrocatalysts within ACES. Graphene is also under investigation as an electrode material for liquid DSSCs and has been supplied to both our national and international collaborators.

P3 – Energy Storage: The development of a number of processible polythiophenes has opened up opportunities in the battery, capacitor and electrochromics areas. Functionalised polythiophenes such as **4-6** have been produced in large amounts.

P4 – Bionics: Polythiophenes continue to be investigated as platforms for both nerve and muscle cell growth, and researchers in the P4 area are utilising polythiophenes such as **4** and **5** for these activities.

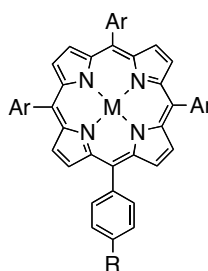
Soluble photochromic polymers based on **5**, where the R group is a spiropyran ester (see polyTThSP1 in the Activity Highlights section), have been synthesised in collaboration with Prof. Dermot Diamond at Dublin City University. The exciting potential of these multifunctional polythiophenes as switchable chemosensors is under investigation.

Since the development within ACES of soluble chemically converted graphene (CCG) in 2007, there have been a number of innovations related to graphene. The graphene synthesis has been scaled up to 20 litres (10 grams), a new route to graphene electrodes has been developed, organic solvent graphene dispersions have been developed, and a range of functionalised graphenes with alkyl, ferrocenyl and porphyrinyl functionalities have been synthesised. The use of these



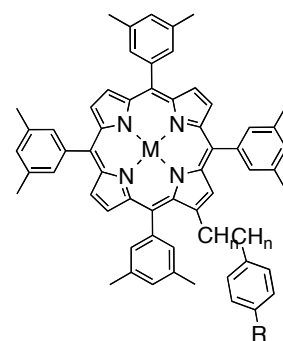
Ar = phenyl, ethylphenyl, octylphenyl, mesityl, tolyl or xylyl
n = 0 or 1
R = CN or CO₂H
M = H₂ or Zn

1



Ar = mesityl, tolyl or phenyl
Ar' = mesityl, tolyl, phenyl, thiophenyl, benzthiophenyl, ferrocenyl, diphenylaminophenyl or styrylporphyrin.
R = H, CO₂H, CHCHCNCO₂H or CHCH(CO₂H)₂
M = H₂, Zn or Co

2



M = H₂, Zn, Co or Ni
n = 1 or 2
R = CO₂H or PO₃H

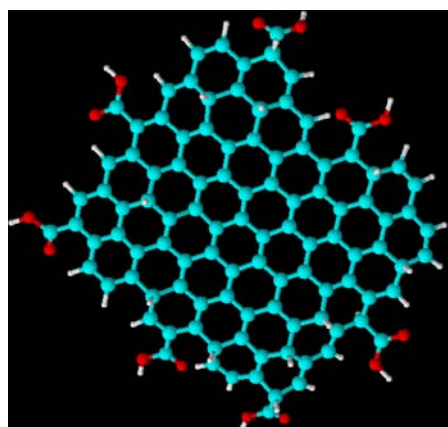
3

unique graphene materials is under investigation in a variety of applications including batteries (both as neat graphene and in TiO_2 composites) and in layer-by-layer composites for electrodes.

MILESTONE 9

Preparation of functionalised inorganic nanoparticles and nanofibres for P2 and P3.

Work on the synthesis and characterization of families of alkylimidazolium, alkylpyrrolidinium, alkylpiperidinium and alkylphosphonium imidazoliumsiloxyl iodides, and their application as iodide sources in DSSC electrolytes, has continued as part of a collaboration with Prof. Michael Graetzel (EPFL). This has led to a number of publications (see below). Our efforts have concentrated on the parent siloxyl iodides as there is a clear correlation between DSSC performance and the structure of the siloxyl iodide.



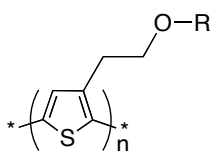
Functional electrolytes

Building on our earlier ACES work published in *Advanced Functional Materials*, which detailed the application of alkylammonium functionalised SiO_2 nanoparticles as DSSC electrolytes, SiO_2 nanoparticles (400 nm) were successfully functionalised (10 mol% loading) with siloxane compounds containing pyrrolidinium iodides. These compounds were tested as iodide sources in DSSCs. Devices constructed using these nanoparticles as the sole iodide source in the absence of solvent failed to produce devices with significant efficiencies. However, when using methoxypropionitrile solvent and 0.25 M iodide concentration (calculated based on 10 mol% loading), devices with appreciable, albeit, low efficiencies (ca. 3%) were able to be constructed.

Publications

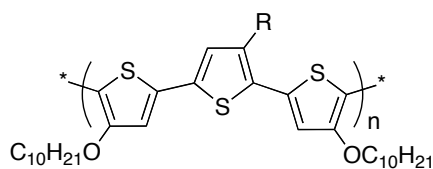
1. Novel nano-structured silica-based electrolytes containing quaternary ammonium iodide moieties S. A. Cerneaux, S. M. Zakeeruddin, J. M. Pringle, Y.-B. Cheng, M. Grätzel and L. Spiccia, *Adv. Funct. Mater.*, **2007**, *17*, 3200-3206.
2. New functional triethoxysilanes as iodide sources for Dye-Sensitized Solar Cells. S. A. Cerneaux, S. M. Zakeeruddin, M. Grätzel, Y.-B. Cheng and L. Spiccia, *J. Photochem. Photobiol. A: Chemistry*, **2008**, *198*, 186-191.
3. Alkylpyrrolidiniumtrialkoxysilyl iodides as organic iodide sources for Dye-Sensitized Solar Cells. N. A. Lewcenko, M. J. Byrnes, Y.-B. Cheng, S. M. Zakeeruddin, M. Grätzel and L. Spiccia, *Chem. Commun.*, **2008**, 3852-3854.
4. A new family of substituted triethoxysilyl iodides as organic iodide sources for dye-sensitized solar cells. N. A. Lewcenko, M. J. Byrnes, T. Daeneke, M Wang, S. M. Zakeeruddin, M. Grätzel and L. Spiccia, submitted to *J. Mater. Chem.*

A possible structure of chemically converted graphene (CCG)



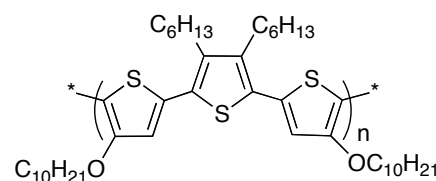
$\text{R} = \text{H}, \text{COC}_7\text{H}_{15} \text{ or } \text{CH}_2\text{CH}_2\text{SO}_3^-$

4



$\text{R} = \text{CO}_2\text{H}, \text{CO}_2\text{CH}_3 \text{ or } \text{CH}_2\text{CO}_2\text{H}$

5



6

MILESTONE 12

Prepare functionalised aligned CNTs for P2 and P3. Prepare aligned carbon nanotube samples for:

- ▶ **Energy conversion:** Aligned CNT-polythiophenes composite solar cells
- ▶ **Energy storage:** Aligned CNT PEDOT composites for batteries
- ▶ **Bionics:** Aligned CNT-biopolymer composites for cell stimulation.

Aligned CNT structures were supplied to the Bionics program for *in vivo* safety studies.

MILESTONE 14

Supply of fabricated structures to P2-P4 (End Year 2, then on-going).

Carbon nanoweb structures were supplied for studies in energy storage. Wet spun fibres were supplied for studies in energy storage and bionics.

MILESTONE 19

Supply/refinement of electrolytes for P2-P4 (End Year 2, then on-going).

For P2 requirements, see milestones 27 and 32. For P3 requirements, see milestone 36.

P4 requirements were associated with producing biocompatible electrolytes for bio batteries.

P1-2 Characterisation

MILESTONE 21

Dr Peter Innis (QEI Fellow) will coordinate and educate on the use of conventional characterisation tools such as SEM, AFM, NMR, UV-vis and electrochemical methods, as well as specialist in-situ techniques such as Electrochemical-Electronspin Resonance, Electrochemical-Raman and Localised Electrochemical Impedance Spectroscopy (on-going).

Additional characterisation capabilities have been acquired via our participation in the NCRIS-funded Materials Node of the Australian National Fabrication Facility. In 2009 this capability has been further expanded through winning a further \$3.9M in equipment funding, expanding our capabilities in the area of synthesis and supply of advanced organic materials for application in areas such as polymer electronics, OLEDs and organic photovoltaics. Other activities include providing expertise via consultancies in the area of materials synthesis, processing and characterisation. Details on these capabilities can be found at the following links;

- ▶ www.electromaterials.edu.au/resources/AIIMP&D.html
- ▶ www.electromaterials.edu.au/Resources/anff.html
- ▶ http://anff.org.au/page/materials_node.html

The characterisation tools based within the ACES network have critically underpinned the research publication outputs of the Centre.

MILESTONE 22

Utilisation of novel characterisation tools in P1-P4 (on-going).

Wollongong Node

During 2009 a number of educational workshops were organised by ACES to educate its members and the broader scientific community. These educational characterisation activities include:

- ▶ BIO-Atomic Force Microscopy Training Workshop, Wollongong, 28 August 2009
- ▶ ACES In-House Workshop on Fabrication and Characterisation of Batteries and Supercapacitors, 25 June 2009
- ▶ Full ACES Centre Meeting at Innovation Campus, 3 February 2009 – Characterisation tools
- ▶ Electrochemistry week, ACES/IPRI, UOW, 9-12 February 2009. (Electrochemistry theory and background and advanced techniques)

Additional educational resources on these capabilities have been made available on the ACES website, see:

- ▶ www.electromaterials.edu.au/resources/educationalindex.html

Monash Node

- ▶ A microcell electrochemical technique has been developed for assessing the effectiveness of coatings on Mg alloys. The technique allows rapid characterization of the coating resistance and multiple measurements for a single coating to reduce scatter.
- ▶ Synchrotron based techniques are being developed for the characterization of interphase materials on reactive metal surfaces. Currently, two proposals for beam-time are being assessed – 'Enabling electrolyte design for Mg-Air batteries using in-situ synchrotron x-ray diffraction analysis of the salt film on the Mg anode' & 'Chemistry

and structure of ionic liquids and their interfacial characteristics as effective coatings'. Both of these projects require extensive student involvement. PhD students Julie-Anne Hill, Ji Lin, Wayne Neil, Tim Khoo & Anthony Somers are all actively involved in the planning and implementation of these studies.

- 'In-situ neutron diffraction studies of Mg anodes for use in Mg/air batteries' will be initiated with access to the Echidna and Wombat beamlines at ANSTO. This work is intended to provide complementary information to the Synchrotron experiments.

MILESTONE 23

Characterisation of reactive metal interfaces to develop understanding of interfacial phenomena at electromaterials interfaces and in applications including corrosion, electrowinning and energy storage and conversion (on-going).

A range of light metal alloy and ionic liquid (IL) coated alloy surfaces have been investigated using XPS, ToF-SIMS and MAS solid-state NMR. These measurements are contributing to our understanding of the IL – metal surface interactions.

A similar range of surfaces was investigated using XPS and NEXAFS on the soft x-ray beamline at the Australian Synchrotron. The surfaces of an appropriate range of ILs were also investigated so that they could be employed as reference standards to inform the analysis of the IL-coated surfaces.

The more sensitive synchrotron data revealed an absence of the P=O bond on the surface which is present in the IL anion. This indicates a possible metal ester process as previously proposed.

A proof-of-concept study of the speciation of ions/solvent at a reactive metal anode immersed in an electrolyte medium visualized by NMR imaging via collaboration with Dr Melanie Britton and Dr. Alison Birmingham (University of Birmingham) has shown that this technique will be useful in studying the anode/electrolyte interfaces in metal/air batteries (*Electrochemistry Communications* accepted Oct 2009).

MILESTONE 25

Integrate advanced characterisation and theory for material development (End Year 4).

Modelling of chemical processes at the interface has not yet commenced however the new information provided through the advanced characterization successfully undertaken this year will contribute to and be integrated into future modelling.

P2 Energy Conversion

P2-1 Solar energy Conversion

MILESTONE 27

Develop nanostructured solid state solar cells with >4% efficiency.

A significant number of key developments were made in the area of dye-sensitised solar cells (DSSC). A monolithic all-solid state DSSC giving 3.65% efficiency was achieved (**Appl. Phys. Lett.** 2009), approaching the Centre milestone of 4% for such a device. However, a 4.2% efficient flexible polymer-based DSSC was attained using ball milling to create mechanically stable TiO_2 films on polymer electrodes (**J. Photochem. Photobiol. A: Chem.** 2009). The integration of two developments within ACES, the formation of highly conductive PEDOT and a PEDOT-based solid state DSSC, led to the invention of the Goretex-PEDOT membrane electrodes (**Langmuir** 2009).

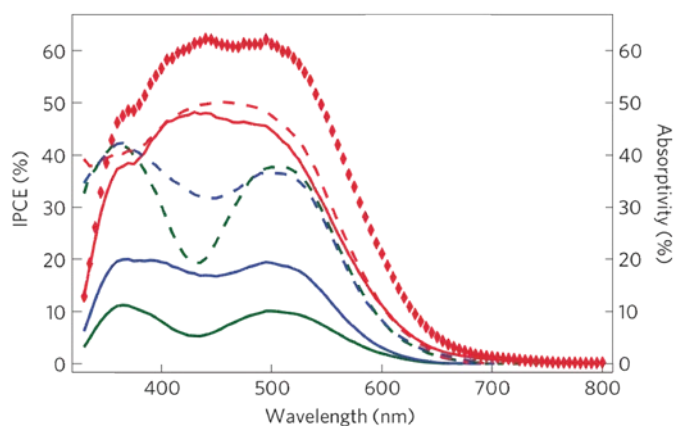
All of these achievements pave the way for the future development of low cost flexible DSSCs. In this regard, the development of the first high efficiency porphyrin-sensitised solar cell incorporating an ionic liquid eutectic mixture (submitted to **Chem. Commun.**) and a solid-state dye-sensitized solar cell based on spiro-OMeTAD and the ruthenium dye Z907 was fabricated that yielded an energy conversion efficiency of 4.38 % at full sun illumination (simulated AM1.5, 100 W/m²).

Equally significant was the publication of the first example of charge injection into TiO_2 in a DSSC from both the porphyrins in a porphyrin dimer (**J. Am. Chem. Soc.** 2009). Other highlights include the development with international collaborators, in Korea and Switzerland, of high molar extinction coefficient ruthenium dyes (**J. Phys. Chem. C.** 2009), the use of phosphinic acids to increase the efficiency of porphyrin-sensitised solar cells (**Energy Environ. Sci.** 2009), and a US patent application on dye mixtures for use in photoelectric materials (**US Prov. Patent Appl.** 60/202,164).

MILESTONE 28

Development of nanostructured photocathodes for integration into tandem solar cells.

High efficiency DSSCs typically operate as photoanodes (n-DSSCs), where photocurrents result from dye-sensitised electron injection into n-type semiconductors. Dye-sensitised photocathodes (p-DSSCs) operate in an inverse mode, where dye-excitation is followed by rapid electron transfer from a p-type semiconductor to the dye (dye-sensitised hole injection). Such p-DSSCs and n-DSSCs can be combined to construct tandem solar cells (pn-DSSCs)³ with a theoretical efficiency limitation well beyond that of single junction DSSCs⁴. Nevertheless, the efficiencies of such tandem pn-DSSCs have so far been hampered by the poor performance of the available p-DSSCs.



The IPCE (Incident photon to electron conversion efficiency) spectra of p-DSSCs assembled from mesoporous NiO electrodes (solid lines), sensitised with 3 different sensitisers: dyes 1 (green), 2 (blue) and 3 (red) as well as the percentage of incident photons that are absorbed by the dye inside the p-DSSC (absorptivity, dashed lines). The red diamonds indicate the IPCE of a mesoporous 2.3-μm-thick NiO electrode sensitised with 3.

We have now shown that p-DSSCs can convert absorbed photons to electrons with yields of up to 96 %, resulting in a seven-fold increase in energy conversion efficiency compared to previously reported photocathodes. A new class of donor-acceptor dyes, available through a collaboration with the University of Ulm was studied as photocathodic sensitizers, comprising a variable-length oligothiophene bridge which provides control over the spatial separation of the photogenerated charge carriers. As a result, charge recombination is decelerated by several orders of magnitude and tandem pn-DSSCs can be constructed that exceed the efficiency of their individual components (**Nature Materials**, 2009, online publication: 29.11.2009). The highest energy conversion achievable with a photocathodic DSSC was 0.41 %.

P3 Energy Storage

P3-1 All Solid State Thin Film Lithium-Ion Microbatteries

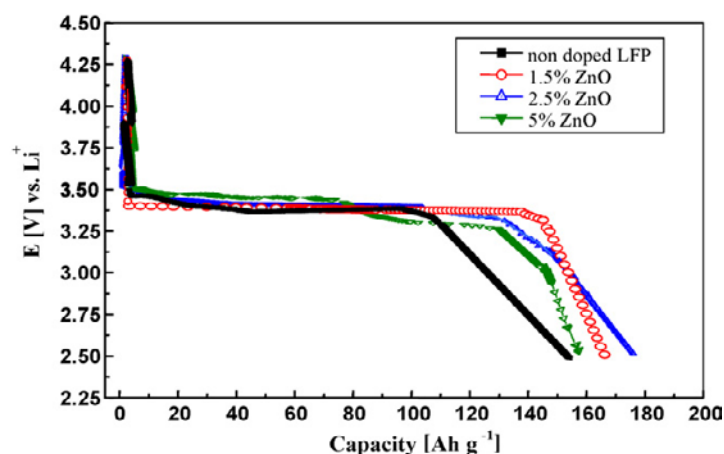
MILESTONE 38

Develop chemically stable and structurally stable thin film cathodes.

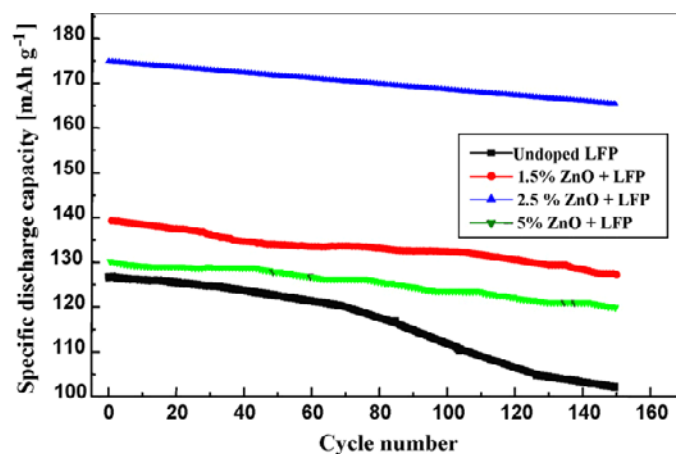
(1) The effects of zinc oxide doping on LiFePO_4 have been studied by X-ray diffraction (XRD), scanning electron microscopy (SEM), electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and galvanostatic measurements. The XRD patterns demonstrate that the samples have the phase of LiFePO_4 with an ordered olivine structure indexed to the orthorhombic *Pmna* space group. Also, XRD patterns show the presence of LiZnPO_4 phase for zinc oxide doped samples. The EIS results show that the conductivity is enhanced by zinc oxide doping. The 2.5% ZnO-doped LiFePO_4 demonstrated higher conductivity than the 1.5% ZnO and 5% ZnO-doped LiFePO_4 or the un-doped sample. The CV curves

show that 2.5% ZnO-doped LiFePO_4 has higher electrochemical reactivity for lithium insertion and extraction than the un-doped material. The mean redox potential is $E_{1/2} = 3.45\text{V vs. Li}^+/\text{Li}$. The first discharge curve of the 2.5% ZnO-doped LiFePO_4 shows a mainly flat voltage plateau over the 3.45–3.5V range, indicating the lithium extraction and insertion reactions between LiFePO_4 and FePO_4 . A specific discharge capacity of about 177mAh/g was achieved, with little decrease during cycling.

(2) A new approach has been developed to rapidly synthesize nanostructured LiMn_2O_4 thin films by flame spray deposition (FSD) and *in situ* annealing. A precursor solution of lithium acetylacetonate and manganese acetylacetonate in an organic solvent was supplied through a flame spray pyrolysis (FSP) reactor. The liquid solution spray was ignited and stabilized by a premixed methane/oxygen flame ring surrounding the FSP nozzle. Thus, LiMn_2O_4 nanoparticles were formed by combustion and deposited onto a current collector followed by *in situ* annealing. Two different types of



First discharge curves of cells 0, 1.5, 2.5 and 5% ZnO-doped LFP



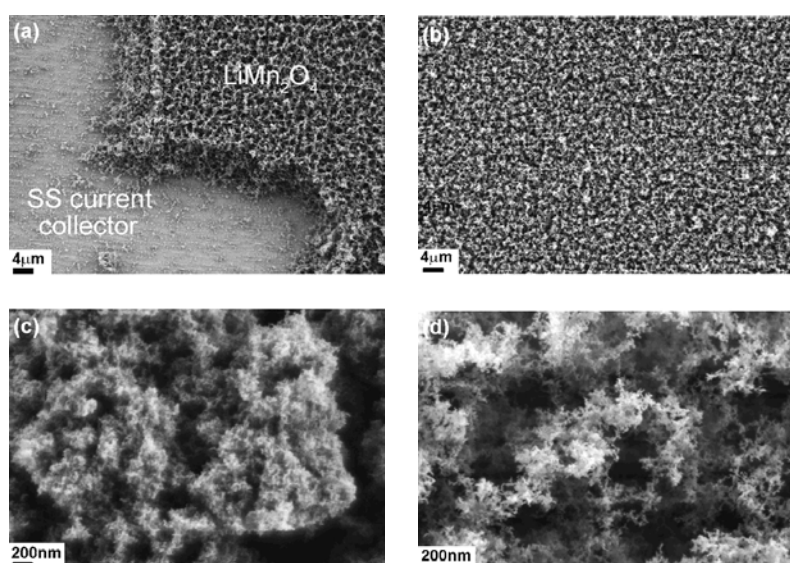
Discharge cyclic curves at a discharge current intensity of 20 mAcm^{-2} for 0, 1.5, 2.5 and 5% ZnO-doped LFP.

current collectors, i.e. stainless steel and aluminium coated with carbon-based primer were tested. The prepared thin films were characterized by X-ray diffraction and field-emission scanning electron microscopy. The electrochemical properties of the thin films were evaluated by cyclic voltammetry and galvanostatic cycling. The LiMn_2O_4 films exhibited good cyclability. Films that underwent sintering and crystal growth during *in situ* annealing developed more robust film structures on the current collector surface and exhibited better electrochemical performance than poorly adhered films.

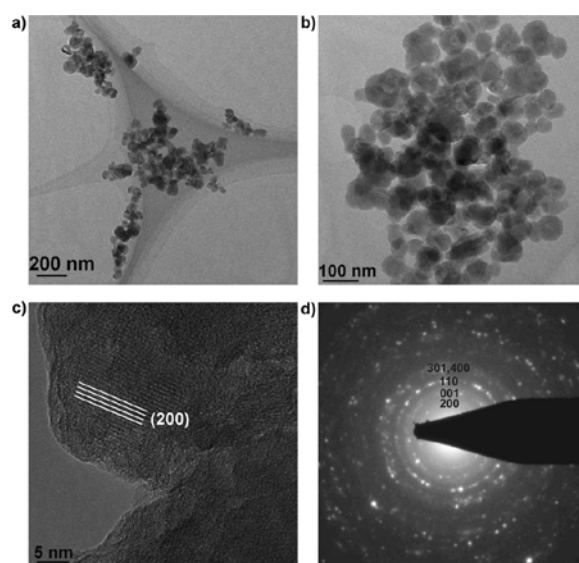
(3) Vanadium pentoxide (V_2O_5) nanoparticles (30–60 nm) were made by a one-step and scalable flame spray pyrolysis (FSP) process. Optimization of the FSP processing conditions (precursor concentration and injection rate) enhanced the electrochemical performance of these nanoparticles. Increasing the cut-off potential for discharging from 1.5 to 2.5 V vs. Li/Li^+ improved the cycle life of these V_2O_5 nanoparticles. Particles with the lowest specific surface area (ca. $32 \text{ m}^2/\text{g}$) and highest phase purity (up to 98 wt%) showed excellent cyclability between 2.5 and 4.0 V vs. Li/Li^+ , retaining a specific charge of 110 mAh/g beyond 100 cycles at a specific current of 100 mA/g, and also superior specific charge of 100 mAh/g at specific current up to 20C rate (or 2000 mA/g).

(4) Triazines are well known as flame retardants; however, their properties for battery applications have not been much explored. Flame retardants can play an important role in preventing dangerous situations that may occur when battery packs malfunction or are misused. However, the addition of flame retardants to batteries can degrade their performance due to the non-ionic properties of the additives. In order to overcome this drawback of additives, fluorinated material has been investigated, because fluorination frequently prevents deterioration of performance.

A fluoride-rich triazine used as an additive to the electrolyte, 2,4,6-tris(trifluoromethyl)-1,3,5-triazine (TTFMT), showed excellent thermal stability with charged cathodes and anodes. Addition of 5 wt.% TTFMT to the



The morphology of FSP-made LiMn_2O_4 nanoparticles as-deposited onto (a) SS and (b) ACP current collectors; and after *in situ* annealing onto the (c) SS and (d) ACP current collectors.



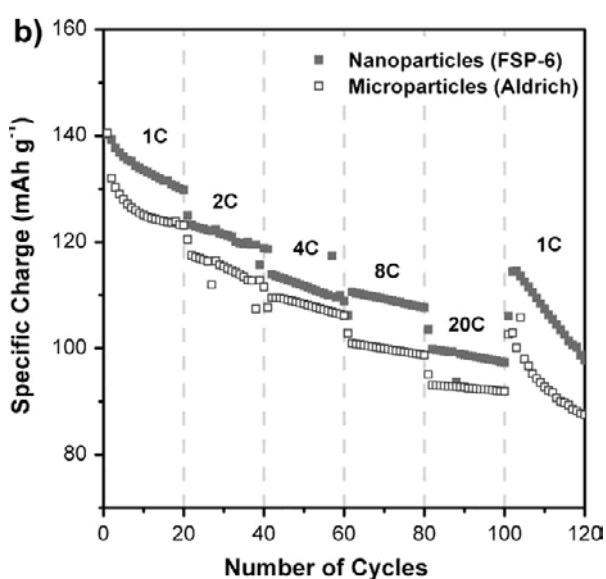
TEM images of FSP-made V_2O_5 nanoparticles (here FSP-6): (a) and (b) are overview images, showing nanoparticles connected by sinter necks forming chain-like aggregates; (c) high-resolution TEM image highlighting the (200) lattice planes; and (d) the selected area electron diffraction (SAED) pattern taken from image (b).

electrolyte reduced the exothermic heat from the oxygen release reaction in the cathode by 54%.

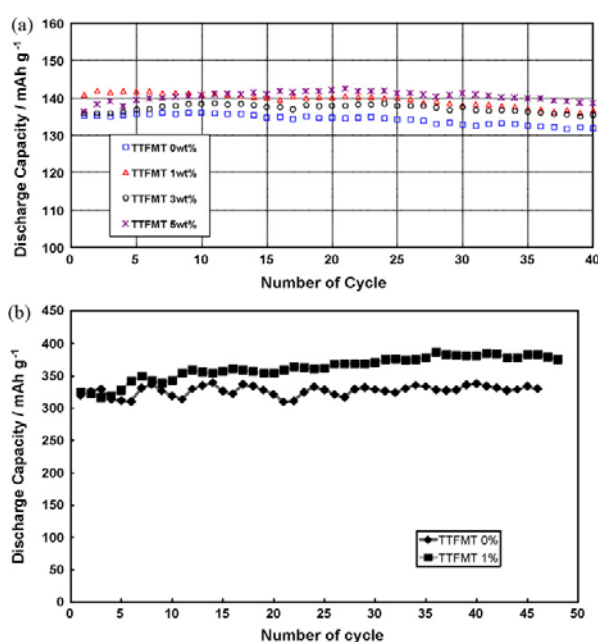
Surface film formation on the cathode is discussed with reference to cyclic voltammetry combined with impedance spectroscopy and differential scanning calorimetry. The properties of the film were influenced by the additive so as to markedly reduce the charge-transfer resistance, which enhanced the charge retention during cycle life, the capacity, and the high-rate discharge capacity of the battery.

Publications (Milestone 38)

1. A.Y. Shenoudaa, H.K. Liu, Studies on electrochemical behaviour of zinc-doped LiFePO_4 for lithium battery positive electrode, **Journal of Alloys and Compounds**, 477 (2009) 498–503
2. S.Y. Chew, T.J. Patey, O.Waser, S.H. Ng, R. Büchel, A. Tricoli, F. Krumeich, J. Wang, H.K. Liu, S.E. Pratsinis, P. Novák, Thin nanostructured LiMn_2O_4 films by flame spray deposition and *in situ* annealing method, **J. Power Sources**, 189(1) 449–453
3. S.H. Ng, T.J. Patey, R. Buchel, F. Krumeich, J.Z. Wang, H.K. Liu, S.E. Pratsinis and P. Novák, Flame spray-pyrolyzed vanadium oxide nanoparticles for lithium battery cathodes, **Physical Chemistry Chemical Physics**, 2009, 11, 3748–3755
4. K. Kim, S. Ahn, H.S. Kim, H.K. Liu, Electrochemical and thermal properties of 2,4,6-tris(trifluoromethyl)-1,3,5-triazine as a flame retardant additive in Li-ion batteries, **Electrochimica Acta** 54 (2009) 2259–2265



Galvanostatic cycling behaviour of V_2O_5 electrodes for nanoparticles (here FSP-6) and for microparticles (Aldrich): (a) cycling at a specific current of 100 mA/g, and (b) consecutive cycling at different specific currents. Electrodes were cycled between 2.5 and 4.0 V vs Li/Li^+ . Here 1C-rate is set to 100 mA/g.



Discharge capacity vs. cycle life of the cathodes (a) and the anodes (b).

MILESTONE 39

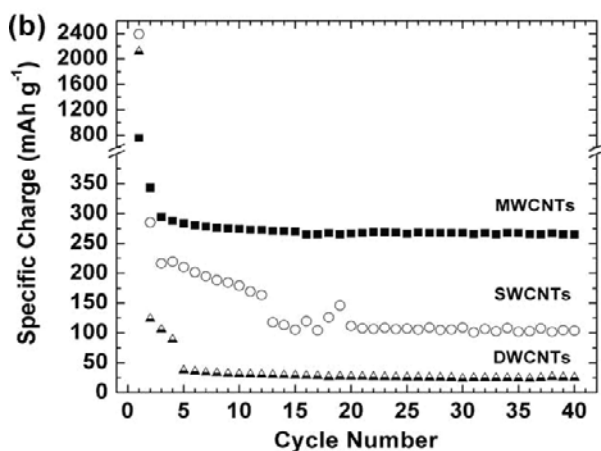
Develop long life, high energy density all-solid state thin-film Li-ion microbatteries (End Year 5).

(1) A comparative study of conductive, free-standing, binder-free flexible films made from three different types of commercial carbon nanotubes (CNTs), i.e., single-wall, double-wall, and multi-wall was carried out. The conductive CNT films were prepared by adding the CNTs to the starting dispersion of carbon black and Triton X-100, followed by a vacuum filtration technique.

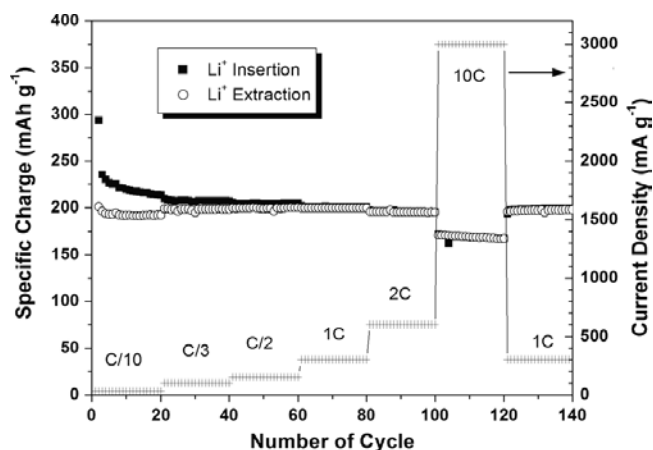
These films have been characterized as model free-standing, binder-free electrodes for flexible lithium-ion batteries. Our experiments revealed that films based on multi-wall CNTs (MWCNTs) are much better than single-wall and double-wall CNTs films in terms of their electrochemical performance. The flexible MWCNT electrodes show stable cycling behaviour and allow up to a 10 C-rate.

(2) Self-supported free-standing polypyrrole films have been prepared using the electrochemical polymerization method.

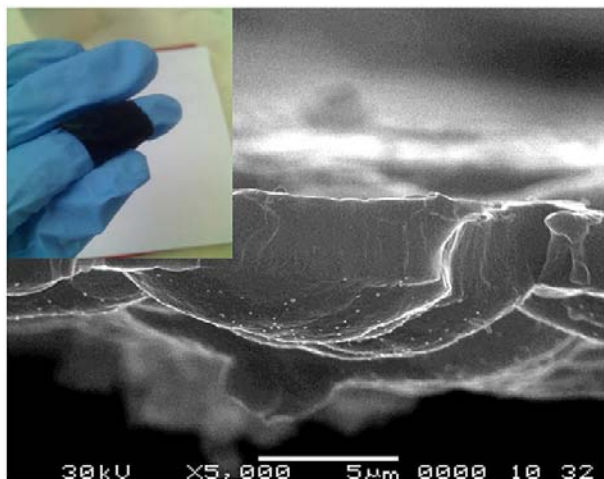
The results show that the free-standing films can be directly used as electrode materials for batteries without the need for metal substrate support. The flexible cathode materials can be combined with a flexible carbon nanotube paper anode and a polymer electrolyte to make flexible and bendable rechargeable batteries.



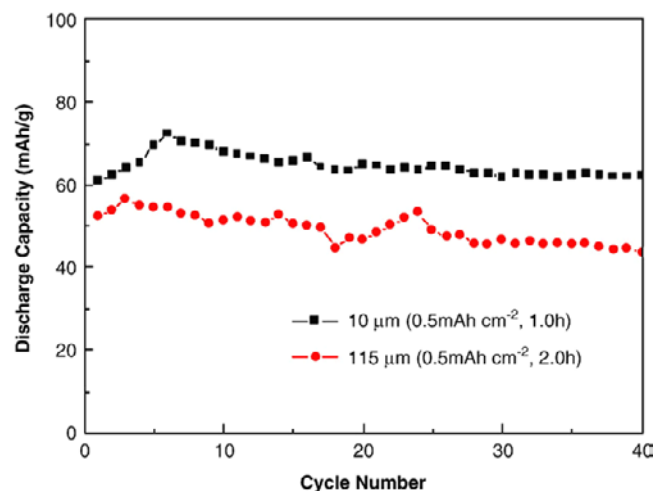
The electrochemical performance of the free-standing CNT films: (a) galvanostatic charge–discharge profiles in the 1st cycle and (b) cycling behaviour between 0.01 and 2.00 V vs. Li/Li⁺ at a specific current of 25 mA/g.



Typical rate capability of the MWCNT electrodes. A 1 C-rate is assumed to be 300 mA/g.



Cross-section of free-standing PPy film with photograph of rolled-up film (inset).



Discharge capacities vs. cycle number for the free-standing PPy electrodes with different thicknesses.

Publications (Milestone 39):

1. S.Y. Chew, S.H. Ng, J. Wang, P. Novák, F. Krumeich, S. L. Chou, J. Chen, H.K. Liu, Flexible Free-Standing Carbon Nanotube Films for Model Lithium-Ion Batteries, *Carbon*, **47**, (2009), 2976–2983.
2. J.Z. Wang, S.L. Chou, H. Liu, G.X. Wang, C. Zhong, S.Y. Chew, H.K., Highly Flexible and Bendable Free-standing Thin Film Polymer for Battery Application, *Materials Letters*, **63** (2009) 2352–2354.

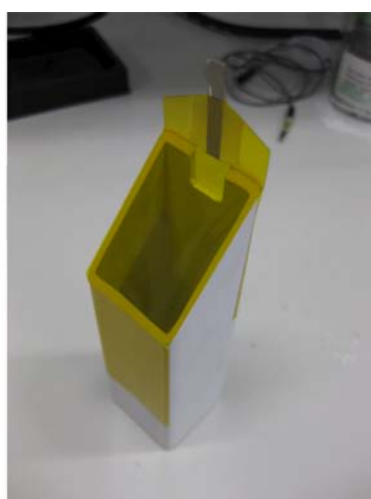
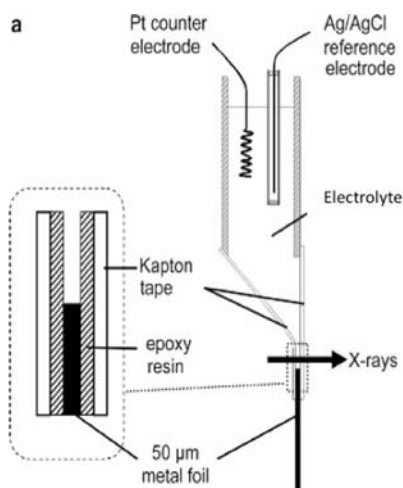
P3-2 Advanced Metal Batteries

MILESTONE 41

Develop an understanding of the interfacial phenomena at the electrode surfaces and use this to develop optimal performance in operational batteries (End Year 5).

The role of a range of aqueous and non-aqueous ionic liquid electrolytes in the formation of surface films on magnesium and the effect on magnesium-air cell operation were investigated. Substantial differences were observed depending on the electrolyte system employed.

An *in-situ* electrochemical cell has been developed in collaboration with Dr Alison Davenport (Univ. Birmingham) and Dr Trevor Rayment (Diamond Light Source) to allow x-ray characterisation to be performed on the salt films. A proposal has been submitted to the Australian Synchrotron for beamtime. Lab based measurements are also being undertaken with Dr Ian Madsen (CSIRO Minerals) on an Inel XRG 3000 X-ray diffractometer fitted with an Inel CPS 120 position sensitive detector (PSD).

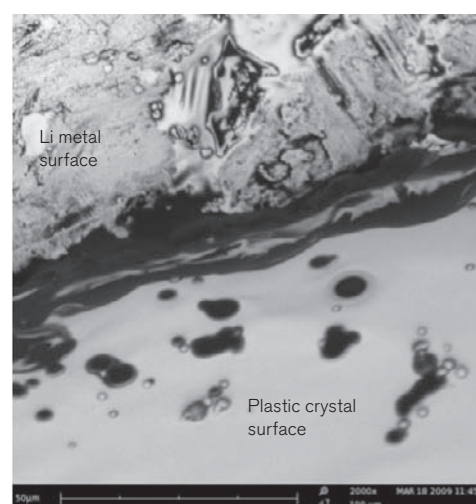


The *in-situ* electrochemical cell that has been developed in collaboration with Dr Alison Davenport (Univ. Birmingham) and Dr Trevor Rayment (Diamond Light Source) to allow x-ray characterisation to be performed on the salt films.

These experiments will allow initial data to be obtained as well as for the development of a suitable alignment system and methodology.

Lithium-air cells have been assembled incorporating an ionic liquid electrolyte and a PEDOT air electrode. The cell rate capability and cycling properties are dominated by reaction of the lithium electrode with components of the atmosphere. Surface film formation by modification of the electrolyte composition is effective in improving the cell performance. These surfaces may be studied after further development of the *in-situ* cell.

Lithium metal rechargeable cells incorporating solid-state plastic crystal electrolytes have been investigated and found to exhibit improved rate capability after subjection to a low-current preconditioning process. (P. C. Howlett, Y. Shekibi, D. R. MacFarlane, M. Forsyth, *Adv. Eng. Mater* 2009, in press.) This behaviour appears to emanate from a rearrangement of the plastic crystal microstructure at the electrolyte-electrode interface.



The plastic crystal microstructure at the electrolyte-electrode interface.

P3-3 Organic Batteries

MILESTONE 45

Develop wet-spinning techniques that enable the use of wet-spinning to produce fibre batteries and supercapacitors (End Year 4).

Wet-spun fibres based on PEDOT:PSS polymer were tested but exhibited very low capacity.

MILESTONE 46

Integrate fibre batteries into textile structures (End Year 5).

The low capacities achieved with fibre battery studies to date mean that this activity will be abandoned for now.

P4 Bionics

P4-1 Nerve Cell Communications

P4-2 Bio-stability and Biocompatibility

MILESTONE 50

Develop nanofabrication protocols that allow construction of 3-dimensional networks and devices for integration with fibrous tissue as well as cell adhesion and proliferation (End Year 5).

50.1 Achieve directed nerve growth over 1 cm using aligned fibre conduit.

Directed nerve fibre growth has been achieved both in vitro (2D structures) using a novel conducting polymer/biodegradable polymer fibre platform (see 50.3 milestone below), (Quigley et al, 2009, *Adv. Mat.*) providing the basis for a biodegradable nerve repair conduit consisting of a knitted sheath, electrospun with biodegradable

polymer nanofibres and an internal engineered matrix consisting of fibres for neuronal support and Schwann cell mobilisation suspended within a hydrogel containing biofactors. These conduits promoted the repair of a 1.2 cm gap created in the sciatic nerve of rats. This prototype conduit was seen to restore some function (assessed by autotomy score) and neurons were seen to grow through the conduit and bridge the nerve gap (Quigley et al., 2009, *J Neurol Eng*, in preparation).

The development of a second-generation conduit has received support from NHMRC, with funding starting in 2010.

Publications (milestone 50.1):

1. Quigley, A.F., Razal, J.M., Thompson, B.C., Moulton, S.E., Kita, M., Kennedy, E.L., Clark, G.M., Wallace, G.G., Kapsa R.M.I., A Conducting-Polymer Platform with Biodegradable Fibers for Stimulation and Guidance of Axonal Growth, *Advanced Materials* 2009, 21, 4393-4397. (IF= 8.191)

50.2 Complete safety study on aligned CNT arrays for cochlear implant applications.

There has been concern regarding the safety of nanomaterials for biological use, from both the lay and scientific community. Therefore, the important first step of this work was to investigate the safety and efficacy of proposed composite nanomaterials for neural (and other bionic) prostheses.

We studied the biocompatibility of composite materials containing CNTs *in vivo* to determine whether they could be used safely in a physiological setting. In addition, the growth of biological material on the surface of the chronically implanted

nanomaterials was examined. Characterising the extent of this tissue 'build-up' is important as it limits the performance of devices using electrodes to communicate with nearby nerves. The experimental phase is complete and the results of the chronic study are currently being evaluated.

50.3. Develop nanofabrication protocols that allow construction of 3-dimensional networks and devices for integration with fibrous tissue as well as cell adhesion and proliferation.

Two biomaterials fabrication protocols have been developed for the construction of 3D networks for integration with muscle and nerve (fibrous) tissue. These protocols involve: (A) a 2D sheet configuration consisting of wet-spun fibres overlaid on an Organic Conducting Polymer (OCP) substratum that can be rolled up to form a 3D linearly-fasciculated matrix (by cross-section); (B) 3D printing protocols arising from the development of unique printing machinery by ACES researchers, in conjunction with collaborators from Department of Materials and Textiles College of Engineering Massachusetts Institute of Technology, at Dartmouth. The wet-spun fibrous tissue platform has shown that the functional components of sensory nerve explants (neurons and Schwann cells) can be made to undergo guided and enhanced growth by the application of electrical stimulation.

In parallel studies, application of primary muscle cultures to this wet-spun fibre/OCP platform have likewise shown that myofibre growth can be guided on these structures (Razal et al., 2009, *Adv. Func. Mater.*), but that concurrent electrical stimulation imposes complex changes on myogenic precursor cells' growth and differentiation

dynamics during culture *in vitro*. These complex effects are being investigated to identify an effective electrical stimulation protocol that can be developed for muscle regeneration *in vitro* and then applied *in vivo*. Investigations into the influence of nanostructure on muscle and nerve growth on these platforms have shown that directionally aligned nanostructure on OCP substrata has a profound effect on the directional alignment of nerve axons and myofibre outgrowth.

Publications milestone 50.3

1. Joselito M. Razal, Magdalena Kita, Anita F. Quigley, Elizabeth Kennedy, Simon E. Moulton, Robert M. I. Kapsa, Graeme M. Clark, and Gordon G. Wallace, Wet-Spun Biodegradable Fibers on Conducting Platforms: Novel Architectures for Muscle Regeneration, *Adv. Funct. Mater.*, **19**, 1-8, 2009 IF=6.808
2. Gilmore KJ, Kita M, Han Y, Higgins MJ, Moulton SE, Clark GM, Kapsa R and Wallace GG. (2009) Skeletal muscle cell proliferation and differentiation on polypyrrole substrates doped with extracellular matrix components. *Biomaterials*, 30(29):5292-5304. IF=6.646

Other publications from Bionics in 2009, from previous milestones.

- ▶ G.G. Wallace, S.E. Moulton, G.M. Clark, Electrode-Cellular Interface, *Science*, **324**,185-6, 2009.
- ▶ B. C. Thompson, S. E. Moulton, K. J. Gilmore, M. J. Higgins, P. G. Whitten and G. G. Wallace, Carbon Nanotube Biogels, *Carbon*, **47**, 1282-91, 2009.
- ▶ Gordon Wallace, Simon Moulton, Organic Bionics: molecules, materials and medical devices, *Chemistry in Australia*, **76**, 3-8, 2009

P5 Ethics

P5-2 “Bionic People”

MILESTONE 54

Develop an integrated position on the development of bionics, human health and ethical relations (End Year 5).

Work towards this milestone has proceeded at a slower pace than originally intended due to the CI's move to the University of Tasmania in February 2009, the resignation of the UOW based Research Fellow in January 2009 and the delay in transfer of ACES funds to Tasmania which has prevented the appointment of a new Research Fellow. Nonetheless, the grounding research is completed and there is a good prospect for a new PhD student commencing research on this project in early 2010.

Publications from previous milestones published in 2009:

1. Kyle, R.; Dodds, S, Avoiding empty rhetoric: Why and when to engage publics in debates about nanotechnologies. *Sci Eng Ethics*, **2009**, 15 (1), 81-96. IF= 0.563 Available www.springerlink.com/content/I723432xq56657xw/
2. R.Kyle and S.Dodds, *Tiny Technologies Raise Big Ethical Issues*, Issues 2009, 89 (March 2009), 16-19 (non-refereed journal).

Other developments

ARC Centre of Excellence

2010-2013: The Australian Research Council (ARC) Chief Executive Officer, Professor Margaret Sheil, has announced that the University of Wollongong's ARC Centre of Excellence for Electromaterials Science will receive a further \$7.7 million in funding from July 2010 until December 2013.

The ACES entity (facilities, personnel and market presence) had enabled the development of other important research initiatives not funded by the Centre of Excellence core funding. These include (For 2009):

ARC Discovery Projects

The ARC Discovery Project scheme supports excellent research projects and individual researchers and teams of researchers within ACES.

2009-2011: **Development of inorganic-conducting polymer composites and ionic liquid-based electrolytes for rechargeable lithium batteries**, Dr JZ Wang (ACES/ISEM) (DP0987805, \$330k). The project will lead to development of safe lithium batteries for electric vehicles and hybrid electric vehicles to contribute to the national priority goal of reducing and capturing emissions in transport to improve our environment. Small, flexible batteries for new implantable medical devices will also be developed to treat millions of people suffering from different diseases.

2009-2011: **Interphase Engineering of Reactive Metal Surfaces Using Ionic Liquids**, Prof M Forsyth; Prof DR MacFarlane; Dr PC Howlett. (DP0986205, \$750k). Corrosion is a multi-billion dollar problem for all developed countries which limits the use of a number of advanced, light weight alloys in applications ranging from aircraft components to artificial hip-joints.

The outcomes of this project will be surface treatments which will enable a range of these applications including magnesium alloys in a wider range of engineering uses, magnesium for advanced metal batteries and coatings for medical implant applications.

2009 -2013: **Development of novel drug delivery systems** (DP DP0987344, Total Amount \$1.22mil). A collaborative venture with research at St Vincent's Hospital, involving Prof GG Wallace; Dr SE Moulton; Prof MJ Cook including a QEII Dr SE Moulton. Dr Simon Moulton joins A/Prof. Peter Innis, Dr Dan Li, Dr Jenny Pringle and Dr Andrew Minett as previous ARC QEII Fellows associated with ACES. The polymer based structures targeted for production in this project will bring unique capabilities to the field of drug delivery. A multi-drug delivery platform is expected to bring significant improvements in administering therapeutic drugs for a wide range of illnesses and applications. Here we will demonstrate the capabilities of these novel polymer structures both in-vitro and in-vivo.

2010-2012: **Fully ab initio, large-scale calculations of thermodynamic and transport properties of ionic materials** (DP 1095058, \$340k), awarded to Dr Katya Izgorodina, Prof Doug MacFarlane (both ACES/Monash), along with Prof Mark Gordon (University of Iowa). Advanced batteries, fuel cells, and photonic device technologies are beginning to use ionic materials as electrolytes due to their superb stability and technologically valuable properties. As a broad class these materials have only been known for just over a decade. The project will develop new advanced computational methods as a basis for understanding their properties and thereby allowing us to design-in desired

features. Ultimately these advances will have support the development of energy efficient CO₂ replacement technologies.

ARC Future Fellowships

Soft carbon nanotube materials to Dr MP in het Panhuis (FT0990846, \$686.4k).

There is no doubt that the realisation of new bionic materials will dramatically improve quality of life for many individuals. The new soft conducting materials proposed will impact on several areas of bionics, including the development of the next generation Bionic Ear, conduits for spinal cord regeneration as well as muscle regeneration and other applications. This project will further enhance the international profile of the ARC Centre of Excellence for Electromaterials Science in the field of Bionics. The end-user network already in place will ensure all opportunities are fully exploited.

ARC Linkage Projects

The ARC Linkage Projects scheme funds collaborative projects between university researchers and Partner Organisations.

Funding begins July 2009: **Advanced Materials for Stents** Prof GG Wallace; Dr SE Moulton (ACES/IPRI); Prof M Forsyth (ACES/Monash); A/Prof RM Kapsa (ACES/St Vincents) Dr LL Atanasoska; Dr J Weber (Boston Scientific) (LP0990621, \$470k).

The polymer based materials targeted for production in this project will bring unique capabilities to the field of stent design. A multi-component degradable stent system is expected to bring significant improvements in vascular therapeutic treatments for a wide range of illnesses and applications. The project brings together world leaders in their respective fields to address a highly multidisciplinary area of research and will provide excellent training for the PhDs and post doctoral research associates, enabling

them to work in and contribute to the development of new biomedical industries in Australia.

2009-2011 **Nanostructured Carbon Electrodes**, Prof GG Wallace; Dr J Chen; Dr AI Minett (ACES/IPRI); Dr AT Harris; Dr P Aitchison. (LP0989266, \$350k). This project is in collaboration with CapXX and Sydney University to develop new materials for capacitors. The development of higher capacity energy storage devices is critical to the efficient use of energy. The fundamental knowledge gained in this project will enable the production of the next generation advanced electrode materials for this purpose and hence provide many new commercial opportunities for Australian industry.

Funding to begin 2010: **Metal-air batteries with improved rate capability and safety for hearing applications** with the team including Professor Maria Forsyth, Professor Doug MacFarlane, Dr Bjorn Winther-Jensen and Dr Patrick Howlett (ACES/Monash) and partners Cochlear Ltd and Varta GmbH (LP100100066, \$448k ARC funds plus \$150k industry funds). The project will develop improved energy and power density batteries which will lead to immediate implementation of more powerful signal processing algorithms, making hearing aids more effective and appealing to the user. This will improve recipient compliance and in turn improve the quality of life for those with severe hearing impairment.

In 2009 we also completed an ARC Linkage proposal with SMR Automotive (previously Visiocorp) on development of **New Materials and Devices for Electrochromics**.

ARC Linkage International

2009- **Inkjet printing bio-functional materials**, Prof GG Wallace; Dr MP in het Panhuis (both ACES/IPRI); Prof P Calvert (USA). (LX0989950, \$95k). Professor Paul Calvert, a materials scientist from the University of Massachusetts Dartmouth in the US is here in IPRI to work on this project. The proposed research will benefit existing biomedical industries in Australia and provide opportunities for new start-up companies, as well as potentially attracting biomedical industries from overseas to establish a presence in Australia. This exciting area of research will provide an excellent multidisciplinary research environment for the proposed ARC International Fellow. The new bio-inkjet printing equipment, materials and configurations developed here may also have impact on other areas of Bionics, including the development of the next generation Bionic Ear, conduits for spinal cord regeneration as well as for muscle regeneration.

International Science Linkages – Science Academies Program

Dr Simon Moulton (ACES/IPRI) will undertake research with Dr Philippe Poulin at CNRS Bordeaux and Prof Eric Anglaret at University Montpellier II to develop **Aligned Carbon Nanotube Biomaterial Structures**.

NHMRC Funding

New health and medical research funding awarded to researchers at ACES has reinforced its reputation in the pursuit of medical bionics.

Funding start 2009: **Polymers for Skeletal Muscle** for researchers A/Pr Robert MI Kapsa (ACES/St Vincents), Dr Anthony J Penington, Prof Gordon G Wallace (ACES/IPRI), Prof David L Officer (ACES/IPRI) (573430, \$506.5k).

Funding start 2010: **Multimodal Woven BioPolymer Fibre Conduits for Remodelling Damaged Peripheral Nerve** for a collaborative research team comprising Associate Professor Robert Kapsa from St Vincent's, Melbourne, Professor Gordon Wallace, Dr Ilias Kyratzis, Associate Professor Michael Murphy, Dr Anita Quigley and Dr Joselito Razal (635243, \$662.5k)

Advanced Polymer Systems for the Delivery of Anti-Epileptic Drugs to the CNS to be conducted by the research team comprising Professor Mark Cook and Associate Professor Rob Kapsa from St Vincent's along with Professor Gordon Wallace and Dr Simon Moulton (IPRI) (619614, \$514.3k). Their research will pursue advanced polymer systems for the delivery of anti-epileptic drugs to the central nervous system.

ANFF-NCRIS Funding

The IPRI node of ACES also acts as the host of the Australian National Fabrication Facility (Materials nodes). The ANFF Materials Node brings together specific strengths in the fabrication of both hard and soft materials, particularly nano-organic and inorganic electronic materials. In 2009 this capability has been further expanded through winning a further \$3.9M in equipment funding, expanding our capabilities in the area of synthesis and supply of advanced organic materials for application in areas such as polymer electronics, OLEDs and organic photovoltaics. Other activities include providing expertise via consultancies in the area of materials synthesis, processing and characterisation. Details on these capabilities can be found at the following links;

- ▶ www.electromaterials.edu.au/resources/AIIMP&D.html
- ▶ www.electromaterials.edu.au/Resources/anff.html
- ▶ http://anff.org.au/page/materials_node.html

The Materials Node is based at the state-of-the-art **Australian Institute for Innovative Materials (AIIM)** at the University of Wollongong's Innovation Campus and the **University of Newcastle**. It combines the skills, facilities and expertise of the University of Wollongong's Intelligent Polymer Research Institute (IPRI) and the Institute for Superconducting and Electronic Materials (ISEM), and the University of Newcastle's Centre for Organic Electronics (COE). Between them, these three partners offer extensive and unique capabilities in the design, development and fabrication of nanostructured electronic materials and devices for researchers and industry. Researchers are able to either work at the node under expert guidance, or to contract for specialised products to be fabricated at a reasonable cost.

Other Direct Funding

- ▶ Boston Scientific for advanced stent materials
- ▶ DSTO Fellowship for A Polymer/Carbon Nanotube - Actuated Swimming 'Fish' Robot
- ▶ The Hearing CRC for the optimisation of the electro-neural interface
- ▶ CRC for Polymers : Functional Polymers for Photovoltaic Devices
- ▶ Department of State and Regional development for Titanium Dioxide/Carbon Nanotube Composites for Energy Devices



In 2009 the ANFF Materials Node, hosted at IPRI, obtained a further \$3.9M in equipment funding which further expands ACES capabilities.

EIF Funding

Building on the success of ACES (and other elements of ISEM) a successful EIF bid was lodged by UOW to establish a prototype and device fabrication facility for electromaterials – in particular for energy and medical bionic related projects.

On 13 May 2009, the Illawarra region received a jobs boon as the Budget delivered funding for a new Australian first facility for UOW. At least 200 construction jobs created for the initial phase to build the \$43 million “Australian Institute for Innovative Materials (AIIM) - Processing and Devices” Facility. The new building will be developed alongside the existing AIIM Building at the Innovation Campus and when developed will house 150 staff and students. Building is expected be completed by the end of 2010.

The Australian Institute for Innovative Materials Processing & Devices Facility (AIIM P&D) is an Australian first. It will offer the innovative processes and facilities required to take multifunctional materials from fundamental research to proof of concept, using novel fabrication methods (\$19 million for equipment).

The AIIM P&D Facility will build upon UOW's existing world-class research capabilities and enable:

- ▶ innovative materials research that links with novel materials processing research to develop next-generation materials and diverse applications
- ▶ proof-of-concept for multifunctional materials development projects (including prototype development, manufacturing scale-up and early-stage clinical trials)
- ▶ R&D of new electromaterials fabrication and processing methods, which can then be applied to next-generation multifunctional materials being developed by UOW and others around Australia
- ▶ accelerated market application of next-generation multifunctional materials (by bridging the gap between lab-based studies and manufacturing scale-up and proof-of-concept)
- ▶ postgraduate training to produce the personnel required for technology transfer to industry
- ▶ enhanced national and international collaboration.

Studies continued on the porphyrin-based organic solar cell collaboration between Prof Paul Dastoor, in the Centre for Organic Electronics (CoE) at the **University of Newcastle**, and Prof David Officer (ACES/IPRI). As a result of this collaboration, Officer and Dastoor submitted a \$5 million application for funding to the first round of the Australian Solar Institute grants for a structure integrated solar cell project involving 10 research institutions and companies, totalling \$30 million. While this application was not funded, it has created the momentum for a future multi-institutional research project that will capitalise on ACES solar cell research that will not be on-going in the extended Centre research program.



An artist's impression of the new AIIM facility once the AIIM P&D is complete.

Activity Plan 2010

2010 will be a year in transition as we complete our investigations into the original ACES milestones and embark on other activities as detailed in the Strategic Plan submitted to the ARC as part of the review process.

Complete Year 5 milestones

P1 Electromaterials

P1-1 Synthesis and Processing

MILESTONE 5:

Supply of new materials to P2 –P4

MILESTONE 9

Preparation of functionalised inorganic nanoparticles and nanofibres for P2 and P3.

MILESTONE 12

Prepare functionalised aligned CNTs for P2 and P3. Prepare aligned carbon nanotube samples for: Energy conversion: Aligned CNT-polythiophenes composite solar cells. Energy storage: Aligned CNT -PEDOT composites for batteries. Bionics: Aligned CNT-biopolymer composites for cell stimulation.

MILESTONE 14

Supply of fabricated structures to P2-P4 (End Year 2 then ongoing).

MILESTONE 19

Supply/refinement of electrolytes for P2-P4 (End Year 2 then ongoing).

P1-2 Characterisation

MILESTONE 21

Dr Peter Innis (QEII Fellow) will coordinate and educate on the use of conventional characterisation tools such as SEM, AFM, NMR, UV-vis and electrochemical methods, as well as specialist in-situ techniques such as Electrochemical-Electronspin Resonance, Electrochemical-Raman and Localised Electrochemical Impedance Spectroscopy (Ongoing).

MILESTONE 22

Utilisation of novel characterisation tools in P1-P4 (Ongoing).

P2 Energy Conversion

MILESTONE 28

Development of nanostructured photocathodes for the integration into tandem solar cells.

P3 Energy Storage

MILESTONE 39

Develop long life, high energy density all solid-state thin-film Li-ion microbatteries (End Year 5).

P3-2 Advanced Metal Batteries

MILESTONE 41

Develop an understanding of the interfacial phenomena at the electrode surfaces and use this to develop optimal performance in operational batteries (End Year 5).

P3-3 Organic Batteries

MILESTONE 45

Develop wet-spinning techniques that enable the use of wet-spinning to produce fibre batteries and supercapacitors (End Year 4).

MILESTONE 46

Integrate fibre batteries into textile structures (End Year 5).

P4 Bionics

50.3. Develop nanofabrication protocols that allow construction of 3-dimensional networks and devices for integration with fibrous tissue as well as cell adhesion and proliferation.

P5 Ethics

P5-2 “Bionic People”

MILESTONE 54

Develop an integrated position on the development of bionics, human health and ethical relations (End Year 5).

MILESTONES (MID 2010-2013)

ACES milestones covering mid 2010-2013 period will be included as part of the ARC extension agreement.

Appendix 1: ACES visitor list

Every year ACES hosts numerous visitors [international (92 from 19 different countries), national (39) and enduser groups (35)] for discussion about ACES research.

Visitors hosted by Monash

- 1 Dr. Zurina Osman, Physics Department, University of Malaya, Malaysia
- 2 Professor M Stanley Whittingham, Chemistry and Materials, SUNY at Binghamton, Binghamton
- 3 Dr Teh Lay Kuan from Robert Bosch
- 4 Mr Facundo Varela Capital Federal, Argentina
- 5 Mr Etienne WASSER, University of ECSM, Lyon, France
- 6 Mr Simon Coleman, Dublin City University, Ireland
- 7 Don Kearley and Mike James, ANSTO
- 8 Dr. Wenlong Cheng, Department of Biological and Environmental Engineering, Cornell University
- 9 Prof Leslie Lyons, Department of Chemistry, Grinnell College
- 10 Dr Mark Newton, Millburn House Magnetic Resonance Centre, Department of Physics, University of Warwick, Coventry
- 11 Prof Julie Macpherson, Department of Physics, University of Warwick, Coventry
- 12 Prof Ruth Lynden Bell, University Chemical Laboratory, Cambridge
- 13 Mr. Stephen William Gramet, Strasbourg, France
- 14 Prof. Paul Burn, University of Queensland
- 15 Dr. John Slattery of York University, UK
- 16 Dr Yong Peng
- 17 Dr. Alison Davenport, University of Birmingham
- 18 Dr. Michel Armand, Laboratoire de Reactivite et Chimie des Solides, NCRS

Visitors hosted by St Vincents

- 1 Professor Patrick Kwan, Division of Neurology, Department of Medicine and Therapeutics, Prince of Wales Hospital, Hong Kong, China
- 2 Professor Edward Byrne, University College, London, United Kingdom
- 3 Associate Professor Vivian K. Mushahwar, Dept Cell Biology and Centre for Neuroscience, Faculty of Medicine and Dentistry, The University of Alberta, Canada
- 4 Professor Keiichi Torimitsu, Nippon Telegraph and Telephone Corporation- Basic Research Laboratories, Tokyo, Japan
- 5 Professor Brent Reynolds, College of Medicine, University of Florida, Florida, USA
- 6 Associate Professor Jesse Owens, WWAMI Biomedical Program and the Department of Biological Sciences, University of Alaska Anchorage, Alaska, USA
- 7 Associate Professor Stephen Davies, Dept Neurosurgery, University of Colorado, Colorado, USA
- 8 Associate Professor Jean Peduzzi-Nelson, Department of Anatomy & Cell Biology, School of Medicine, Wayne State University, Michigan, USA
- 9 Professor Carlos Lima, Hospital de Egaz Moniz, Lisbon, Portugal
- 10 Professor Maiyadhaj Samsen, Prasat Neurological Institute, Mahidol University, Bangkok, Thailand
- 11 Professor Gustavo Moviglia, Regina Mater Institute Clinic, Buenos Aires, Argentina
- 12 Professor Jim Faed, Dept. Pathology, Dunedin School of Medicine, University of Otago, Dunedin, New Zealand

Visitors hosted by UOW

1	Mr Jiangfeng Wu, Manager, DLG battery (Shang Hai) CO Ltd, China	23	Dr. A.G. (Tony) Pandolfo, Energy Technology, CSIRO, Australia	54	Prof. Frank Caruso, University of Melbourne
2	Dr Yao Chen, General Manager, DLG battery (Shang Hai) CO Ltd, China	24	Dr. Xiangdong Yao, The University of Queensland	55	Senator the Hon Kim Carr, Federal Minister for Innovation, Industry, Science and Research
3	Prof Jung Ho Ahn, Andon National University, Korea	25	Dr. Manickam Minakshi, Murdoch University	56	Tony Romeo, University of Sydney
4	Assoc Prof Yun Long Xu, East China University of Science and Technology, Shanghai	26	Bridget Ogilvie	57	Bjorn Winther-Jensen, Monash University
5	Prof Yu Chen Zai, Northeastern University, China	27	Greg Smith, SciVentures	58	Arash Takshi, University of British Columbia, Canada
6	Mrs Limei Fan, University of Electronic Science & Technology of China	28	Tan Troung, DSTO	59	Dr Ben Qi, Composites CRC
7	Dr Yao Chen , General Manager, DLG battery (Shang Hai) CO Ltd, China	29	Frank Walsh, University of Southampton	60	Prof Sang-Yeup Park, Kangnung National University, Korea
8	Dr Xianjun Zhu, Central China Normal University, China	30	Jan Weber, Boston Scientific	61	Dr David Mazzocchi-Jones, Cardiff University, UK
9	Mrs. Limei Fan, from the University of Electronic Science & Technology of China	31	Radoslav Atanasoska, 3M	62	Peter Murphy, University of South Australia
10	Dr Xianjun Zhu from the Central China Normal University	32	Liliana Atanasoska, Boston Scientific	63	Sherry Kothari, University of South Australia
11	Dr. Young-Hee Cho, University of Queensland	33	Dennis Tallman, North Dakota State University	64	Mark Cook, St Vincent's Hospital Melbourne
12	A/Prof. S.L.I. Chan, UNSW	34	Ric Kaner, UCLA	65	Amy Halliday, St Vincent's Hospital Melbourne
13	Dr. Alexey Glushenkov, ANU	35	Peter Murphy, University of South Australia	66	Ian Dagley, CRC for Polymers
14	Dr. Andrew Dicks, University of Queensland	36	Rob Short, University of South Australia	67	Eimear Ryan, NUI Maynooth, Ireland
15	Prof. Yinong Liu, The University of Western Australia	37	Emer Lahiff, Dublin City University (DCU)	68	Graeme Clark, La Trobe University, Melbourne
16	Assoc. Prof. Scott Donne, University of Newcastle	38	Silvia Scarmagnani, DCU	69	David Rye, University of Sydney
17	Dr. John Stride, The University of New South Wales	39	Robert Byrne, DCU	70	Philip Aitchison, Cap-XX
18	Dr. Shizhang Qiao, The University of Queensland	40	Julie Brien, EDI Medical Imaging	71	Peter Murphy, University of South Australia
19	Dr. Usman Rana, Monash University	41	Samuel Graham, Georgia Tech	72	Edwina Hine, Royal Australian Chemical Institute (RACI)
20	Prof. Huitong Chua, The University of Western Australia	42	Evan Evans, BlueScope Steel	73	Colin Thew, New South Wales Department of State and Regional Development
21	Prof. Janusz Nowotny, University of Western Sydney	43	Robert Reed, Express Promotions Aust Pty Ltd	74	Magda Kita, St Vincent's Hospital
22	Dr. Bjorn Winther-Jesen, Monash University	44	Liz Micallef, Australian National University (ANU), Canberra	75	Rob Kapsa, St Vincent's Hospital
		45	Neville Fletcher, Erich Weigold, C Jagadish, ANU	76	Yimei Yin, Shanghai Jiao Tong University, China
		46	Max Lu, University of Queensland	77	Lay Kuan, Robert Bosch Corporate Research and Technology Centre, Singapore
		47	Peter Majewski, Uni SA	78	Dermot Diamond, Dublin City University
		48	Adam Micolich, University of New South Wales (UNSW)		
		49	Deb Kane, Macquarie University		
		50	Alan Wilson, DSTO		
		51	Steve Duvall, formerly Intel		
		52	Graeme Clark, La Trobe University		
		53	Dr Mohd Nasir, Malaysian Consulate, Sydney		

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|-----|--|-----|--|-----|--|
| 79 | Robert Byrne, Dublin City University | 113 | Bob Cowan, HEARing CRC | 141 | Victor Bivell, EcolInvest |
| 80 | Simon Kavannah, Dublin City University | 114 | Carrie Newbold, HEARing CRC | 142 | Sebastian Perrier, UNSW |
| 81 | Andrew Coleman, Dublin City University | 115 | Martin Svehla, Cochlear | 143 | Nicolas Mano, Centre de Recherche Paul Pascal, France |
| 82 | Roland De Marco, Curtin University, WA | 116 | Akhilesh Verma, University of Adelaide | 144 | Professor Serdar Sariciftci, Johannes Kepler University, Austria |
| 83 | Anatoly Rozenfeld, University of Wollongong | 117 | Christopher Fumeaux, University of Adelaide | 145 | Andrew Harris, University of Sydney |
| 84 | Roger Buckeridge, Allen & Buckeridge | 118 | Lindley Edwards, AFG Venture Group | 146 | Gina Gebhardt, Erlangen, Germany |
| 85 | Richard Kell, ATSE | 119 | Paul Calvert, University of Massachusetts Dartmouth, USA | 147 | Thomas Krusenbaum, EVP Engineering |
| 86 | Neil Wilson, Romar Engineering | 120 | Yong Kong, Jiangsu Polytechnic University, China | 148 | Prof Pavel Nestrenko, University of Tasmania |
| 87 | Alan Morris, Invetech | 121 | Juoko Isojarvi, UCB Pharma | 149 | Prof. Brett Paul, Dublin City University, Ireland |
| 88 | John Baxter, Invetech | 122 | Julie Macpherson, University of Warwick, United Kingdom | 150 | William Clark, Sekisui Chemical Co., LTD, Japan |
| 89 | Sam Lind, University of Otago | 123 | Tony Killard, Dublin City University | 151 | Fumio Ishikawa, Sekisui Chemical Co., LTD, Japan |
| 90 | Pavel Dorozhkin, Coherent Scientific | 124 | Tan Troung, DSTO | 152 | Sang-Yeup Park, Kangwon Fine Ceramics Centre, Korea |
| 91 | Nicola Beattie, University of Melbourne | 125 | Prof. Rainer Fink, Erlangen, Germany | 153 | Won Gyu Park, Gangneung Science Industry Foundation, Korea |
| 92 | Karl Rodrigues, CSIRO | 126 | Gerry Swiegers, Datatrace DNA Pty Ltd | 154 | Beom-Soo Kim, Gangneung Science Industry Foundation, Korea |
| 93 | Stephen O'Leary, Bionic Ear Institute | 127 | Noric Dilanchian, DILANCHIAN Lawyers & Consultants | 155 | Prof. Peter Choong, University of Melbourne |
| 94 | Woongnam Kim, Consulate General of the Republic of Korea | 128 | James V. Scicolone, New Jersey Institute of Technology, USA | 156 | Prof. Terry O'Brien, University of Melbourne |
| 95 | Chikeun Son, Deputy Consulate General of the Republic of Korea | 129 | Chan Khai Leok, Institute of Materials Research and Engineering, Singapore | 157 | Prof. Margaret Morris, UNSW |
| 96 | Lee Hee Gyoung, Korea Polytechnic University, Korea | 130 | Steve Ranford, Ag Research, New Zealand | 158 | Courtney Suhr, St Vincent's Hospital Melbourne |
| 97 | Kazuo Tominaga, Kyushu Institute of Technology, Japan | 131 | Saisunee Liawruangrath, Chiang Mai University, Thailand | 159 | Karen McLean, St Vincent's Hospital Melbourne |
| 98 | Rowan Hendeson, University of Tasmania | 132 | Kwanchanok Wanawananon, Chiang Mai University, Thailand | 160 | Leena Van Ray, University of Melbourne |
| 99 | Veronica Strong, UCLA, USA | 133 | Parawee Rattanakit, Chiang Mai University, Thailand | 161 | Prof H Wang and student, Beijing Normal University |
| 100 | Trevor Lewis, University of Tasmania | 134 | Thomas Kinkeldei, ETH Zurich, Switzerland | 162 | Dr C.R. Creton (ESPCI Paris) |
| 101 | James Nicholson, Visiocrp | 135 | Dr Stephen Beirne, Dublin City University, Ireland | | |
| 102 | Scott Edwards, SMR-Automotive | 136 | David Nayagam, Bionic Ear Institute | | |
| 103 | Liz Jaswinska, Australian Research Council, Canberra | 137 | Chris Williams, Bionic Ear Institute | | |
| 104 | Elaine Saunders, Monash University | 138 | Suvi Paivikki Haimi, University of Tampere, Finland | | |
| 105 | Christine Scala, DSTO | 139 | Aliisa Palli, University of Tampere, Finland | | |
| 106 | Doug MacFarlane, Monash University | 140 | Jani Peltto, VTT Technical Research Centre of Finland | | |
| 107 | Maria Forsyth, Monash University | | | | |
| 108 | Hans Griesser, University of South Australia | | | | |
| 109 | Ping Cao, DSTO, Sydney | | | | |
| 110 | Bernard Kachoyan, DSTO, Sydney | | | | |
| 111 | Alan Theobald, DSTO, Sydney | | | | |
| 112 | Marc West, DSTO, Sydney | | | | |

Appendix 2:

ACES Media Coverage 2009

Date	Medium	Source	Description	Impact	Journalist	Type
21/1/09	Print	Diamond Valley Leader	"Scientists are working with a team at UOW's Intelligent Polymer Research Institute to trial the use of ""carbon nanotubes"" to connect cochlear implants with the human brain."	Positive	William Jackson	News
27/1/09	Television	WIN Wollongong	The NSW Minister for Science and Medical Research Jodi McKay today announced a new program initiative involving UOW that promises to have a huge impact on devices such as mobile phones and digital cameras	Positive		News
27/1/09	Online	Nanowerk	Australian/Korean nanotechnology collaboration to develop high-performance battery	Positive		News
27/1/09	Web	www.azonano.com/news	"Researchers from the Intelligent Polymer Research Institute yesterday received half of the \$100,000 grant from the visiting Minister for Science and Medical Research, Jodi McKay."	Positive		News
27/1/09	Radio	ABC Illawarra	The University of Wollongong has collaborated with a Korean university to become the recipient of a joint grant from the New South Wales and Korean governments.	Positive	Nick McLaren	News
28/1/09	Online	ABC Illawarra Website	The University of Wollongong has collaborated with a Korean university to become the recipient of a joint grant from the New South Wales and Korean governments.	Positive		News
28/1/09	Print	Illawarra Mercury	Funding to help Wollongong uni wow technology world	Positive	Emma Shaw	News
28/1/09	Online	Illawarra Mercury Website	Wollongong uni receives \$100,000 technology grant	Positive	Emma Shaw	News
28/1/09	Online	The Meridian Institute	Australian/Korean Nanotechnology Collaboration to Develop High-Performance Battery	Positive		News
27/1/09	Radio	ABC Illawarra	Follow-up Drive Time report about a new program initiative involving the Intelligent Polymer Research Institute (IPRI) that promises to have a huge impact on devices such as mobile phones and digital cameras	Positive	Nick Rheinberger	Radio Interview
29/1/09	Web	http://www.nanovip.com/node/54420	Jodi Mackay announced that researchers at UOW's Intelligent Polymer Research Institute (IPRI) have been chosen as the first funding recipients of a joint technology program between the NSW Government and the South Korean province of Gangwon.	Positive		News
1/2/09	Magazine	Australian R&D Review	Dr Gordon Wallace has been selected to work with world-leading scientists and Nobel Prize Laureates in a collaborative research project in Korea.	Positive		News
5/2/09	Television	WIN Wollongong	"Professor Gordon Wallace has been invited to join eminent world scientists, including Nobel Prize Laureates, in a newly-formed international collaborative research project named "World Class University" by the Korean Governmen"	Positive		News
5/2/09	Print	Hanbat Herald (Korea)	The Asia-Pacific Symposium on Nanobionics will begin at the Innovation Campus this week. Gordon Wallace interviewed.	Positive		News
6/2/09	Print	Illawarra Mercury	UOW scientist joins key project	Positive	Emma Shaw	News
6/2/09	Online	Illawarra Mercury Website	UOW scientist joins key project	Positive	Emma Shaw	News
6/2/09	Print	Sydney Morning Herald	Honour for Wollongong Professor	Positive		News Focus
11/2/09	Print	Wollongong Advertiser	UOW 'research star' set to shine regarding the WCU Project.	Positive	Nathan Simpson	News
18/2/09	Print	Wollongong Advertiser	Report on the 2009 ACES Electromaterials Symposium held in Wollongong	Positive		Book Review
15/2/09	Magazine	Cosmos	"Professor Gordon Wallace provided book reviews in the ""sci-five"" section"	Positive		News
19/2/09	Print	Illawarra Mercury	Report on the \$7.7 million funding boost from the Australian Research Council.	Positive	Emma Shaw	News
25/2/09	Print	Wollongong Advertiser	Report on the \$7.7 million funding boost from the Australian Research Council.	Positive		News
1/3/09	Print	Australian R & D Review	"UOW's Gordon Wallace has been invited by the Korean Government to join the ""World Class Univeristy"""	Positive		News

Date	Medium	Source	Description	Impact	Journalist	Type
9/3/09	Television	WIN Wollongong	"Report on the opening on the Australian Institute for Innovative Materials at the Innovation Campus, which was officially opened by Kim Carr, Minister for Innovation, Industry, Science and Research"	Positive		News plus interviews
9/3/09	Radio	ABC Illawarra	"Report on the opening on the Australian Institute for Innovative Materials at the Innovation Campus, which was officially opened by Kim Carr, Minister for Innovation, Industry, Science and Research"	Positive	Nick McLaren	News plus interviews
9/3/09	Radio	i98 FM	"Report on the opening on the Australian Institute for Innovative Materials at the Innovation Campus, which was officially opened by Kim Carr, Minister for Innovation, Industry, Science and Research"	Positive		News
9/3/09	Print	Illawarra Mercury	Preview of the opening mentioning institute directors Professor Gordon Wallace from ACES and Professor Shi Xue Dou from ISEM.	Positive	Emma Shaw	News
10/3/09	Radio	ABC Illawarra	"Follow up report on the opening during the Mornings show with Steve Parsons, including an interview with Kim Carr, Minister for Innovation, Industry, Science and Research."	Positive	Steve Parsons	Radio Interview
10/3/09	Print	Illawarra Mercury	"Follow up on the opening of the Australian Institute for Innovative Materials, including a overview of research at IPRI and profiles of two phd students, Brianna Thompson and Peter Sherrell."	Positive	Emma Shaw	News
10/3/09	Online	Illawarra Mercury Website	Minister launches cutting edge campus at Wollongong	Positive	Emma Shaw	News
14/3/09	Print	Illawarra Mercury	Professor Gordon Wallace has been honoured with a Smart Structures and Materials lifetime achievement award for 2009 by the International Society for Optical Engineering in the United States	Positive	Emma Shaw	News
15/3/09	Print	Illawarra Mercury	UOW welcomes nanotech study	Positive	Courtney Trenwith	News
18/3/09	Print	"DaeJeon Today, Korea"	News story on Professor Gordon Wallace's visit to Korea in March.	Positive		News
18/3/09	Magazine	Mobile Tex	Professor Doug MacFarlane was interviewed about the development in fuel cell technology using Gore-Tex that he and researchers at Monash University in Melbourne	Positive		News
25/3/09	Print	Wollongong Advertiser	UOW's Gordon Wallace has won the 2009 Smart Structures and Materials Lifetime Achievement Award.	Positive	Nathan Simpson	News
6/4/09	Radio	ABC National Radio	An interview with Professor Graeme Clark first broadcast on ABC radio's Conversation Hour program was repeated	Positive	Richard Fidler	Radio Interview
15/4/09	Print	Illawarra Mercury	"FURTHER research into the potential health risks associated with nanotechnology would be welcome, the University of Wollongong's head of nanotechnology Professor Gordon Wallace said yesterday"	Positive	Courtney Trenwith	News
15/4/09	Print	Illawarra Mercury	Unions have called for stricter guidelines to help protect the health of workers and consumers after research in Scotland showed some nanotechnology materials might be as deadly as asbestos. Gordon Wallace quoted.	Positive	Courtney Trenwith	News
15/4/09	Radio	ABC Illawarra	"Interview with Professor Gordon G. Wallace, Director of the Intelligent Polymer Research Institute, University of Wollongong, about concerns surrounding nano technology."	Positive	Suzanne Hill	Radio Interview
18/4/09	Print	Illawarra Mercury	Gordon Wallace featured in an extended piece on nanotechnology in the weekend paper	Neutral	Michelle Hocter	Feature
18/4/09	Radio	ABC Illawarra	Interview with Gordon Wallace regarding discussion about the possible dangers of nanotechnology	Positive	Nick Rheinberger	Radio Interview
23/4/09	Television	ABC TV	"The Catalyst Program on ABC TV featured a story on solar prints which featured the research being undertaken by Dr Dr Udo Bach, who is a Research Fellow with ACES at Monash University"	Positive	Mark Horstman	Feature and interviews

Date	Medium	Source	Description	Impact	Journalist	Type
29/4/09	Print	The Australian	"Polymers Rescue Bionic Man From Fantasy World"" by Jane McCredie also featured a photo of Gordon outside the AIIM Facility in Wollongong"	Positive	Jane McCredie	Feature
2/5/09	Print	Illawarra Mercury	"O•ce star Elvis says ""Thank you very much"". ACES Administration O•cer Phil 'Elvis' Smugreski wins o•ce star award"	Positive	Jodie Minus	News
2/5/09	Online	Illawarra Mercury Website	Elvis is king of the o•ce	Positive	Jodie Minus	News
13/5/09	Print	Illawarra Mercury	Announcement of funding for the Australian Institute for Innovative Materials (AIIM) -Processing and Devices Facility	Positive		News
13/5/09	Radio	ABC Illawarra	The announcement of funding for the Australian Institute for Innovative Materials (AIIM) -Processing and Devices Facility	Positive		News
19/5/09	Online	Angewandte Chemie	Progress toward artificial tissue? Soft and tough like biological tissue: DNA-wrapped carbon nanotubes	Positive		Feature
25/5/09	Television	WIN Wollongong	"IPRI/ACES node played a large role in this year's Illawarra Innovation Showcase, which is part of the National Innovation Festival, footage of lab tours and Bionics for 2020 High School Competition launch"	Positive		News
26/5/09	Print	Illawarra Mercury	"News story on launch of the Bionics for 2020 High School Competition, a ACES sponsored event in conjunction with National Science Week"	Positive	Emma Shaw	News
26/5/09	Print	Illawarra Mercury	Feature article on Bionics for 2020 Competition in IQ Education Supplement	Positive		Feature
27/5/09	Print	Illawarra Mercury	"Mentions the The Perspectives article, entitled Electrode-Cellular Interface, was contributed by Gordon Wallace and Simon Moulton.in 'Science'"	Positive		News
28/5/09	Online	Expertguide.co m.au	Report on the robotic fish called WANDA (Wireless Aquatic Navigator for Detection and Analysis) with a camera that can seek out and 'swim' towards a particular object of interest.	Positive		News
29/5/09	Television	SBS News	Report on the robotic fish called WANDA	Positive		News
29/5/09	Television	Channel 9 News	Report on the robotic fish called WANDA	Positive		News
29/5/09	Television	WIN Wollongong	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	Science Alert	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	Insciences Organisation	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	The Engineer Online	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	The Indian News	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	The Hindu News Update Service	Report on the robotic fish called WANDA	Positive		News
29/5/09	Online	Machines Like Us	Report on the robotic fish called WANDA	Positive		News
29/5/09	Radio	ABC Illawarra	Report on the robotic fish called WANDA and interview with Dr Scott McGovern	Positive		Radio Interview
30/5/09	Print	Daily Telegraph	""Robofish on Small Scale", article and photo"	Positive		News
30/5/09	Online	Daily Telegraph Website	Report on the robotic fish called WANDA	Positive		News
30/5/09	Print	Illawarra Mercury	Report on the robotic fish called WANDA	Positive	Emma Shaw	News
12/7/09	Web	Poland -blog	"Candidate for a doctor's degree Cameron Ferris from the institute of research on the intelligent polymers University of Wollongong made use of rubber gellanowa, produced by the bacteria Pseudomonas elodea"	Positive		News

Date	Medium	Source	Description	Impact	Journalist	Type
14/7/09	Web	SmashHits.com	"Nanotechnology graduate Cameron Ferris, and supervisor Dr. Marc in het Panhuis have developed a sca••old with the help of gellan guma biopolymer produced by the bacteria Pseudomonas elodea that can help get cells to grow into the right kind of tissue."	Positive		News
14/7/09	Web	SmashHits.com	"Nanotechnology graduate Cameron Ferris, and supervisor Dr. Marc in het Panhuis, have developed a sca••old with the help of gellan gum-a biopolymer produced by the bacteria Pseudomonas elodea- that can help get cells to grow into the right kind of tissue."	Positive		News
14/7/09	Web	Thandian News	"Nanotechnology graduate Cameron Ferris, and supervisor Dr. Marc in het Panhuis, have developed a sca••old with the help of gellan gum-a biopolymer produced by the bacteria Pseudomonas elodea- that can help get cells to grow into the right kind of tissue."	Positive		News
14/7/09	Web	Top News India	"Nanotechnology graduate Cameron Ferris, and supervisor Dr. Marc in het Panhuis, have developed a sca••old with the help of gellan gum-a biopolymer produced by the bacteria Pseudomonas elodea- that can help get cells to grow into the right kind of tissue."	Positive		News
20/7/09	Web	Punjab Kesari News	"Nanotechnology graduate Cameron Ferris, and supervisor Dr. Marc in het Panhuis, have developed a sca••old with the help of gellan gum-a biopolymer produced by the bacteria Pseudomonas elodea- that can help get cells to grow into the right kind of tissue"	Positive		News
29/7/09	Radio	i98 Newswire	"Wollongong University researchers have made a medical bionics breakthrough, using polymers to guide the growth of nerve and muscle cells and eventually help those with spinal injuries."	Positive	Renee Criddle	News
30/7/09	Television	WIN Wollongong	Significant inroads into the development of the latest materials for "smarter" medical bionic devices were announced at a special demonstration held at IPRI	Positive		News
30/7/09	Radio	ABC Illawarra	Significant inroads into the development of the latest materials for "smarter" medical bionic devices were announced at a special demonstration held at IPRI	Positive	Nick Rheinberger	Radio Interview
30/7/09	Web	ABC Online	New medical bionic research developed at the University of Wollongong's Intelligent Polymer Research Institute could have applications for the spinal cord or muscle regeneration	Positive		News
30/7/09	Print	Illawarra Mercury	"Article describes how researchers at ACES/IPRI have claimed a seat at the cutting edge of medical bionics, taking a 'giant step' towards repairing spinal injuries."	Positive	Angela Thompson	News
1/8/09	Print	Illawarra Mercury	"A special 16-page feature celebrating the first year of operation of the Innovation Campus, home of the Intelligent Polymer Research Institute and the administrative home for ACES."	Positive		Feature
2/8/09	Print	Racjonalista •Poland	UOW have developed a sca••old with the help of gellan gum-a biopolymer produced by the bacteria Pseudomonas elodea	Positive		News
11/8/09	Print	Illawarra Mercury	"IQ Education Supplement featured an article on the upcoming Public Lecture by Professor Graeme Clark, sponsored by ACES"	Positive		Feature
11/8/09	Radio	ABC Illawarra	"Promotion of Public Lecture by Professor Graeme Clark, sponsored by ACES"	Positive		News
11/8/09	Radio	i98 FM	"Promotion of Public Lecture by Professor Graeme Clark, sponsored by ACES"	Positive		News
19/8/09	Radio	ABC Illawarra	Featured part of Prof Clark's talk as well as interviews with ACES and UOW researchers and winning students from the 'Bionics for 2020' Competition.	Positive	Nick Rheinberger	News
19/8/09	Television	WIN Wollongong	"Reported on Graeme Clark lecture, including interviews with Prof Clark and the mother of four-month old Felix Williams. who is due to receive bilateral cochlear implants next month"	Positive		News
10/9/09	Print	The Irish Times	Run a news story on A Robot Fish Called WANDA about collaborative research between ACES and DCU	Positive		News

Date	Medium	Source	Description	Impact	Journalist	Type
14/9/09	Print	Illawarra Mercury	Two researchers within ACES have been named as recipients of ARC (Australian Research Council) Future Fellowships	Positive		News
14/9/09	Radio	ABC Illawarra	Prof Judy Raper interviewed about the Future Fellowships awarded to UOW and ACES	Positive		Radio Interview
14/9/09	Online	Nature Asia-Pacific Materials website	Featured a research highlight of the article 'Tough supersoft sponge fibers with tunable stiffness from a DNA self-assembly technique' by Professor Geoffrey Spinks from IPRI/ACES node and collaborators at Hanyang University in South Korea which featured in	Positive		News
1/10/09	Print	Illawarra Mercury	"Article on visiting Professorial Linkage Fellow Professor Paul Calvert, a world-renowned materials scientist from the University of Massachusetts Dartmouth in the US, currently at IPRI in Wollongong."	Positive		News
2/10/09	Online	Research Australia	"Article on visiting Professorial Linkage Fellow Professor Paul Calvert, a world-renowned materials scientist from the University of Massachusetts Dartmouth in the US, currently at IPRI in Wollongong."	Positive		News
27/10/09	Print	Illawarra Mercury	The University of Wollongong's Community Connections Feature which appeared in the Illawarra Mercury and Wollongong Advertiser featured an article on IPRI community lab tours and a profile on IPRI PhD student Cameron Ferris	Positive		Feature
8/12/09	Print	Illawarra Mercury	"(IPRI) PhD student Matthew Griffith has been named as one of 20 postgraduate students in Australia to receive a \$63,500 Prime Minister's Australia Asia Endeavour Award."	Positive		News
21/12/09	Print	Illawarra Mercury	"Professor Gordon Wallace interviewed about current research in the area of medical bionics, including comments on the bionic eye design for the future"	Positive		News

Appendix 3:

ACES Intellectual Property Register

Organisation	Names of Inventors	Intellectual Property (IP) Details	Date
UOW/IPRI	G.M. Spinks,G.G. Wallace,D. Zhou	PCT/Au02/01608: An electrochemical actuator and means of providing same	Nov 2001
UOW/IPRI/, BRL	G.Wallace, P.Innis, J.Steele, D.Zhou, G. Spinks	PCT/AU2002/001074: Feedback Device having Electrically Conducting Fabric	Aug 2001
UOW/ISEM	G.X. Wang , K. Konstantinov, H.K. Liu, S.X. Dou	PCT/2002100000: Cathode materials for rechargeable batteries and a process for production	Jan 2002
UOW/ISEM	S.X. Dou, K. Konstantinov, H.K. Liu G.X. Wang	PCT/2002100190: Fabrication of cathode materials for Li-ion batteries	Mar 2002
UOW/ISEM	K. Konstantinov , G.X. Wang, H.K. Liu, S.X. Dou, S. Bewlay	PCT/2002100403: Development of new positive compounds for lithium-ion batteries	May 2002
UOW/IPRI	G.Wallace, S. Ralph, J. Ding, W.Price	PCT/AU2002/001408: Separation and recovery of Precious Metals using Polymer Materials	Oct 2002
UOW/IPRI, Hearing CRC	G.Wallace, G. Spinks, D. Zhou, C. Treaba, P. Gibson, R. Cowan, J. Xu	PCT/AU2002/001660: Control and Shape of an Implant electrode Array	Dec 2002
UOW/IPRI, CSIRO	G. Wallace, J. Chen, C. Too G Sweigers	PCT/AU2003/00143: Novel Catalysts and Processes for their Preparation	Feb 2003
Royal North Shore/, UOW/IPRI	T. Scott, V. Vare, P. Abolfathi, G. Wallace, G. Spinks, D. Zhou	PCT/AU2003/001138: Movement facilitation device	Sept 2003
UOW/IPRI, Trinity College Dublin	G.G. Wallace, S. Moulton, A. Minett, W. Blau	PCT lodged, Use of biomolecules as selective dispersants for carbon nanotubes.	Feb 2004
Monash/CSIRO	P. Howlett, T. Hollenkamp D. MacFarlane, M.Forsyth	PCT/AU2004/000263: Energy Storage Devices	Mar 2004
UOW/IPRI/ Virginia Tech	M. Bennett, D. Leo , G. Spinks G. Wallace	US Patent 10/921347: Ionic solvents for ionic polymer transducers, sensors and actuators	Aug 2004
CSIRO/, UOW/IPRI	B. Holcombe, P.Waters, M.Looney G.Wallace, P. Innis, S. Ashraf, D. King	PCT/AU2004/000860: Electroconductive Textiles	
UOW/ VISIOCORP	G.Wallace, P. Innis, S. Edwards, C. Hall, R. Fabretto, J.Mazurkiewicz	PCT/AU2006/000916;: Charge Conducting Medium	June 2006
UOW/IPRI	G.G. Wallace, P. Innis	PCT/AU2007/000119, Self Powered Sensing Devices: Filed as WO/2007/090232	Feb 2007
UOW/IPRI/BEI	G.G. Wallace, J. Chen, A.Minett, G.Clarke	PCT/AU2007/000913, Nanostructured Composites	June 2007
UOW/IPRI, Dublin City University	G.Wallace, D. Diamond, S.Coyle K.Tong Lau, D. Morrise, Y.Wu	PCT/IB3008/051423,: Flow Analysis Apparatus and Method	Feb 2007
UOW/IPRI	G.G. Wallace , S.E. Moulton, C. Lynam, P. Whitten	PCT/AU2007/000104,: Biocompatible Composites	Feb 2007
UOW/IPRI, Dublin City University	A. Morrin, M. Smythe, A. Killard O. Ngamna, G. Wallace, S. Moulton, K. Crowley	PCT/IE2007/000047,: Sensor Comprising Polymer Materials	April 2007
UOW/IPRI, Dublin City University	D. Diamond, R. Shepherd , C. Smyth, G.G. Wallace, G. M. Spinks Y. Wu	PCT/IB2007/004285: A self maintained sensor using a low power actuator: WO/2008/062316	Feb 2007
UOW/IPRI	G.Wallace, J. Chen, A Minett	PCT/AU2007/001933: Nanotube and Carbon Layer Nanostructured Composites	Dec 2007
UOW/ IPRI/, VISIOCORP	J. Mazurkiewicz, G. Wallace, P. Innis, S. Edwards, P. Murphy, C. Hall, R. Fabretto, J. Henryk, K. Zubar	PCT 2008201373: Processes for Producing Electrochromic Substrates and Electrochromic Articles made therefrom	Mar 2008
UOW/IPRI	G.Wallace, D. Li	PCT/AU2008/001543: Process for the Preparation of Graphene	Oct 2008
UOW/IPRI	Not given	PCT 2008906611: Polymer Electrolytes and Devices Containing them	Dec 2008
UOW/IPRI	D. Officer, G. Wallace, G. Tsekouras, A. Mozer, Y. Dong	US patent 60/202164: Dye Composition for Use in Photoelectric Materials	Feb 2009
UOW/ISEM	SL Chou, JZ Wang, HK Liu , SX Dou	PCT 2009902074: Hollow Structured Metal-Oxide/Carbon composite having a relatively high surface area	April 2009

Appendix 4:

ACES Staff Members 2009

Member	Role	Affiliation
Prof. G.G. Wallace	Executive Director and Program 1 Co-Leader	University of Wollongong
Prof. M. Forsyth	Associate Director	Monash University
Prof. D.L. Officer	Program 1 Co-Leader	University of Wollongong
Prof. G.M. Spinks	Program 2 Leader	University of Wollongong
Prof. D.R. MacFarlane	Program 3 Leader	Monash University
Prof. G.M. Clark	Program 4 Co-Leader	La Trobe University
A/Prof. R. Kapsa	Program 4 Co-Leader	University of Wollongong
Prof S. Dodds	Program 5 Leader	University of Tasmania
Prof. W.E. Price	Education Director	University of Wollongong
A/Prof C.O. Too (Jan - Sept)	Chief Operating Officer	University of Wollongong
Dr T.E. Campbell (Oct - Dec)	Chief Operating Officer	University of Wollongong
Ms L. Crouch	Communications Officer	University of Wollongong
Mr P. Smugreski	Administration Assistant	University of Wollongong
Ms R. Potter	Administration Assistant	University of Wollongong
Prof. L.A.P. Kane-Maguire	Chief Investigator	University of Wollongong
Prof. H.K. Liu (APF)	Chief Investigator	University of Wollongong
A/Prof. P. Keller	Chief Investigator	University of Wollongong
Prof. H. Brown	Chief Investigator	University of Wollongong
A/Prof. P. Innis	Chief Investigator	University of Wollongong
Dr. A. Minett (QEI Fellow)	Chief Investigator	University of Wollongong
A/Prof. G. Alici	Chief Investigator	University of Wollongong
Prof. L. Spiccia	Chief Investigator	Monash University
Prof. Y-B. Cheng	Chief Investigator	Monash University
A/Prof. M. net in Panhuis	Chief Investigator	University of Wollongong
A/Prof. A. Paolini	Chief Investigator	La Trobe University
Prof. M. Cook	Chief Investigator	St Vincents
Dr J. Chen	Research Fellow	University of Wollongong
Dr L. Dennany	Research Fellow	University of Wollongong
Dr. B. Kim	Research Fellow	University of Wollongong
Dr Xiao Liu	Research Associate	University of Wollongong
Dr J. Locke	Research Fellow	University of Wollongong
Dr S. McGovern	Research Associate	University of Wollongong
Dr S. Moulton (QEI Fellow)	Research Fellow	University of Wollongong
Dr A. Mozer	Research Fellow	University of Wollongong
Dr J. Razal (APD Fellow)	Research Fellow	University of Wollongong
Dr S. Saricilar	Research Fellow	University of Wollongong
Dr D. Sharma	Research Fellow	University of Wollongong
Dr J. Wang	Research Fellow	University of Wollongong
Dr C. Wang	Research Fellow	University of Wollongong
Dr Philip Whitten	Research Fellow	University of Wollongong
Dr A. Quigley	Research Fellow	St Vincents

Member	Role	Affiliation
Dr D. Nayagam	Research Fellow	Bionic Ear Institute
Ms K. Magee (nee Shiphams)	Research Assistant	Bionic Ear Institute
A/Prof Chris Williams	Research Fellow	Bionic Ear Institute
S. Vogrin	Research Fellow	Bionic Ear Institute
Prof. R. Shepherd	Medical Research Fellow	Bionic Ear Institute
Dr J. Tan	Research Fellow	Bionic Ear Institute
Dr U. Bach	ARC Fellow	Monash University
Dr J. Efthimiadis	Research Fellow	Monash University
K. Fraser	Research Associate	Monash University
Dr P. Howlett	Research Fellow	Monash University
Dr K. Izgorodina (APD Fellow)	Research Fellow	Monash University
Dr. N. Lewcenko	Research Fellow (VICOS)	Monash University
Dr D. Li (QEII Fellow)	QEII Fellow	Monash University
Dr J. Pringle (QEII Fellow)	QEII Fellow	Monash University
Ms S. Shekibi	Administration Assistant	Monash University
Dr J. Sun	Research Fellow	Monash University
Dr B. Thompson	Research Associate	Monash University
Dr F. Wang	Research Associate	Monash University
Dr O. Winther-Jensen (APD Fellow)	Research Fellow (VICOS)	Monash University
Dr Z. Zeng	Research Associate	Monash University
Dr X. Zeng	Research Associate (VICOS)	Monash University
Dr Y. Zheng	Research Associate	Monash University
Prof. S. Adeloju	Associate Investigator	Monash University
Prof J-H. Ahn	Associate Investigator	Andong National University
Prof A. Bond	Associate Investigator	Monash University
Prof. D.N. Butler	Associate Investigator	University of Wollongong
Dr D. Buxton	Associate Investigator	BlueScope Steel Limited
Dr E. Evans	Associate Investigator	BlueScope Steel Limited
Dr T. Bastow	Associate Investigator	CSIRO-Manufacturing Science & Technology
Dr T. Hollenkamp	Associate Investigator	CSIRO Energy Technology
Dr G.F. Swiegers	Associate Investigator	CSIRO-Molecular and Health Technologies
Dr W. Humphries	Associate Investigator	CSIRO-Textile & Fibre Technology
Dr A. Hill	Associate Investigator	CSIRO-Manufacturing Science & Technology
Prof. S. De Leeuw	Associate Investigator	Delft University of Technology
Prof. L. Dai	Associate Investigator	Wright Brothers Institute
A/Prof P. Dastoor	Associate Investigator	University of Newcastle
Prof. D. Diamond	Associate Investigator	Dublin City University
Prof. R. Forster	Associate Investigator	Dublin City University
Prof J. Hill	Associate Investigator	University of Wollongong
Prof. A. Ivaska	Associate Investigator	Abo Akademi University
A/Prof S.J. Kim	Associate Investigator	Hanyang University

Member	Role	Affiliation
Prof. J-Y. Lee	Associate Investigator	Korean Institute of Metals and Materials
Assist. Prof. J. Madden	Associate Investigator	University of British Columbia
Dr P. Poulin	Associate Investigator	CNRS
A/Prof S. Ralph	Associate Investigator	University of Wollongong
Prof. L. Samuelson	Associate Investigator	University of Massachusetts Lowell
Prof. M.E. Smith	Associate Investigator	University of Warwick
Prof. D.E. Tallman	Associate Investigator	North Dakota State University
Prof D. Theodorou	Associate Investigator	National Technical University of Athens
Dr V-T. Truong	Associate Investigator	DSTO
Prof F. Walsh	Associate Investigator	University of Southampton
Prof R.N. Warrener	Associate Investigator	University of Wollongong
Prof K. West	Associate Investigator	Riso National Laboratory
Dr Z. Guo	Associate Investigator	University of Wollongong
Dr K. Konstantinov	Associate Investigator	University of Wollongong
Dr G. Wang	Associate Investigator	University of Wollongong

Appendix 5:

ACES PhD Students

In 2009, 9 new PhD students were recruited and there were 6 completions. There are currently 38 PhD students enrolled in the Centre, who receive funding from ACES such as for scholarships, scholarship top-ups or project consumables.

Name	Host Institution	Commenced	Title	Financial Arrangement
Nickita Rajoo	Monash	2003; Graduated in 2009	Development of Biosensors Based on Peptide Nucleic Acids.	ARC
Mehrdad Samani	IPRI/UOW	2004; Graduated in 2008	Modelling of polypyrrole helix tube actuators	Iranian Government
Liu Yong	IPRI/UOW	2004; Graduated in 2008	Nanostructured electrodes based on carbon nanotubes.	UOW. ARC scholarship
Orawan Ngamna	IPRI/UOW	2004; Graduated in 2008	Synthesis and characterisation of ICP nanoparticles.	UOW. ARC scholarship
Jenny Causley	IPRI/UOW	2004; Graduated in 2008	Use of electrode nanostructures for fluid movement.	UOW scholarship/ARC top up
See How Ng	ISEM/UOW	2004; Graduated in 2007	Nano-structured materials for electrode in Li-ion battery.	UOW
Tracey Markley	Monash	2005; Graduated in 2009	Electrochemical and Surface characterisation of rare earth inhibited aluminium alloys	Monash/ CSIRO
Youssof Shekibi	Monash	2005; Youssof has submitted his thesis in 2009 - employed at CSIRO Energy Technology.	Novel Plastic Crystal Electrolyte Materials	ARC & CSIRO Energy Technology top up.
Xiao Liu	IPRI/UOW	2005; Graduated 2009	Cell culturing on organic conductors	ARC Centre scholarship
Salvador Larios	IPRI/UOW	2005; Submitted 2009	Hydrogel micro and nano actuators	IPRS
Stephen John	UOW	2005 Graduated 2009	Conducting polymer based micro and nano manipulation systems	APA
Brianna Thompson	IPRI/UOW	2005; Submitted 2009 -working at Monash University	Cell culturing on conducting polymers	APA scholarship/ARC top up
Min Sik Park	ISEM/UOW	2005; Graduated in 2008	Thin film lithium-ion batteries	ISEM
Katarina Johansson	Monash	2005; Graduated in 2009	New ionic liquids	Monash
Sau Yen Chew	ISEM/UOW	2006; Graduated in 2009	Develop highly conductive nanocomposite electrolytes and electrodes for lithium batteries	ACES grant
Javad Foroughi	IPRI/UOW	2006; Submitted 2009	Nanostructured fibres	ARC
Andrew Nattestad	Monash	2006	Dye Sensitised Tandem Solar Cells for Improved Conversion Efficiency	Monash
Wayne Neil	Monash	2006	Effect of composition and morphology on reactivity of magnesium alloys & constituent metals	Monash
Aleksey Izgorodin	Monash	2006	Synthesis and characterisation of electroluminescent inorganic nanoparticles	ARC
Vanessa Armel	Science/Monash	2006	Ionic Materials for Photochemical Solar Cells	ARC
Kristian Bulluss	St Vincent's Hospital/ University of Melbourne	2006	Molecular Pathways of Nerve Degeneration and Rescue	Australian College of Surgeons
Wen Zheng	IPRI/UOW	2007	Polypyrrole actuators	UOW Federation Fellow Scholarship
Sina Nafici	IPRI/UOW	2007	Novel biopolymer fibres	UOW Federation Fellow Scholarship
George Lee	IPRI/UOW	2007	Controlled Release of Nano Particles from Conducting Polymers	ACES Scholarship
Dillip Panda	IPRI/UOW	2007	Development of Photoactive Polymer	UOW Scholarship ACES
Benjamin Mueller	IPRI/UOW	2007	Aligned Carbon Nano Tube-Biopolymer Structures	UOW Federation Fellow Scholarship
Robert Breukers	IPRI/UOW	2007	Biodegradable Conducting Polymers	APA/ARC top up
Shannon Little	IPRI/UOW	2007	Nanostructured Organic Conducting Electrodes	APA/ARC top up
Grace Stevenson	IPRI/UOW	2007	Characterisation of Nano-bio-electromaterials.	UOW Federation Fellow scholarship
Weimin Zhang	IPRI/UOW	2007	Nanostructured Electrodes for Catalysis	IPRI scholarship

Name	Host Institution	Commenced	Title	Financial Arrangement
Charles Mire	IPRI/UOW	2007	Printing Polymer Biopolymer Structures	UPA/ ARC top up
Alberto Javier, Granero Rodriguez	IPRI/UOW	2007	Synthesis and characterisation of polyion complex fibres	UOW Federation Fellow Scholarship
Shideh Nasrullah	Engineering /UOW	2007	Studies of toughening mechanisms in double network hydrogels	ARC/ACES
Shulei Chou	ISEM/UOW	2007	Nano-structured anodes in Li-ion rechargeable batteries	OPRS/UPRS
Adrian Gestos	IPRI/UOW	2008	Investigating the physical and mechanical properties of individual electrospun nanofibres	IPRI scholarship
Matthew Griffith	IPRI/UOW	2008	Artificial Photosynthesis: The Development of Novel Organic Photovoltaic Devices	APA/ARC top up
Nurul Idris	ISEM/UOW	2008	Advanced materials for lithium rechargeable battery	Malaysian Scholarship
Chao Zhong	ISEM/UOW	2008	Advanced anode materials for Li-ion batteries	Private/ARC Centre grant
Md. Mokhesur Rahman	ISEM/UOW	2008	Advanced Electrodes materials for Li-ion batteries	UOW Scholarship
Torben Daeneke	Science/Monash	2008	Novel redox couples and surface passivation techniques for dye sensitized solar cells	Monash/ACES
Hasitha Weerasinghe	Engineering/Monash	2008	Dye Sensitized Solar Cells on Flexible Substrate	Monash/ACES
Q. Zhang	Chemistry/UOW	2008	Fullerene Chemistry	Chemistry/UOW
Yuanhui Zheng	Engineering/Monash	2008	Electrostatic self-assembly of gold nanoparticles	Monash/ACES
Dongchuan Fu	Engineering/Monash	2008	Back contact dye sensitized solar cells	Monash/ACES
Tanmaya Joshi	Science/Monash	2008	Ruthenium metal complexes for biosensor applications	Monash/ACES
Timothy Khoo	Engineering/Monash	2008	Advance Metal-Air Batteries	Monash/ACES
Usman Ali Rana	Engineering/Monash	2008	Novel doped plastic crystals as solid state electrolyte materials	Monash/ACES
Cameron Ferris	IPRI/UOW	2009	Fabrication of 3D, cell-laden architectures by the controlled deposition of biopolymers, conducting polymers, cells and bio-molecules for the engineering of cardiac tissue.	APA/ ARC top up
Dorna Esrafilzadeh	IPRI/UOW	2009	Conducting Fibres for Actuating and Release	UOW Federation fellow scholarship
Mohd Faiz Hassan	ISEM/UOW	2009	Nanocomposites materials for Li-ion batteries	Malaysian Scholarship/ ACES
Lukman Noerochim	ISEM/UOW	2009	All solid-state lithium rechargeable battery	UOW Matching scholarships/ARC Centre grant
Maryam Salari	ISEM/UOW	2009	Study on TiO ₂	OPRS/UPRS ACES
Huy Ha	Science/Monash	2009	Ionic Liquid Media as Protein Stabilizing Agents	Monash/ACES
Archana Singh	Science/Monash	2009	Revolutionary Manganese Clusters as Efficient Water Oxidation Catalysts	Monash/ACES
Solmaz Tubafard	Science/Monash	2009	Development of Bistridentate Ruthenium (II) polypyridyl complexes for Biological Application Based on PNA	Monash/ACES
Rodha Magnanti	Science/Monash	2009		Monash/ACES